

EFORWOOD
Tools for Sustainability Impact Assessment

**Documentation of concept, implementation and use of the Multi-Criteria
Analysis Software component (ToSIA-MCA) in EFORWOOD**

Bernhard Wolfslehner, Werner Rammer and Manfred J. Lexer



EFI Technical Report 51, 2011

Documentation of concept, implementation and use of the Multi-Criteria Analysis Software component (ToSIA-MCA) in EFORWOOD

Bernhard Wolfslehner, Werner Rammer and Manfred J. Lexer

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

Editor-in-Chief: Risto Päivinen

Disclaimer: The views expressed are those of the author(s) and do not necessarily represent those of the European Forest Institute or the European Commission. This report is a deliverable from the EU FP6 Integrated Project EFORWOOD – Tools for Sustainability Impact Assessment of the Forestry-Wood Chain.

Preface

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

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

Uppsala in November 2010

Kaj Rosén

EFORWOOD coordinator

The Forestry Research Institute of Sweden (Skogforsk)

Uppsala Science Park

SE-751 83 Uppsala

E-mail: firstname.lastname@skogforsk.se



EFORWOOD

Sustainability Impact Assessment
of the Forestry - Wood Chain



Project no. 518128

EFORWOOD

Tools for Sustainability Impact Assessment

Instrument: IP

Thematic Priority: 6.3 Global Change and Ecosystems

Deliverable D1.5.7

Documentation of concept, implementation and use of the Multi-Criteria Analysis Software component (ToSIA-MCA) in EFORWOOD

Due date of deliverable: Month 48 (moved to 51)

Actual submission date: Month 54

Start date of project: 011105

Duration: 4 years

Organisation name of lead contractor for this deliverable: BOKU, Austria

Final version

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission	
RE	Restricted to a group specified by the consortium (including the Commission	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

Documentation of concept, implementation and use of the Multi-Criteria Analysis Software component (ToSIA-MCA) in EFORWOOD

Bernhard Wolfslehner, Werner Rammer, Manfred J. Lexer

University of Natural Resources and Applied Life Sciences, Vienna

Executive Summary

The scope of this deliverable is to provide a documentation of the MCA conception in EFORWOOD, the software development process, and the functionalities of the new software tool. It is described how the EFORWOOD concept is implemented in MCA, how methods were adapted for the specific structure in EFORWOOD (e.g., in the indicator set), and which methodological answers to the EFORWOOD demands have been designed in MCA.

Within the EFORWOOD project, a set of sustainability indicators was employed to assess a wide range of sustainability aspects of production, consumption and recycling processes occurring along forest-wood chains (FWCs). Multi-Criteria Analysis MCA is intended to facilitate a multi-indicator evaluation within this framework in order to foster transparent decision-making processes and support group-decision making environments for Sustainability Impact Assessments (SIA). Based on methodological analysis and the stated demands of experts and stakeholders, the PROMETHEE method was selected for further development in EFORWOOD, due to its flexibility and broad applicability. PROMETHEE was adapted to a semi-hierarchical indicator-subindicator structure and, for the purposes of transforming dominance relations among alternative FWCs, to sustainability impact ratings (SIR). Based on a generic process of multi-criteria decision making the EFORWOOD MCA process was designed and implemented as software component ToSIA-MCA. ToSIA-MCA is a stand-alone tool that can be connected to or started from within ToSIA by means of a data exchange interface (xml file transfer). Required inputs are indicator values for alternative FWCs which are either generated by ToSIA or provided from other sources. In the development special focus was given to the modes of interaction with decision makers and stakeholders both for single users and in a group mode. ToSIA-MCA guides the user through a predefined evaluation process including (a) selecting and defining indicators and related thresholds, (b) weighting the indicators, (c) aggregation of individual indicators towards a holistic impact profile, and (d) providing tools for uncertainty and sensitivity analysis for input data and indicator weights.

After a data availability check available indicators can be selected and specified via sub-indicators. Within this module it is possible to both weight the contribution of subindicators to the above-level indicator and to define PROMETHEE preference functions at the lowest level of the indicator structure. If these steps are not touched by the user, the system will work with default settings.

For the weighting of indicators, three different modes are offered (verbal, numerical, and graphical). Weighting is done at the level of indicators and is stated on an absolute scale which then is transformed to a relative weighting scale.

In the analysis, ordinal as well as cardinal ranking of alternative FWCs can be shown as a SIR (sustainability impact rating) profile of performances along different stages of the chain and as a synthesis value for the entire chain.

Advanced analysis tools in ToSIA MCA are important (a) to give insight to the sensitivity of indicator weights for the SIR and (b) to explore effects of uncertainty in input data by means of Monte Carlo analysis. Furthermore, a set of facilities for data and session management (loading, saving, printing, and reporting) is provided.

During the development phase the user perspective was explicitly considered via stakeholder interaction. In a trial workshop a prototype of the MCA tool was tested and evaluated by a panel of stakeholders with regard to (i) flexibility, (ii) consistency, (iii) transparency, and (iv) user-friendliness. The feedback received was used in further development.

Table of contents

- 1 Introduction 4
- 2 Multi-Criteria Analysis in EFORWOOD..... 4
 - 2.1 The role of Multi-Criteria Analysis in Sustainability Impact Assessment..... 4
 - 2.2 Adapting Multi-Criteria Analysis to the demands in EFORWOOD..... 7
 - 2.3 The Promethee Method 9
- 3 Software Implementation 13
 - 3.1 General 13
 - 3.2 Data structures describing FWCs 13
 - 3.3 Software Features 17
 - 3.3.1 Software and session management..... 17
 - 3.3.2 Selection of alternatives 20
 - 3.3.3 Indicator selection and definition 22
 - 3.3.4 Indicator weighting 27
 - 3.3.5 Rank order analysis 30
 - 3.3.6 Sensitivity analysis 35
 - 3.3.7 Uncertainty analysis 36
 - 3.3.8 Constraints..... 38
 - 3.3.9 Reporting function..... 39
- 4 Conclusions 40
- 5 References 42
- 6 Annex - Reporting 45

1 Introduction

The purpose of this report is to give a final summary on the development of the Multi-Criteria Analysis (MCA) tool in EFORWOOD (ToSIA-MCA) in WP1.5. It is designed as documentation of the MCA conception in EFORWOOD, the software development process, and the functionalities of the new software tool. It is described how the EFORWOOD concept is implemented in MCA, how methods were adapted for the specific structure in EFORWOOD (e.g., in the indicator set), and which methodological answers to the EFORWOOD demands have been designed in MCA.

The insights and experiences gained in earlier EFORWOOD deliverables, in deliverable PD 1.5.2 on the choice of proper MCA methodology, and in deliverable D1.5.5 on the testing of the first MCA prototype built the basis for the current outcomes.

2 Multi-Criteria Analysis in EFORWOOD

2.1 The role of Multi-Criteria Analysis in Sustainability Impact Assessment

A variety of tools has been proposed and established for what is called “sustainability assessment” (Ness et al., 2007). Among others, integrated sustainability assessment is strongly fostered by the European Union and requested to provide more useful guidance to navigate to more sustainable waters, to better integrate independent activities of research planning, monitoring, assessment, and decision support (Ness et al., 2007), and to transport collected and reported information to various stages within the decision-making process (Lee, 2006). In this understanding, sustainability assessment is expected to integrate economic, environmental, social as well as institutional issues, to provide prospective analysis of present actions, and to grant a strong involvement of stakeholders and public interests (Gasparatos et al. 2008). The involvement of stakeholders should lead to a disclosure of all relevant aspects and values from a public point of view and, more-over, facilitate rational and informed discussions between decision makers and stakeholders (George and Kirkpatrick, 2003).

Out of a portfolio of different approaches, the EU Commission has been fostering Sustainability Impact Assessment (SIA) to support the European Sustainable Development Strategy and to overcome sectoral boundaries by identifying potential impacts of policy actions and support policy and decision making (Bäcklund, 2009). Sustainability Impact Assessment (SIA) is a participatory forecasting tool aiming at assessing economic, social and environmental impacts of a policy change or rules-measure, and assisting decision-making in a sustainability context (Kirkpatrick & Lee, 2002, George & Kirkpatrick, 2003, Ness et al., 2007).

Lee (2006) emphasizes that, apart from the vertical and the horizontal integration of assessments, i.e. linking together separate impact assessments and integrating different types of impacts at different stages, the integration of assessments into different decision-making stages is crucial for any SIA undertaking. It is this stage when the introduction of evaluation tools to evaluate alternative policy and management options is required in impact assessment

(French and Geldermann, 2005). Yet, the SIA guidelines of the EU Commission (e.g., CEC 2002, 2003, 2005) are not explicit with regard to the methodology. Two of the most commonly mentioned evaluation tools are cost-benefit analysis (CBA) and multi-criteria analysis (MCA) (Lee, 2006).

Sustainability Impact Assessment (SIA) can be defined as “a means of identifying and assessing the likelihood and scale of the economic, social and environmental impacts of a policy change or rules-measure” (George & Kirkpatrick, 2003), and “to better assist decision-making relating to the sustainable development objective” (Kirkpatrick & Lee, 2002), with a specific emphasis on incorporating stakeholder concerns into the assessment process (Ness et al., 2007) to foster a shared understanding of sustainability impacts and impact assessment (Lee, 2006). It appears as accepted that the portfolio of integrated assessment methods has to be broadened by a variety of formal, explorative, experimental, and expert judgment methods (Brouwer & van Ek, 2004). This also implies that there is a shift from mainly technically-based approaches towards hybrid instruments involving “multi-objectives” and “multi-stakeholders” (Journel et al., 2003).

Multi-criteria analysis (MCA) and decision analysis in general have a multitude of conceptual answers to those requirements. Lootsma (1999) outlines the key objectives calling for the application of MCA methodologies as (i) the demand for high-quality, consistent decisions in a complex and un-certain environment, (ii) the demand for transparent and comprehensible decisions, and (iii) the demand for a democratic and participatory decision-process to clarify conflicts and support consensus-building and informed decision-making. Furthermore, there is an increasing demand for formal multi-criteria models that facilitate problem structuring and communication among actors in a process such as SIA (Bouyssou et al., 2006). MCA puts strong emphasis on the decision-making process as such in order to improve the social quality of process by granting transparency, participation and multi-/interdisciplinarity which is the more important the more complex policy issues such as the concept of sustainable development grow (Brunner and Starkl, 2004; Munda, 2004).

As a rather young science, MCA has gained increasing legitimacy on governmental decision-making level and explicit recognition as decision- support tool in public processes (Gamper and Turcanu, 2007). In more specific terms, MCA methodologies have been frequently applied to indicator-based approaches which are one of the backbones of data gathering within a SIA process. Both top-down approaches to gather required information (e.g., in assessment of natural resources) and bottom-up approaches (e.g., in participatory planning processes) are proven fields of indicator-based MCA-methodologies (Prabhu et al., 1996).

What has been identified for former sustainability assessment approaches such as Life-Cycle Analysis (LCA) is essentially true also for SIA: there is a step needed comprising the interpretation of results (e.g., expressed by indicators) in terms of preferences and interests of involved decision makers and stakeholders (French & Geldermann, 2005). One approach is to transfer original indicator values onto a common scale of preferability and to compare policy and management alternatives over a heterogeneous set of indicators (Seppälä et al., 2002).

MCA is one of the approaches proposed to handle such problems, and has been reviewed or applied in context of impact assessment inter alia by Colorni et al.(1999), Ramanathan (2001), Brouwer & van Ek (2004), Lee (2006), Hermann et al. (2007), Gasparatos et al. (2008), Estevez (2008), and Rabl and Holland (2008).

2.2 Adapting Multi-Criteria Analysis to the demands in EFORWOOD

SIA is a data-driven approach for evidence-based decision support. Due to the complexity of sustainability problems and the prospective nature of SIA there is a high demand for data that comprise both empirical and modelling sources (Lee, 2006).

Within EFORWOOD a set of sustainability indicators is employed to assess a wide range of sustainability aspects of production, consumption and recycling processes occurring along Forestry-Wood Chains (FWCs). FWCs consist of a set of processes by which forest resources are converted into services and products. In a process the wood material is changing its appearance and/or moving to another location. Processes include, for instance, planting trees, tree growth, harvesting, transport, sawing, pulping, papermaking, printing, packaging, recycling, and energy production (Päivinen and Lindner, 2008).

As a decision support system (DSS), the software tool ToSIA is the central implementation and outcome of EFORWOOD. ToSIA calculates sustainability indicators along a defined chain topology as a product of indicator values per process and the respective wood flows along the chain that are aggregated for the whole chain or segments of it on indicator level (Lindner et al., 2009). For cross-indicator aggregation, two evaluation methods are available. Cost-Benefit Analysis (CBA) is to perform a monetary valuation, Multi-Criteria Analysis (MCA) is designed to address preferences of decision makers and stakeholders in the evaluation of FWCs (Figure 1).

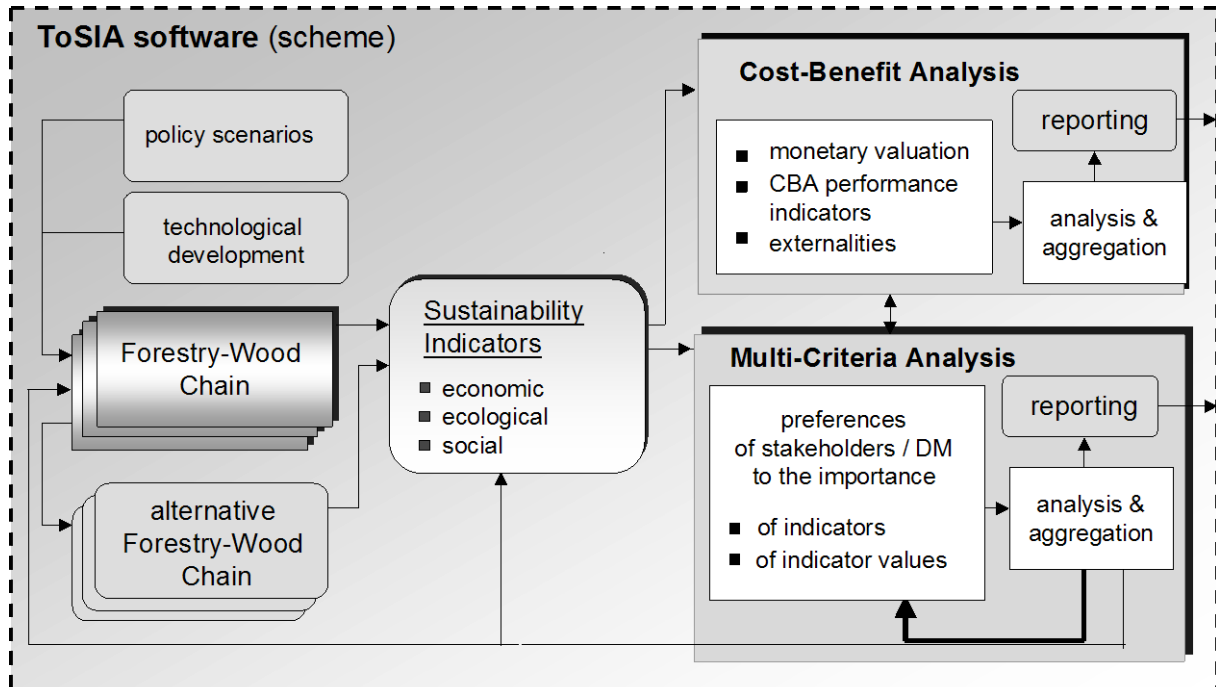


Figure 1: Cost-benefit Analysis and Multi-criteria Analysis in the context of sustainability impact assessment of forest wood chains

SIA may assess the FWC ex post and compare it to some baseline, or in a scenario-based ex ante approach SIA may allow to evaluate the likely impacts of many different actions or

events on the sustainability indicators of the FWC. In any case the assessment objective will include the comparison of two or more FWC alternatives with regard to their multi-dimensional sustainability impacts. In such a context, determining the overall preferable FWC alternative (i.e., scenario) is a classical evaluation problem based on multiple, heterogeneous criteria which has been designed to be implemented in a two-fold approach in EFORWOOD; both Cost Benefit Analysis (CBA) and Multi-criteria analysis (MCA) are integrated within the core product of EFORWOOD, ToSIA. The tool shall permit the analysis of the sustainability impact of a wide variety of global, national and local changes on the FWC from economic, social and environmental perspectives. The evaluation package is designed to evaluate alternative forestry-wood chains (FWCs) with regard to their sustainability impacts. This procedure is utilizing EFORWOOD indicators and indicator values gained from scenario calculations to assess aggregated (utility or monetary) values for alternatives and report them to the user while granting a selection of analysis features to get insight in the procedure and the results.

Based on interaction and feedback from potential users some key demands towards a MCA tool for EFORWOOD were identified:

- (1) There is a high degree of flexibility required within the EFORWOOD evaluation process. There should be allowance for different aggregation levels (e.g., total chain, module-specific), for different indicator structures and absolute vs. relative evaluation of alternative FWCs.
- (2) There is a high demand for consistency regarding the use and interpretation of data and indicator values (e.g., data quality for input and output within MCA), the handling of trade-offs and compensation among indicators, the definition of thresholds for indicators and the way uncertainty is dealt with.
- (3) Addressing decision-makers and stakeholders calls for distinct transparency regarding the evaluation process and the generation and interpretation of results. This shall be supported by the use of comprehensible procedures, clear communication of preference elicitation and aggregation principles, emphasis of interactive components and the facilitation of group decision analysis.
- (4) Finally, the acceptance for MCA tools will strongly depend on the user-friendliness of the tool in terms of intuitive and accommodate ways of using it. It should be applicable in a fair amount of time as well as accessible even for inexperienced users. In the following, it is documented how the new MCA software was developed further since the introduction of the prototype described in D 1.5.5 (Prokofieva et al., 2008).

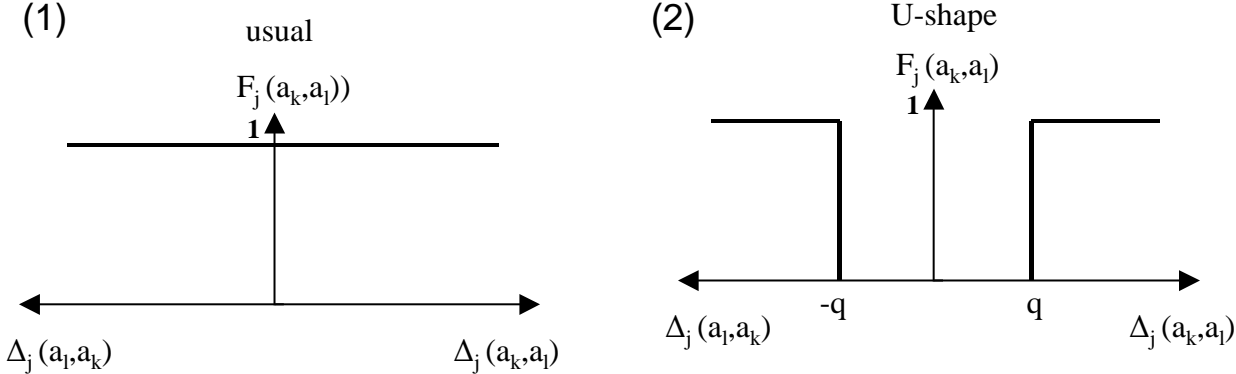
2.3 The Promethee Method

In PD1.5.2 the major phases of MCA procedures for the evaluation of alternative forestry-wood chains (FWC) are reviewed and recommendations for the use of MCA within EFORWOOD are given. Based on the analysis of main requirements as well as identified limitations for EFORWOOD MCA key criteria were defined which allow for screening available MCA methods for their applicability within ToSIA.

Out of the methods portfolio, outranking methods were identified as potential approaches to deal with the evaluation of FWCs in a SIA context since they are efficient in the application through the general definition of preference functions and thresholds respectively. According to the analysis in PD 1.5.2, the method of PROMETHEE (II) would meet many of the criteria relevant for the application in an EFORWOOD MCA (Wolfslehner et al., 2007); that is why it was chosen for the MCA application.

A short summary on the method serving as basic algorithm for ToSIA-MCA:

In PROMETHEE, information is needed (i) on the relative importance of the criteria (w_j) which, for instance, can be elicited by direct rating, and (ii) on the preferences of a decision-making/ user concerning the criteria values of the alternatives. A pseudo-criterion is defined by the setting of two thresholds for pair-wise comparison, the indifference threshold q and the preference threshold q to evaluate each Δ_j , i.e. the deviation of indicator values of two alternatives (a_k, a_l). Analogously, this is done for each of the selected criteria. In classical PROMETHEE pseudo-criteria are defined by choosing and adjusting one of six predefined preference functions (Figure 2).



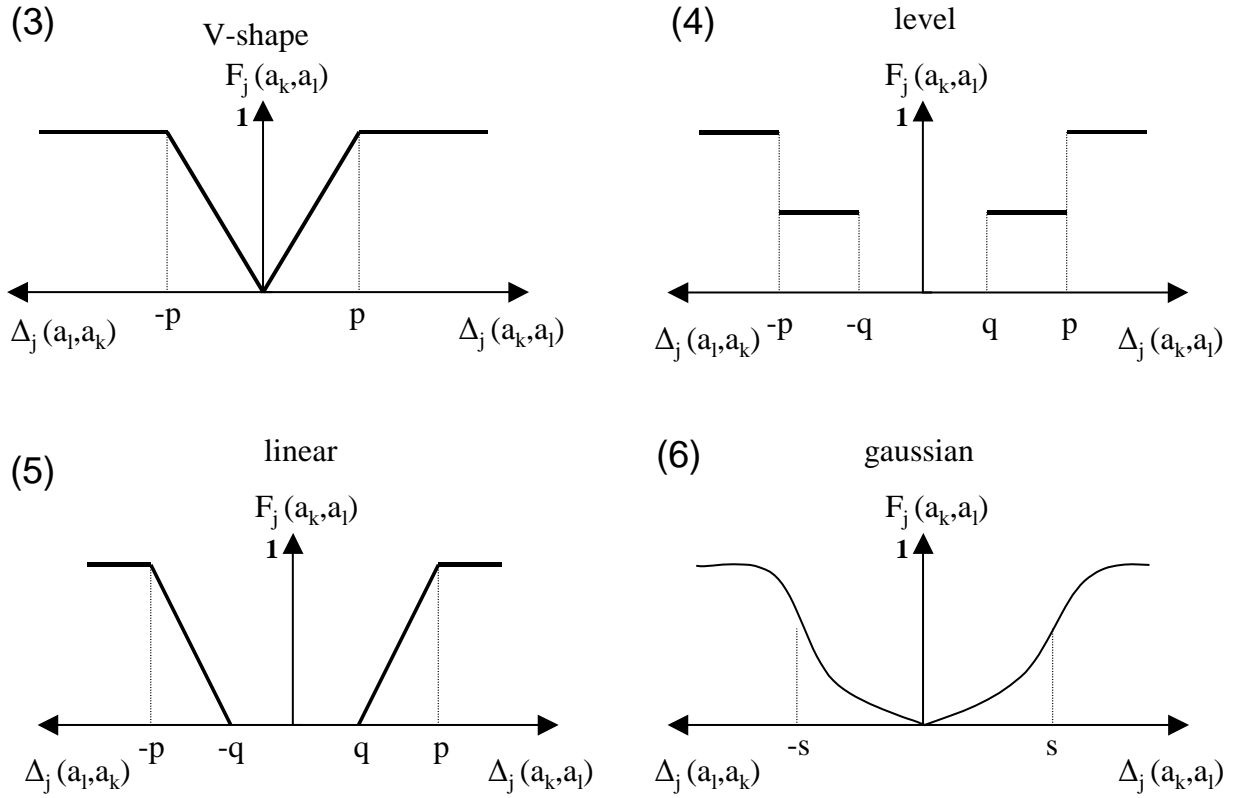


Figure 2: The six explicit preference functions used in PROMETHEE (Brans et al., 1986)

The pair-wise comparisons of alternatives with regard to the evaluation criteria result in a summed-up and weighed degree of dominance Π of one alternative (a_k) over another (a_l) in terms of,

$$\Pi(a_k, a_l) = \sum w_j F_j(a_k, a_l),$$

when $F_j(a_k, a_l)$ is the preference function and w_j the relative weight of a criterion (or indicator).

The degree of the outranking relation (dominance) is determined by the function $F_j(a_k, a_l)$, in terms of

$$F_j(a_k, a_l) = \begin{cases} 1, & \text{when } \Delta_j(a_k, a_l) \geq p_j \\ 0, & \text{when } \Delta_j(a_k, a_l) \leq q_j \\ (\Delta_j(a_k, a_l) - q_j) / (p_j - q_j), & \text{otherwise} \end{cases}$$

From the summary of dominance relations regarding individual decision criteria two overall terms are calculated:

$$\Phi^+(a_k) = \sum \prod (a_k, a_l) / (n-1)$$

$$\Phi^-(a_k) = \sum \prod (a_l, a_k) / (n-1)$$

The positive net flow Φ^+ indicates the degree of dominance of an alternative over the others, whereas the negative net flow Φ^- covers the degree of being dominated by other alternatives.

The total net flow Φ of an alternative (a_k) is then calculated by,

$$\Phi(a_k) = \Phi^+(a_k) - \Phi^-(a_k),$$

where a higher value of net flow Φ indicates a higher dominance of this alternative in terms of being favourable over the others.

The PROMETHEE II method (i.e. a ranking according to total net flow) was implemented by adapting it to the demands of the EFORWOOD structure. In designing the ToSIA-MCA three major deviations to the original PROMETHEE method can be recorded:

(1) Hierarchical indicator structures

Due to indicator-subindicator structure within EFORWOOD and ToSIA a Hierarchical PROMETHEE has been implemented. This approach is new to literature but is currently also under development by a group around one of the PROMETHEE pioneers, Bertrand Mareschal (Hayez et al., 2009). In algorithmic terms this means that a number of small PROMETHEE models are implemented at the bottom below each main indicator and individual net flows aggregated in weighted sum towards a relative SIR, in terms of

$$\Phi(a_k) = \sum_j w_j \sum_i w_i * \Phi(a_i) \text{ where } w_i \text{ is the subindicator weights, } w_j \text{ the indicator weight, and}$$

$\Phi(a_i)$ the net flow at bottom level.

(2) Scaling of the dominance measure

The original dominance measure ranging from -1 to $+1$ is transformed to a 0 to 1 scale because in terms of a sustainability rating negative values are not in the intention to convey the message. The new scale represents a relative sustainability rating (SIR) in ToSIA-MCA, in terms of

$$SIR = \frac{\Phi(a_k) + 1}{2}.$$

This leads to a overall sum of preferences that is dependent on the number of alternatives but determined that equal preferences lead to a value of 0.5 for each alternative.

(3) Calibrating the preference functions

Preference functions are not chosen explicitly but defined by setting the indifference and preference thresholds. For instance, setting both thresholds equal to zero would result in a “usual” shape, while setting both thresholds larger than 0 would result in a “linear” or “U” shape. The “Gaussian” preference function is abandoned in this procedure because no explicit choice of preference functions is used, and the Gaussian function cannot be generated by simply setting indifference and preference thresholds

3 Software Implementation

3.1 General

ToSIA-MCA has been developed in a two-phase procedure. After a prior questionnaire among experts of the EFORWOOD consortium on the needs and demands for evaluating FWCs, a first prototype was developed in 2007. This prototype already comprised essential features such as indicator selection, indicator weighting, and ordinal and cardinal rankings of alternatives. Further, it was put to test in a regional stakeholder workshop in Baden-Württemberg in autumn 2007. Participants were asked to use the software individually, followed by extensive discussion on software features and EFORWOOD topics, and finally were requested to fill out a questionnaire to judge flexibility, consistency, transparency, and user-friendliness of the proposed approach.

Taking into account feedback both from Baden-Württemberg experts and members of the EFORWOOD consortium, development of ToSIA-MCA started in late 2008. As a paradigm, it was decided to design it as a stand-alone tool that has a direct data transfer interface to ToSIA but also facilitates other terms of use, e.g. temporally independent from a ToSIA session.

ToSIA-MCA is written in C++ and it uses the Qt-application and user interface framework (<http://qt.nokia.com>). Reasons for this choice of technology are, inter alia, (i) Qt is an open source framework (LGPL), (ii) it allows platform independent development (i.e. the MCA tool could be compiled and used for Windows, OS X, and Linux) (iii) Qt contains advanced features for e.g. XML-handling or grouping of GUI components.

3.2 Data structures describing FWCs

To reduce complexity and simplify the handling, ToSIA MCA operates with additional structures and information about indicators and sub-indicators. Furthermore, the MCA-tool also relies on sensible default values for indicator value thresholds and preference functions. This data is provided in a XML-text file named “structure.xml” and located in the ToSIA MCA base folder. If indicators are added/removed in the description of FWCs, the structure file needs to be updated accordingly.

The file contains two main data types: **indicatorgroup** (i.e. indicator) and **indicator** (i.e. subindicator). “Indicators” (used in the MCA context) is essentially a logical grouping layer for indicators. The structure of indicators and subindicators is based on Berg et al. (2008) and was readjusted to structural demands of a hierarchical MCA since hierarchy was not always consistent in the data collection protocol. Caution was given that (first and second-level) subindicators are comparable and non-redundant within one level. For the logical structure of subindicators and indicators see also section 3.3.3. Table 1 and

Table 2 describe the applied XML format in greater detail.

Table 1: Description of “indicatorgroups” in the XML format used by ToSIA MCA.

Element: indicatorgroup	
Attribute: id	Numerical ID
Attribute: name	Name of the group (appears in GUI)
Attribute: type	Either “economic”, “ecological”, “social”. Links a group to a sustainability pillar.
Child-element: description	A more verbose description of the group (HTML tags may be used)

Table 2. Description of „indicators“ in the XML format used by ToSIA MCA.

Element: indicator	
Attribute: id	Numerical ID. Corresponds to the ToSIA ID.
Attribute: groupid	ID of the group this indicator belongs to (see above)
Attribute: masterid	If the indicator is a second-level indicator (i.e. is part of a subindicator group), the masterid links to the parent.
Attribute: shortName	A short description of the Indicator (e.g. “Non-productive costs”)
Attribute: active	Defines, whether the indicator is active (“true”) or inactive (“false”) by default
Attribute: unit	Unit of the indicator (e.g. “Euro”)
Child-element: description	A more verbose description of the indicator (HTML tags may be used)
Child-element: mcadefaults	Default values for this indicator used by the MCA tool. See section 2.3 for details.
Mcadefaults – attribute: pf1	Promethee value for ‘p’ (see section 2.3)
Mcadefaults – attribute: pf2	Promethee value for ‘q’ (see section 2.3)

Mcdefaults – attribute: pftype	Type of the preference function. Possible values are: “Linear”, “Usual”, “Level”, “Ushape”, “VShape”, “Gaussian”. Note that the editing of preference functions in the GUI is only supported for the “Linear” type (“Usual”, “Level”, “Ushape”, “Vshape” are border cases of “Linear”).
Mcdefaults - attribute: moreIsBetter	General preference direction of the indicator. Possible values are “true” or “false”, with “true” the default value if omitted. (e.g.: for costs moreIsBetter=false, for revenues moreIsBetter=true)
Mcdefaults - attribute: flaggingThreshold	See section 3.3.8. If this attribute is present, the value is used together with the preference direction (see above), to define an absolute threshold for constraint checking.

The actual indicator values for ToSIA runs are also stored in a XML file format created by the ToSIA application. It contains a cumulative collection of data generated in ToSIA runs that have been selected to be further analysed in the MCA application. By default, ToSIA merges the results of all selected runs and saves them as “tosia.xml” before handing control to the MCA tool. The result file contains besides the actual indicator values some metadata. The MCA tool both displays this metadata (selection of Alternatives, 3.3.2) and uses this data internally e.g. for linking a ToSIA run to a certain point in time. Table 3 shows the metadata imported by the MCA tool.

Table 3. Metadata describing the chains which are imported from the ToSIA result file.

Key	Description
variant_year	Selected point in time (e.g. 2005, 2015, 2025)
variant_reference_future	selected in ToSIA
variant_scenario	selected in ToSIA
chain_name	Name of the chain-file-name selected in ToSIA (e.g. FTP Bioenergy alternative)
chain_shortcode	User-defined name for this case (e.g. “FTP Bio 2005”)
chain_description	Not used

Concerning the utilized data files, various aspects of the ToSIA MCA tool can easily be customized by modifying simple XML/HTML files.

- Help-files: the help content is provided in standard HTML web pages. The files are located in the “help”-subfolder.
- Reports: the report functionality (see section 3.3.9) creates extensive HTML pages containing input data, chosen settings and analysis results. The default location for saved reports is the “export”-subfolder. The report includes stylesheets and images which are expected to be located in the subfolder “resources”. The core report itself is defined as a “template”.
- Templates: modifying the “templates.xml”-file allow very extensive changes. The file contains three types of data: (i) large parts of the GUI (especially the custom-ToSIA-design) in form of CSS-Rules for GUI-elements, (ii) the style-rules for the diagram components (e.g., linewidths, colours, backgrounds), and (iii) the HTML report template
- Session files: the MCA user can save all modifications (indicator selection and weighting, preference functions) to a XML based “session”-file. Subsequently, the user is able to load any previously stored session file. This provides a simple way to continue earlier sessions or to reproduce earlier results (see also next section).

3.3 Software Features

3.3.1 Software and session management

As mentioned above, ToSIA-MCA is a software tool that can be started from within ToSIA or run as a stand alone application. Figure 3 describes a typical procedure where – after alternatives (runs) have been created in ToSIA – ToSIA-MCA is started from within the analysis array in ToSIA. All data generated in ToSIA and selected to be used in the MCA is cumulated into one file (tosia.xml) and directly transferred to ToSIA-MCA in a way that the MCA session is already initialized by this data transfer. Alternately, ToSIA-MCA can be started independently by loading a prepared tosia.xml that has previously been generated (“Load ToSIA data”, Figure 5).

Besides two potentially different entry points, the rest of the MCA procedure is standardized. The essential steps along a MCA procedure are (i) the selection of alternatives for evaluation, (ii) the selection and definition of indicators, (iii) the weighting of indicators, (iv) presentation of results and rank order analysis, (v) sensitivity and uncertainty analysis, and (vi) reporting facilities (Figure 3).

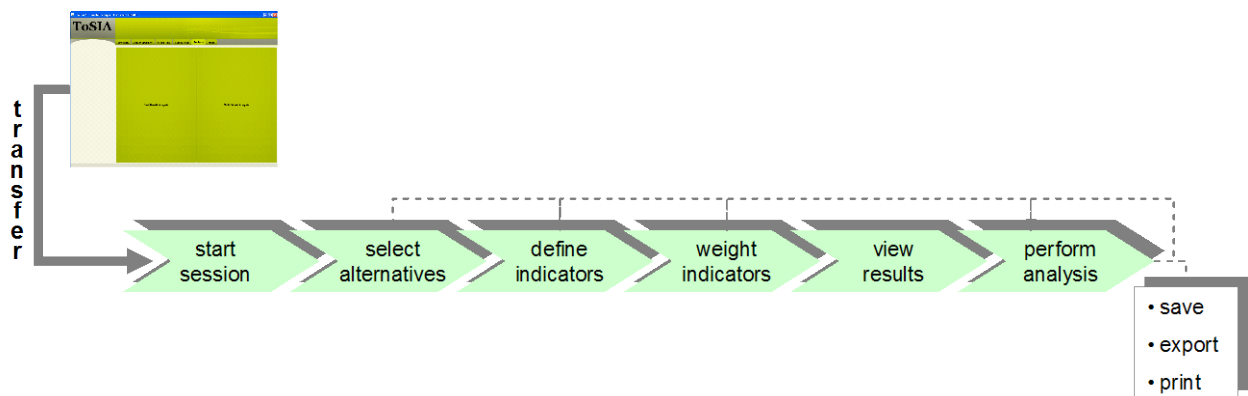


Figure 3: Flow chart of a ToSIA MCA application

Figure 4 shows the start screen of ToSIA-MCA. It is mimicking the visual surface of ToSIA to grant a corporate design for the decision support facilities. The screen is basically segregated in frames for (i) selecting main items and modes of procedure (left side), (ii) main interaction and display (centre) to be steered by a tab bar directly above, (iii) session management (left bottom corner), and (iv) communication (green top-level bar).

Help files in html format are available for all screens indicator by a green-circled “?”.

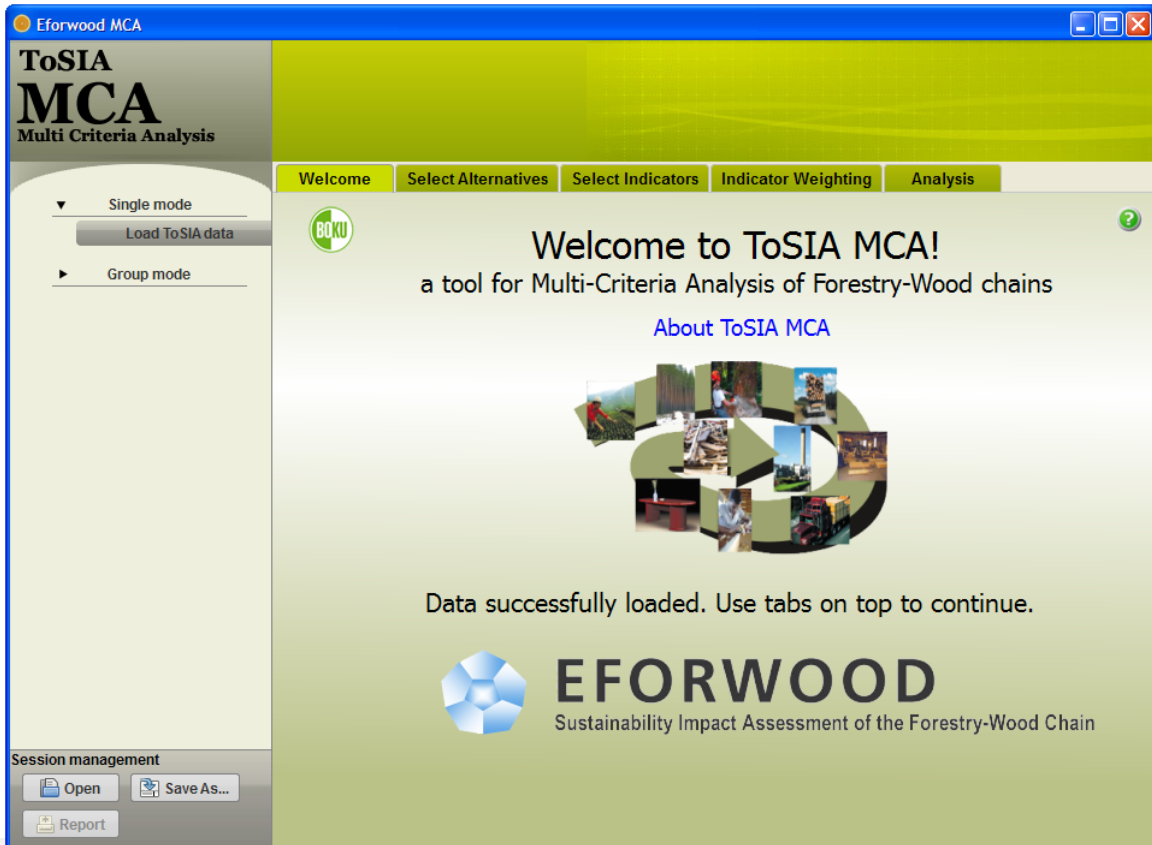


Figure 4: Start screen of ToSIA-MCA

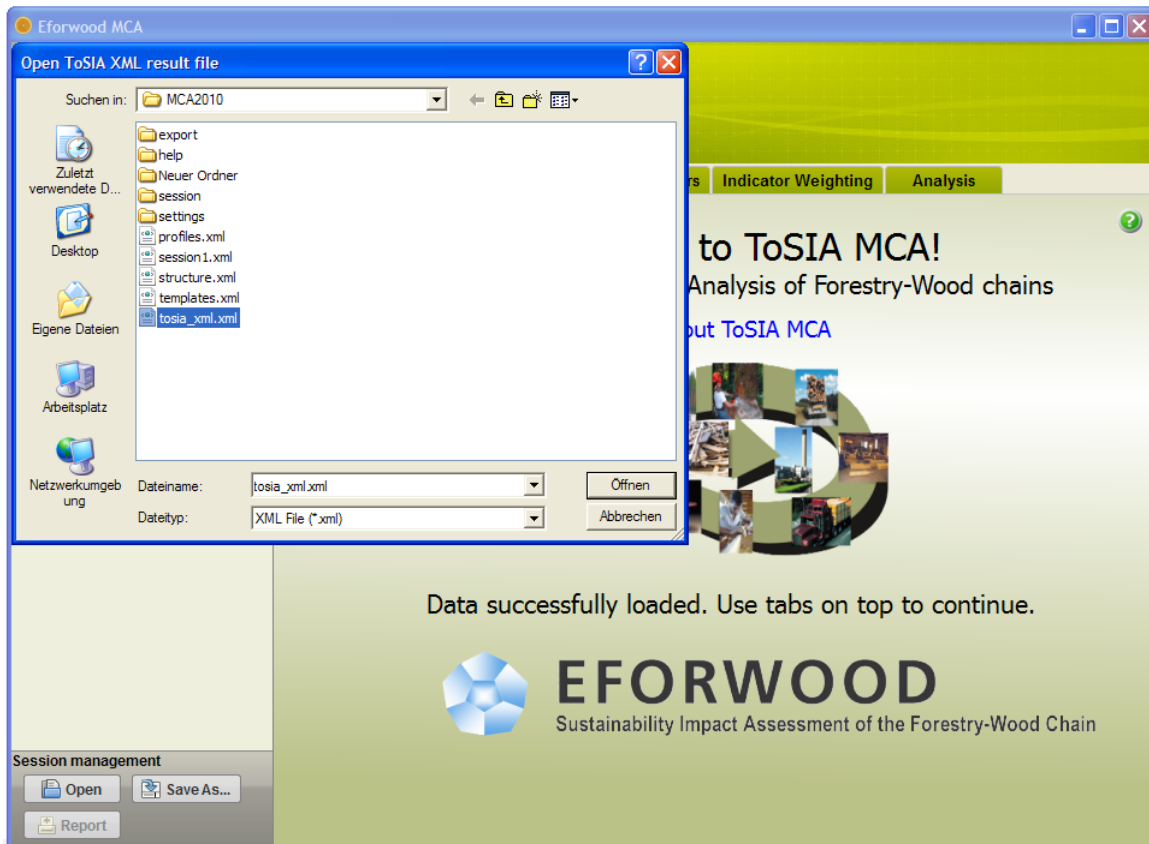


Figure 5: Loading ToSIA data (tosia_xml) in case of a stand alone application of ToSIA-MCA

Session management offers the opportunity to (i) save and (ii) re-access a MCA session, in terms that the selection of indicators and subindicators, subindicator weights and preference functions, and indicator weightings are stored apart from ToSIA data. In addition, by saving a session a file is generated that contains the preference profile of the current session which may be used for profile comparison at a later stage (see Section 3.3.5) It is important to note the difference of ToSIA data (to be opened by “Load ToSIA data”) and inputs generated by the user (to be opened and saved in the session management).

The reporting function is described in section 3.3.8 and its output shown in the Annex.

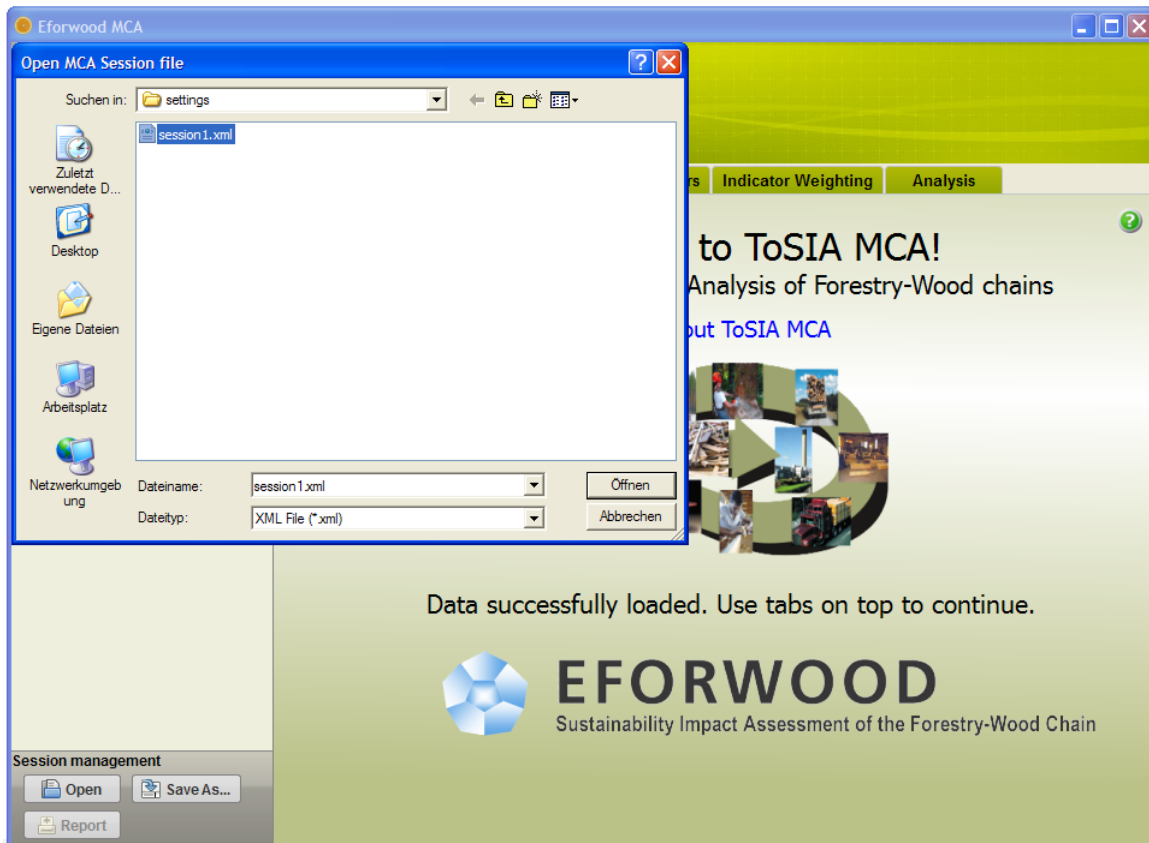


Figure 6: Opening an existing user file (session 1) to continue a MCA session previously created

3.3.2 Selection of alternatives

In principle, alternatives to be evaluated in ToSIA-MCA are generated by means of runs in the ToSIA software. In a first pre-selection, the user can select upon which of the generated runs should really be transferred as alternatives for the MCA and cumulated in the tosia.xml file. Along with ToSIA data, meta-information on the alternative runs is transferred to ToSIA-MCA containing the basic chain, the year of reference, the reference future, the scenario, and a run ID

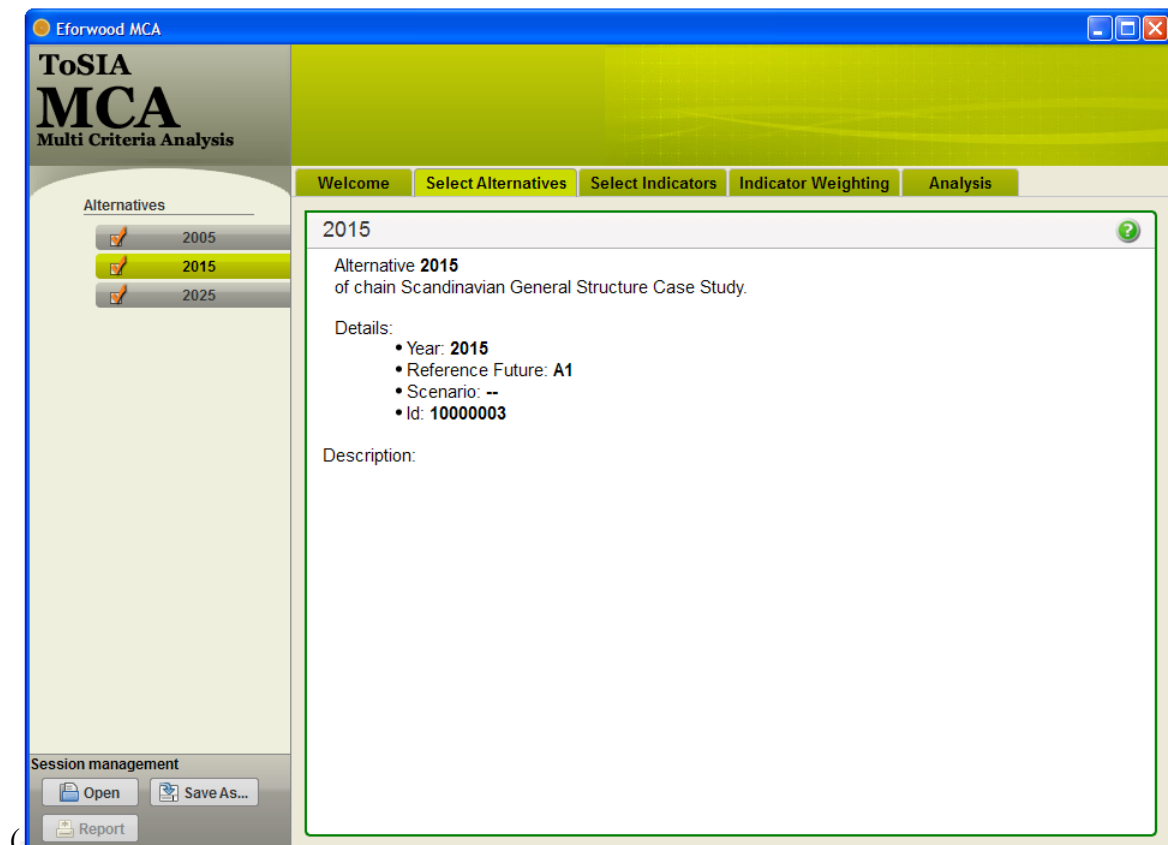


Figure 7). Based on this information, ToSIA-MCA is able to structure the evaluation according to whether (a) a comparison of real alternatives in one time step (e.g. 2005) is demanded, or (b) if there is a comparison of different time steps in one FWC, as the case in Figure 7. All data used in the following screen shots are based on preliminary data for the Scandinavian case study (Wolfslehner et al., 2009) and are for demonstration purposes only.

When entering this tab, all alternatives are selected by default. Clicking on an alternative's button will display meta-information in the centre frame. By clicking the checkmark on the left an alternative can be deactivated, and reactivated by clicking again.

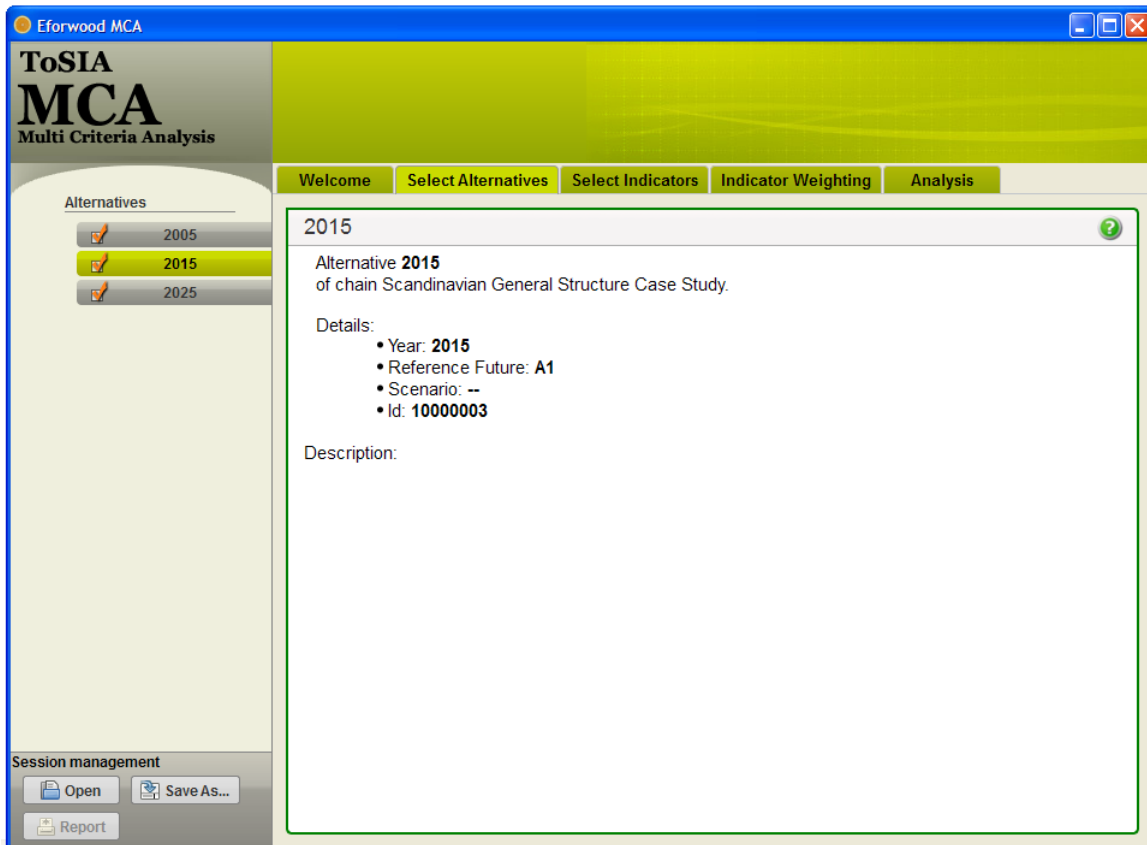


Figure 7: Selection of alternatives for the MCA evaluation

3.3.3 Indicator selection and definition

Once the set of alternatives is fixed, indicator selection and definition is the first extensive interactive component in ToSIA-MCA that hides several tasks for the user.

In the left side frame, lists of main indicators are provided and structured according to the three dimension of sustainability (economic, ecological, social indicators). Showing the three pillars as principal points, the indicators below each pillar can be displayed by clicking on one of three main categories. When changing the category, indicators opened before will disappear and indicators below the newly opened category will be displayed. In Figure 8, all ecological indicators are displayed while the others are hidden. This feature is designed to grant high manageability of even very long indicator lists.

The selection of indicators works in the same manner as demonstrated for the alternatives in the previous section. When entering this tab, all main indicators in the left frame are selected by default. By clicking the checkmark on the left an indicator can be deactivated, and reactivated by clicking again. Clicking on an indicator's button will display information in the top centre field as well as the list of subindicators at the bottom left of the centre frame. We distinguish first-level (e.g., on-site generation) and second-level subindicators (e.g., heat from residues) in this frame (Figure 8). It is defined in a rule-base that

- by default all indicators are evaluated by means of first-level subindicators, hence all second-level subindicators are not active (with the exception of indicator “soil condition”)
- if one or more second-level subindicators are selected the respective first-level subindicator will be set non-active
- if a main indicator is deactivated, all subindicators below are not applicable for MCA even if check-marked

In practice, this means that a main indicator can be defined by one ore more first-level indicators (e.g., onsite generation in Figure 8). If second-level indicators are chosen (e.g., heat

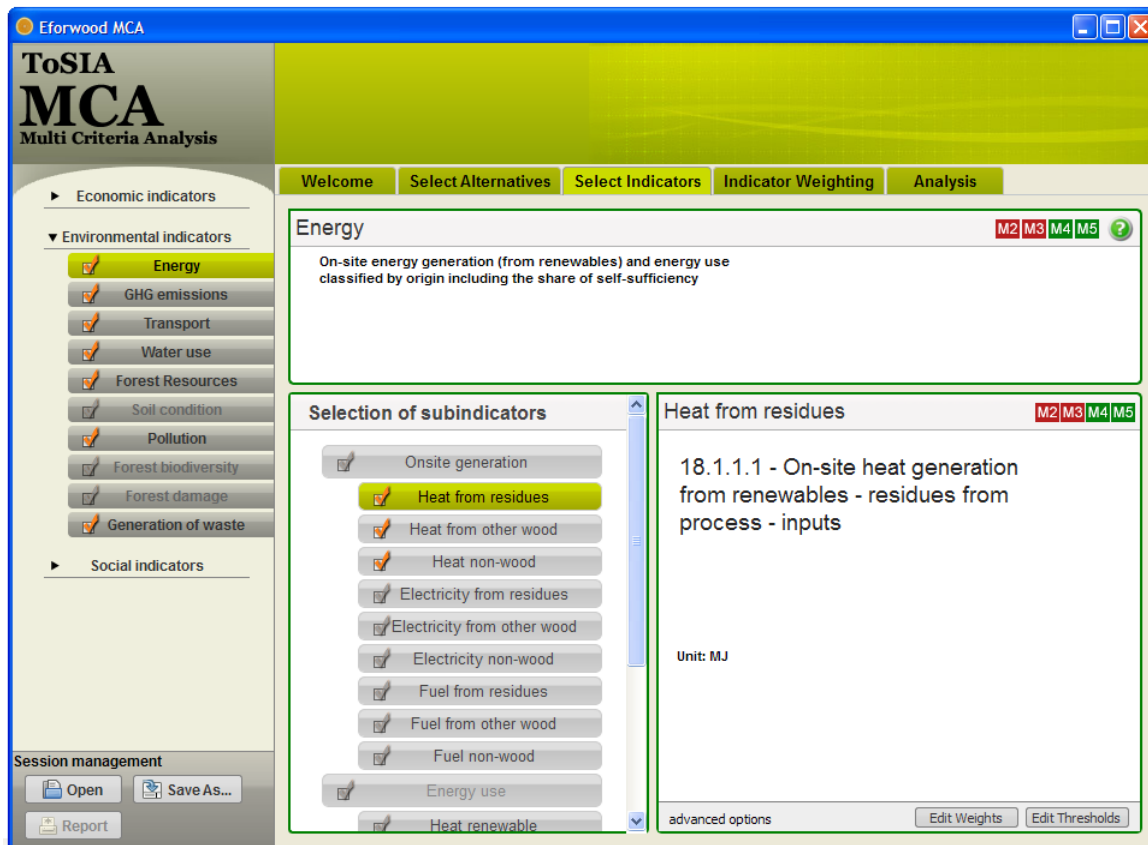


Figure 9) then the first-level subindicator will be deactivated because it is now decomposed and defined by a weighted sum of second-level denominators.

As information services for the indicators selection, ToSIA-MCA provides a cumulative data availability check. Clicking on a subindicator's button will display information in the top centre field as well as a list of subindicators at the bottom right of the centre frame. As well, an indication on data availability is given by coloured instances for the different stages along the FWC. In Figure 8, this indicates that there is only industry and trade data (M4, M5) available for onsite generation of energy from renewable resources. Data availability will be cumulated at main indicator level including all selected subindicators and displayed as flagging (green – available, red- not available). If there are no data available for neither of the stages of a FWC, an indicator or subindicator will be shaded and thus made not applicable for the MCA procedure (e.g., forest biodiversity; energy use in Figure 8).

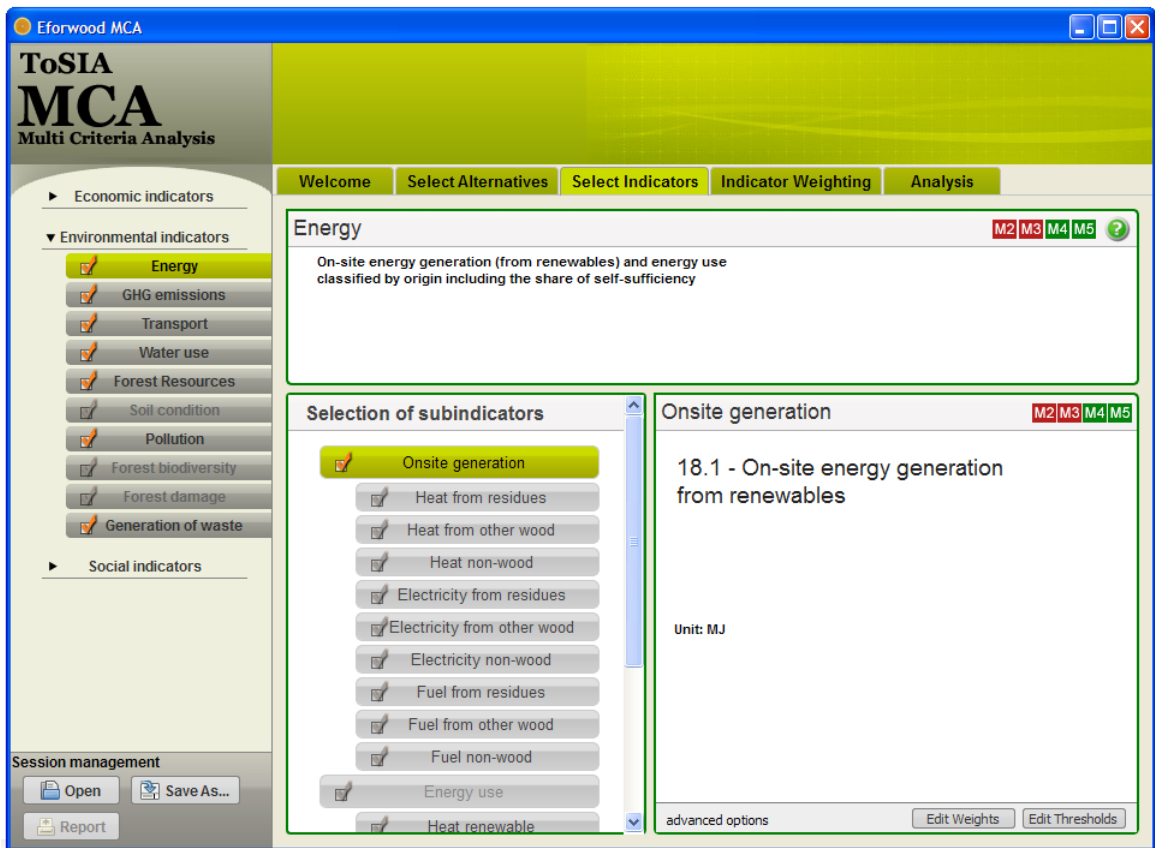


Figure 8: Indicator selection screen with selection of main indicators on the left, and of subindicators in the centre

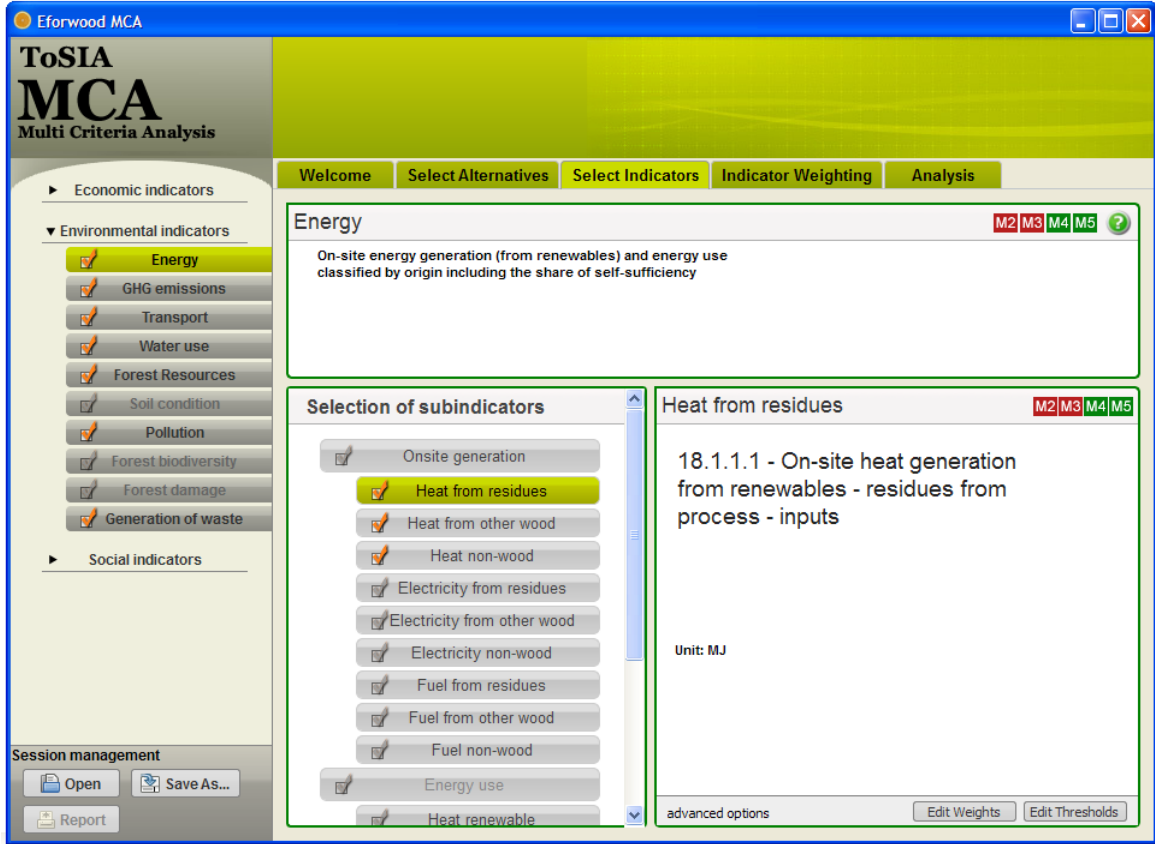


Figure 9: Selection of second-level subindicators

In addition to the selection procedure, advanced options for defining subindicators more specifically are offered for (i) editing subindicator weights, and (ii) editing the preference thresholds for subindicators to be used in the PROMETHEE calculations.

By means of subindicator weights – by default set equal-, it is determined to which amount of total weight of 1 they contribute to the main indicator to which they are subordinated. In Figure 10 it is demonstrated how three second-level subindicators are weighted with regard to their main indicator (i.e., energy). The weighting can be done for both first-level and second-level subindicators, and in a mixed form (such as in Figure 10). In the latter case, second-level items would have the weight of $(1/i * 1/j)$, when first-level weights are $1/i$. If changing the weights in a mixed form, the calculate button has to be activated to properly reallocate the weights.

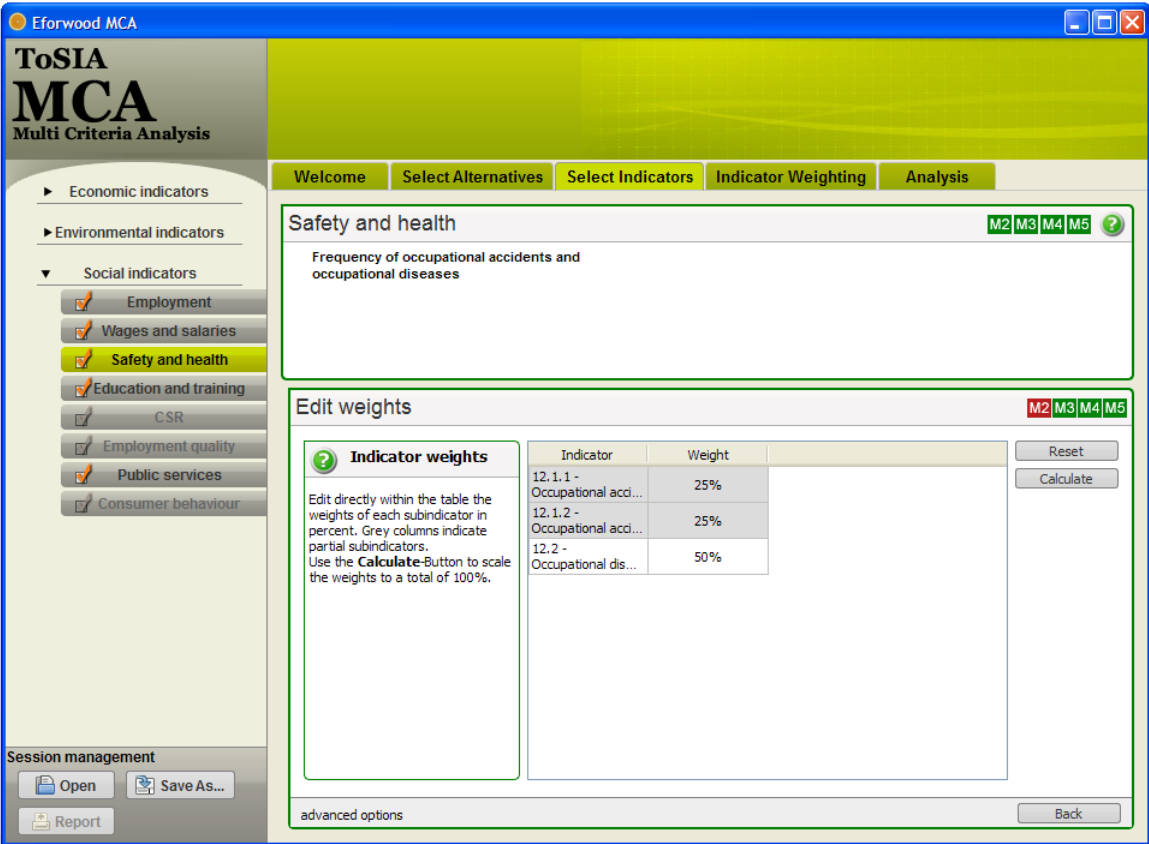


Figure 10: Advanced options - editing subindicator weights

The PROMETHEE algorithm has been described earlier (section 2.3), and made clear that preference information is gained by defining preference functions for each indicator. Defining preference functions for each of the subindicators and again for each of the stages along a FWC would mean an immense task for a user. To create options for handling this resource-binding problem (i) general default values for the preference thresholds have been set in the structure.xml file (indifference threshold of 3%, preference threshold of 10%), but (ii) the opportunity is offered to the experienced user to change both thresholds in terms of a percentage of the maximum occurring indicator value (Figure 11).

In addition, an alert functionality provides a consistency check of input data whether a user-defined threshold is exceeded.

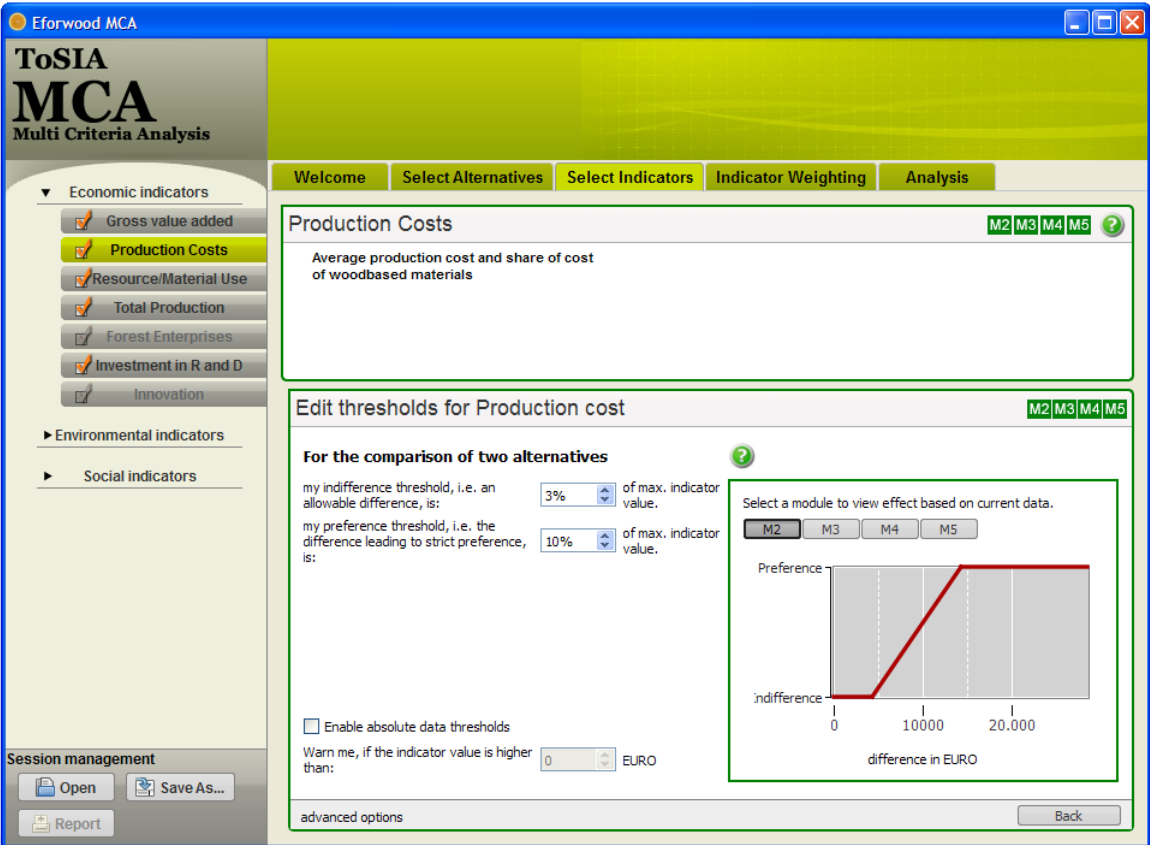


Figure 11: Advanced options – edit thresholds

3.3.4 Indicator weighting

Indicator weighting has been designated to be the major preference statement by the user (when the definition of preferences functions is estimated as a sophisticated procedure) and is performed at the level of main indicators, and for each stage of the FWC. It directly builds upon the prior step of indicator selection in terms that only those indicators can be weighted that have been selected. Data availability will influence that weighting in a sense that in case of no data for a stage of the FWC the indicator will be shaded and made non-applicable for this particular stage (as in Figure 12). This situation may occur when data are not available for all of the stage so that weighting will only happen for stages where applicable.

To respond to needs of different psychological archetypes, three weighting modes are offered to choose amongst (left frame, top):

- The graphical mode allows setting weights by positioning sliders for each indicator on an absolute scale between 0 and 100 (Figure 12).
- The numerical mode requires weighting input in terms of a number between 1 and 9 for each indicator that will be re-calculated onto the absolute 0-100 scale (Figure 13)
- The verbal mode translates verbal statements onto an absolute scale (Figure 14)

It has to be noted that changing the weighting mode during the indicator weighting will reset all statements given so far which will be indicated by an alert pop-up window.

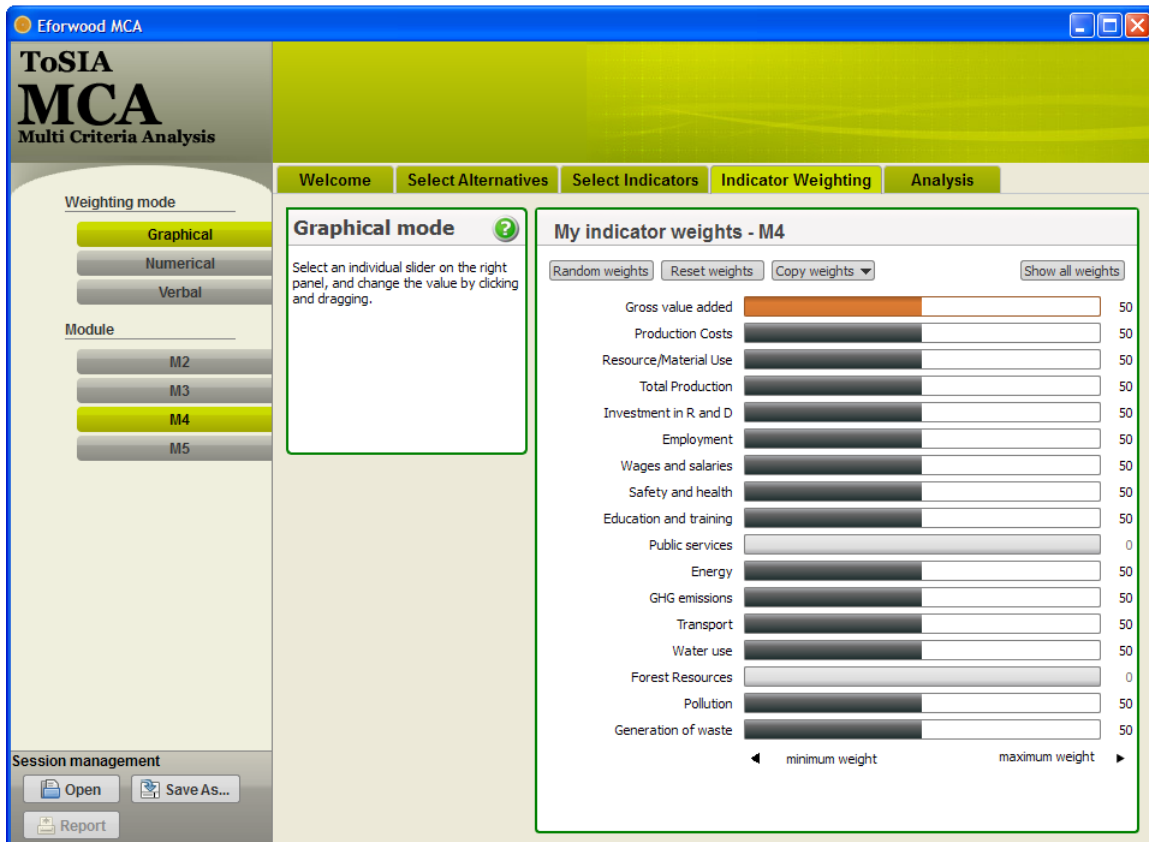


Figure 12: Indicator weighting – graphical mode

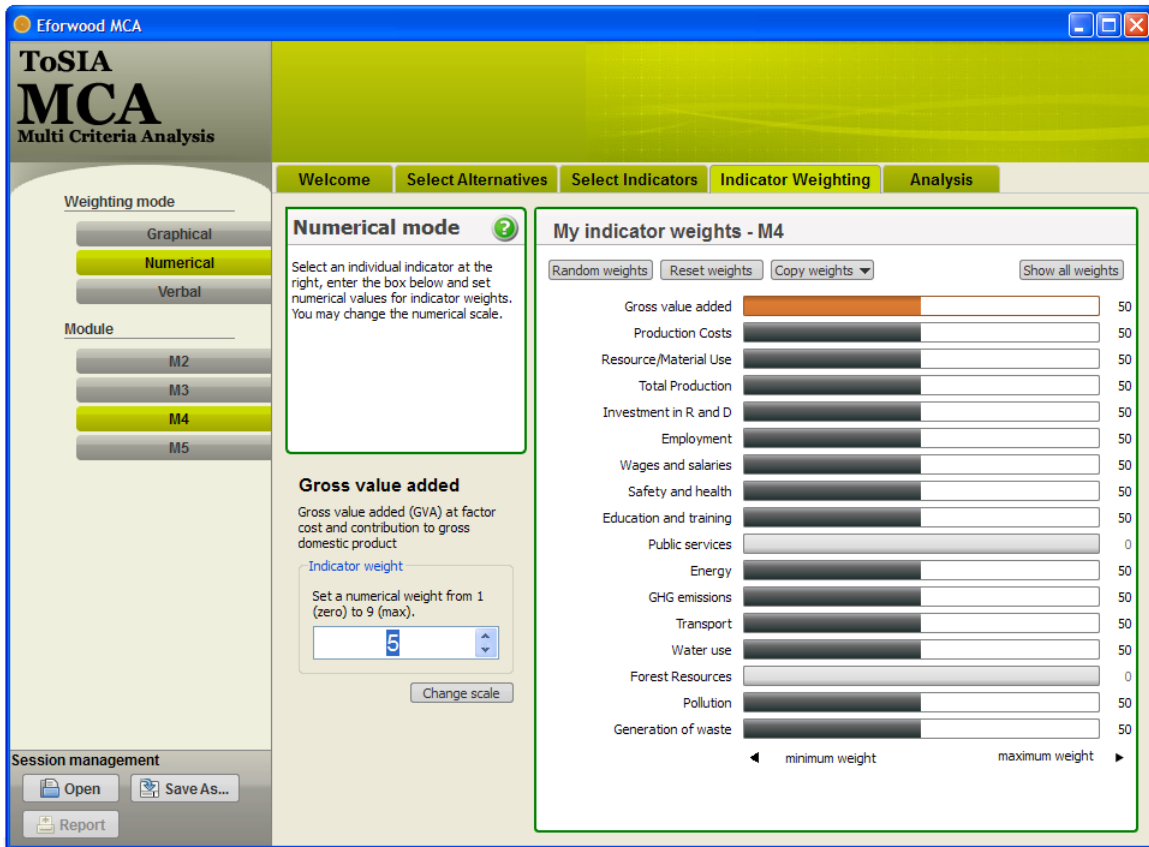


Figure 13: Indicator weighting – numerical mode

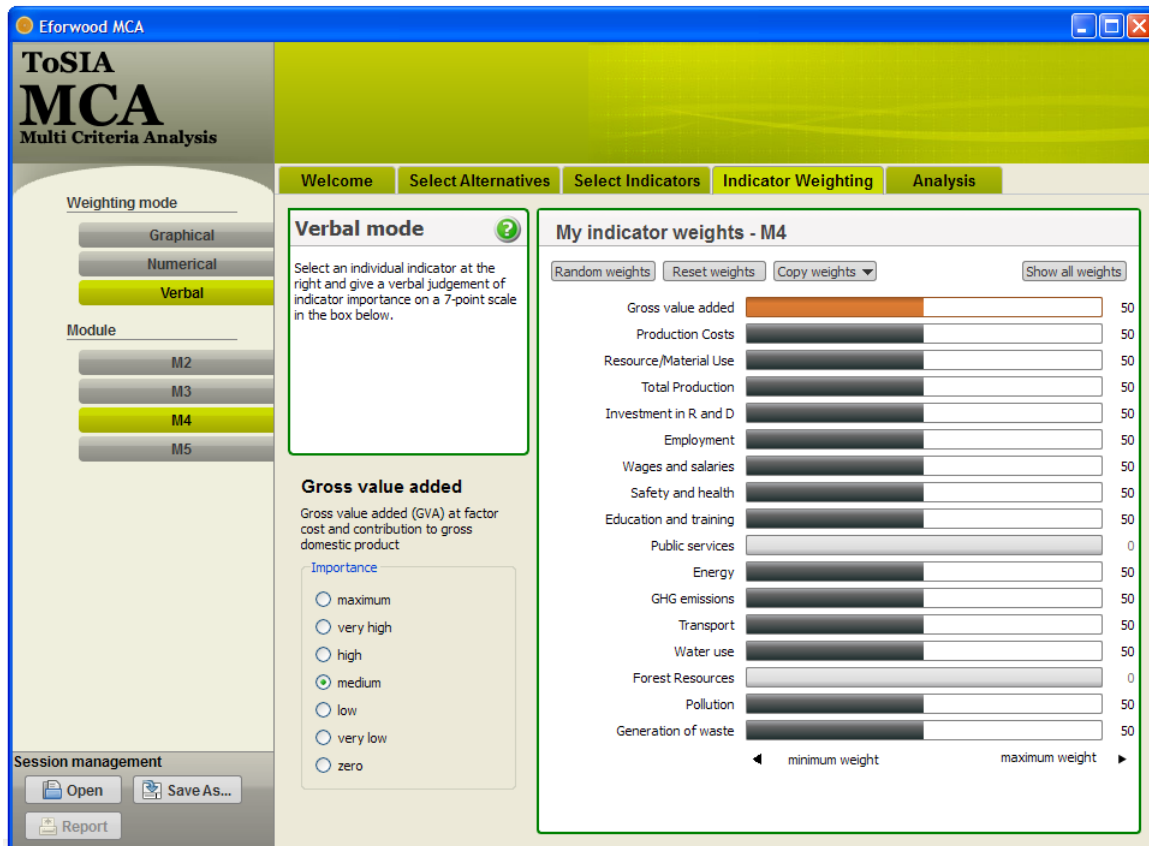


Figure 14: Indicator weighting – verbal mode

At the top of the centre frame, there are four additional buttons with different functionalities. It is possible to assign random weights (for experimental reasons), to reset weights to an equal weighting, and to copy weighting patterns from one FWC stage to another (to prevent repeating the procedure for each of the stages and apply a constant weighting to all stages).

The button “Show all weights” reveals the relative weights derived from normalizing the absolute weighting statements towards a sum of 1 (Figure 15). Relative weights will be used by the algorithm to calculate the rankings of alternatives.

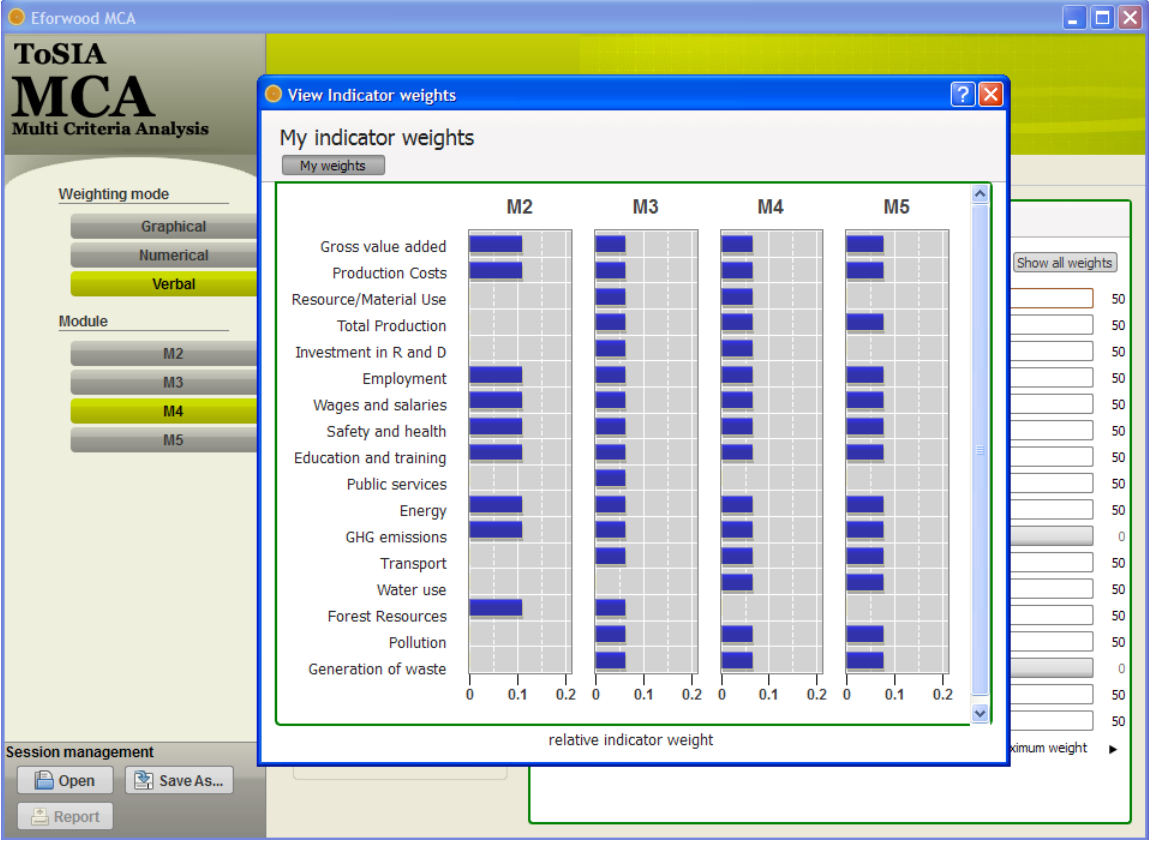


Figure 15: Relative indicator weights for each indicator and each stage of the FWC are represented in a pop-up window

3.3.5 Rank order analysis

After completing the indicator weighting the user may proceed to the analysis tab where different functionalities are offered. It is possible to do a ranking for “real alternative” (chains), for time series or both (if available). In case there are more options for time series by different reference futures, the alternative can be specified under the “select alternative for time series” scroll-down menu. The results section (activated at the top of the left frame) provides (i) an ordinal ranking alternatives per stage of the FWC, and (ii) a cardinal ranking of alternatives along the stages of the FWC. Concerning the derivation of the rankings, the reader is referred to section 2.3.

Figure 16 shows a screen gained from an ordinal ranking of a set of time steps for the preliminary Scandinavian case study data. This setting is indicated by a button in the upper part of the centre frame as well as there is a drop down menu to select among the alternatives to be analysed in a time series. The ordinal ranking indicates the ranks for the alternatives but not how much they differ. The example in Figure 16 indicates that for 2025 an increased performance in transport, industry, and trade is foreseen whereas the forestry sector seems to decline compared to 2005.

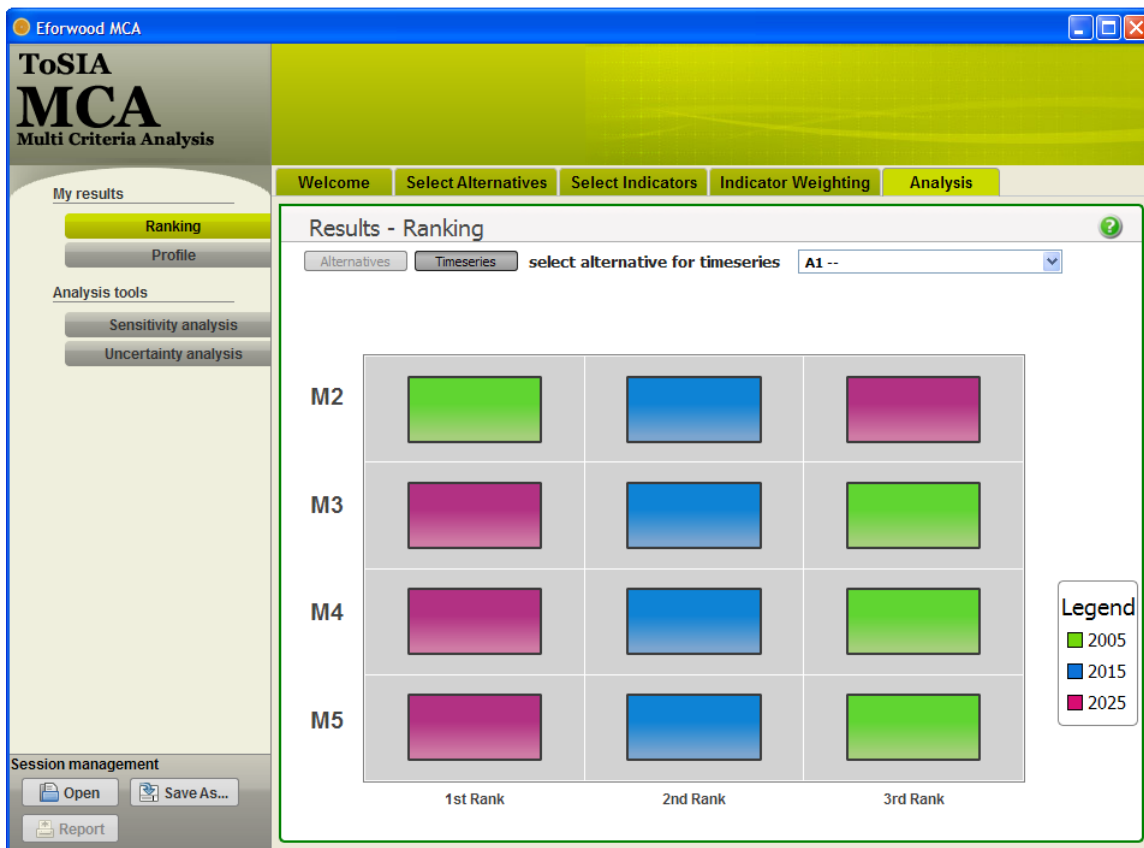


Figure 16: Ordinal ranking of a FWC time series

The cardinal ranking provides more precise information by means of a profile along the stages of the FWC. Numerical values represent a relative SIR value for each alternative and each stage (Figure 17). For supporting the distinctiveness of the visual impression in the profile interval colours and a zoom-in functionality have been designed (Figure 18).

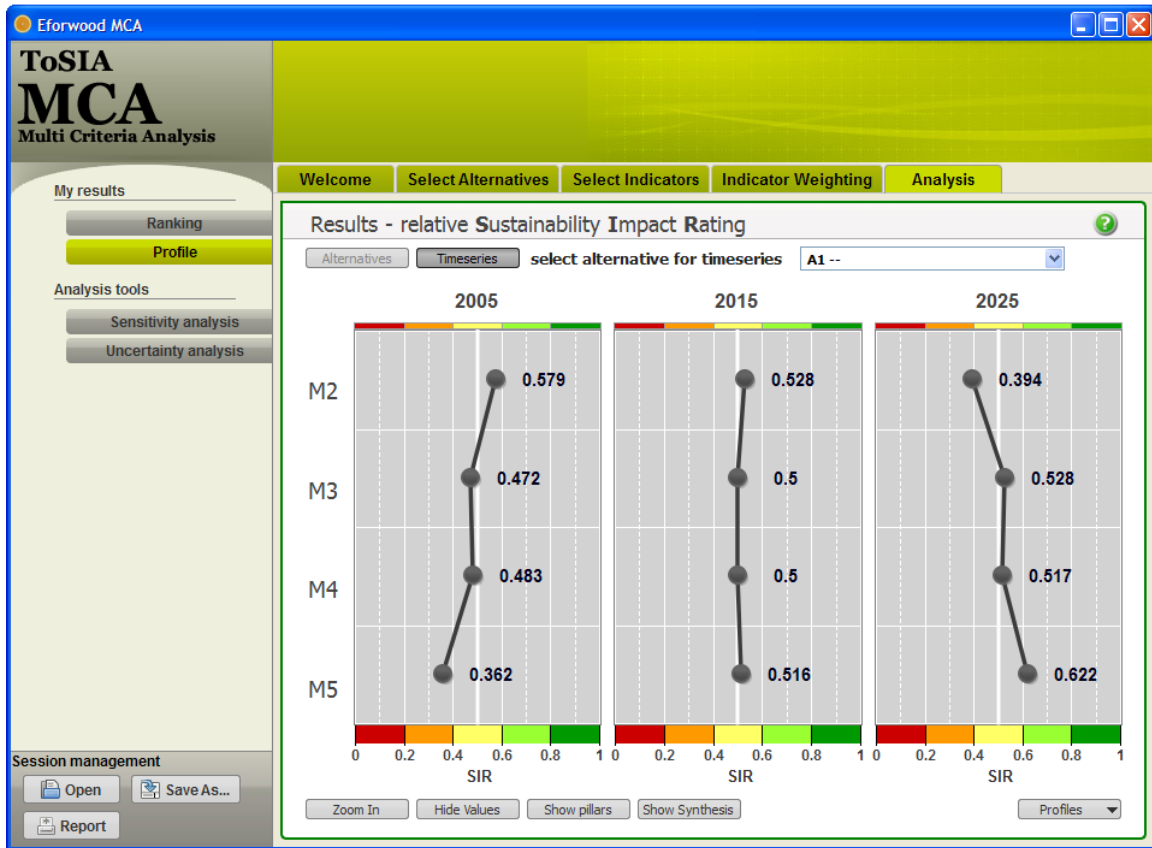


Figure 17: Relative Sustainability Rating: Cardinal preference profile of time steps

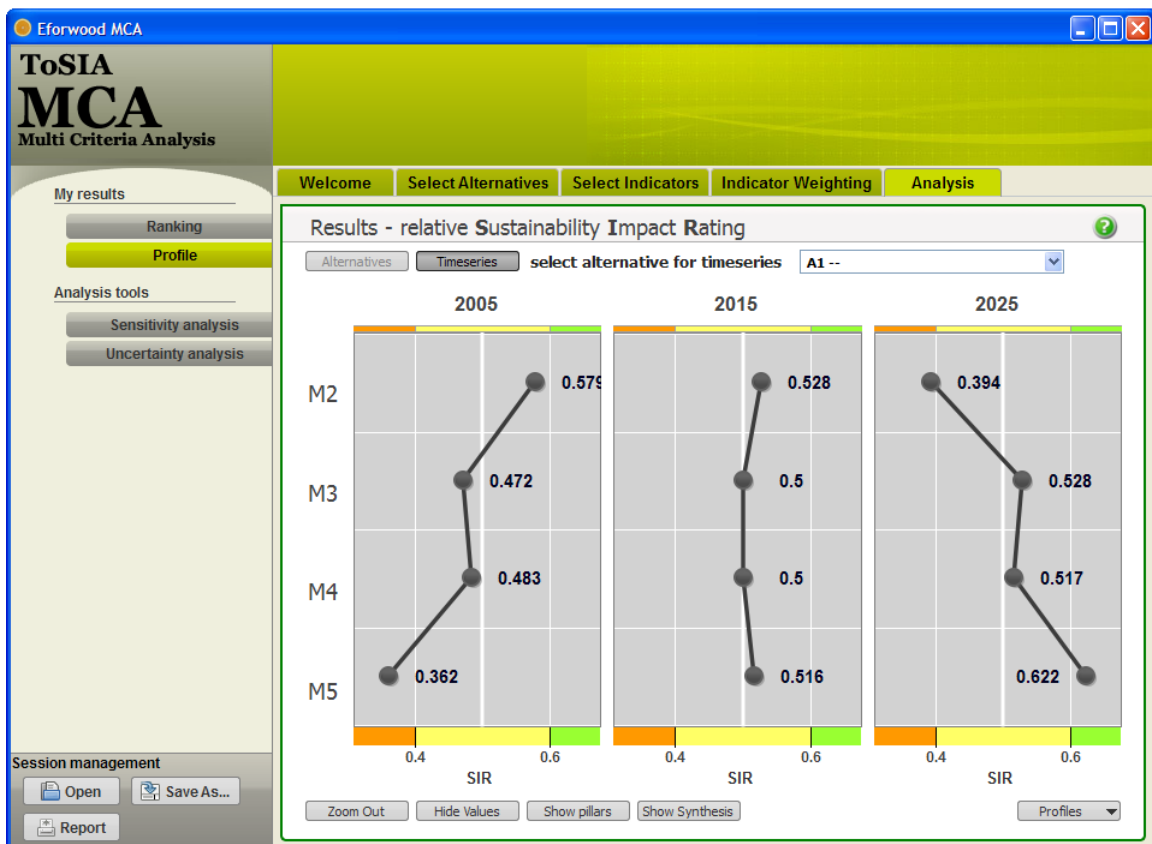


Figure 18: Relative Sustainability Rating: Zoom-in

To gain more particular insight into the sustainability performance of alternatives it is possible to display the relative SIR values that are assigned to the three dimensions of sustainability with a respective button on the bottom of the centre frame. In this example it becomes e.g. evident that the bad performance of M2 - forestry is due to economic reasons in 2025 (Figure 19). Each indicator is labelled as member of one of three dimensions in the structure.xml file, so three separate evaluations are done for each of the dimensions. Note that not the dots per time step (i.e. the “alternatives”) have to sum up to $0.5 * n$ (n is the number of alternatives), but the dots of sustainability dimension over all alternatives.

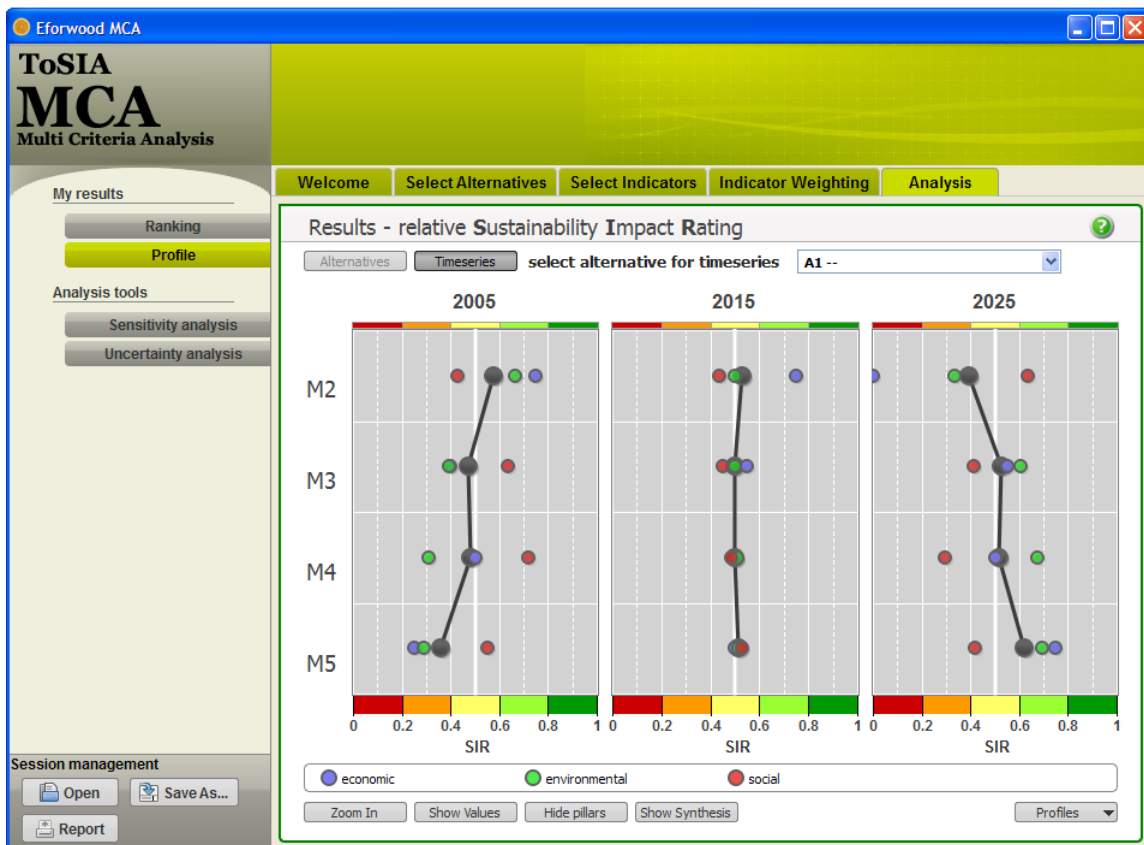


Figure 19: Relative SIR according to the three dimensions of sustainability

In contrast to increasing the amount of information by decomposing, a synthesis button facilitates a collapsing of the profile for gaining overall SIRs for alternatives and/or time steps. The total SIR of an alternative is a weighted sum of its partial SIRs at the four stages and will be displayed below the profile after activating the respective button at the bottom of the centre frame (Figure 20). The weights on how the different stages contribute to the synthesis can be customized left to the synthesis values by means of the “Weights...” button (Figure 21).

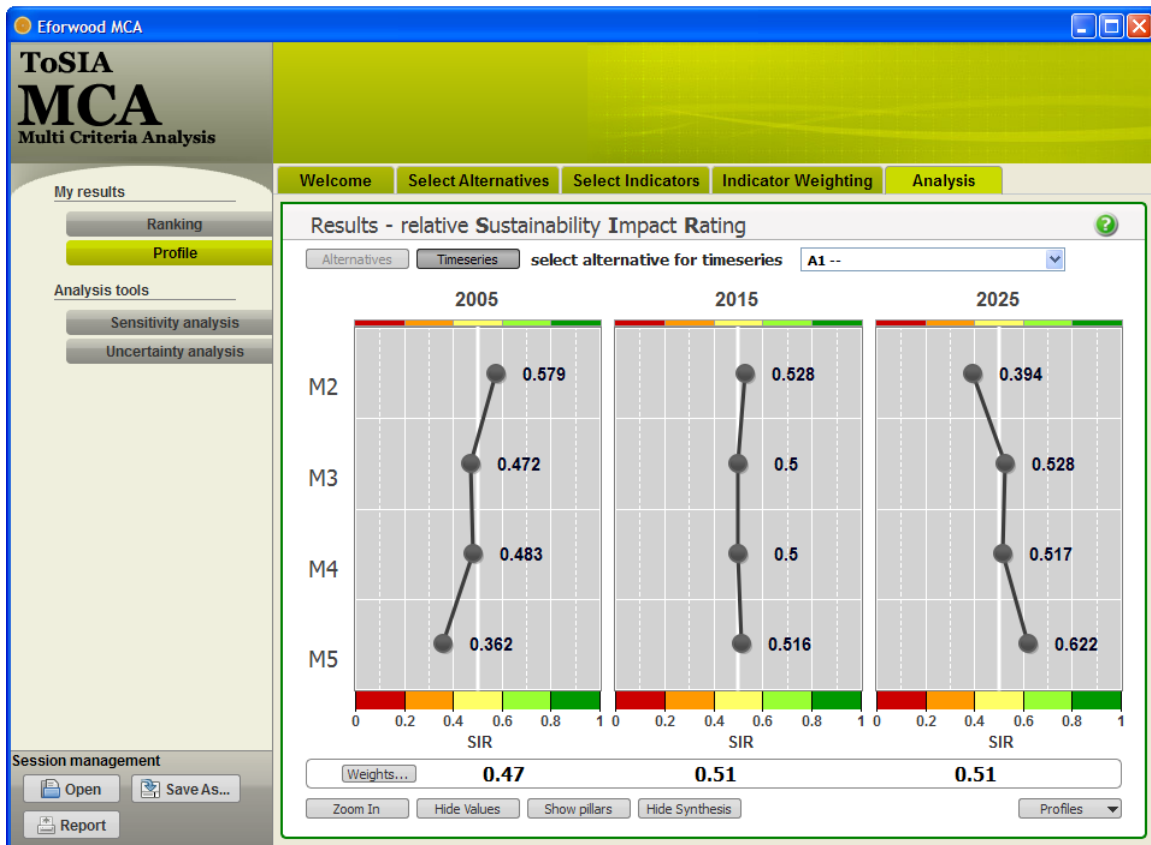


Figure 20: Synthesis of SIR values

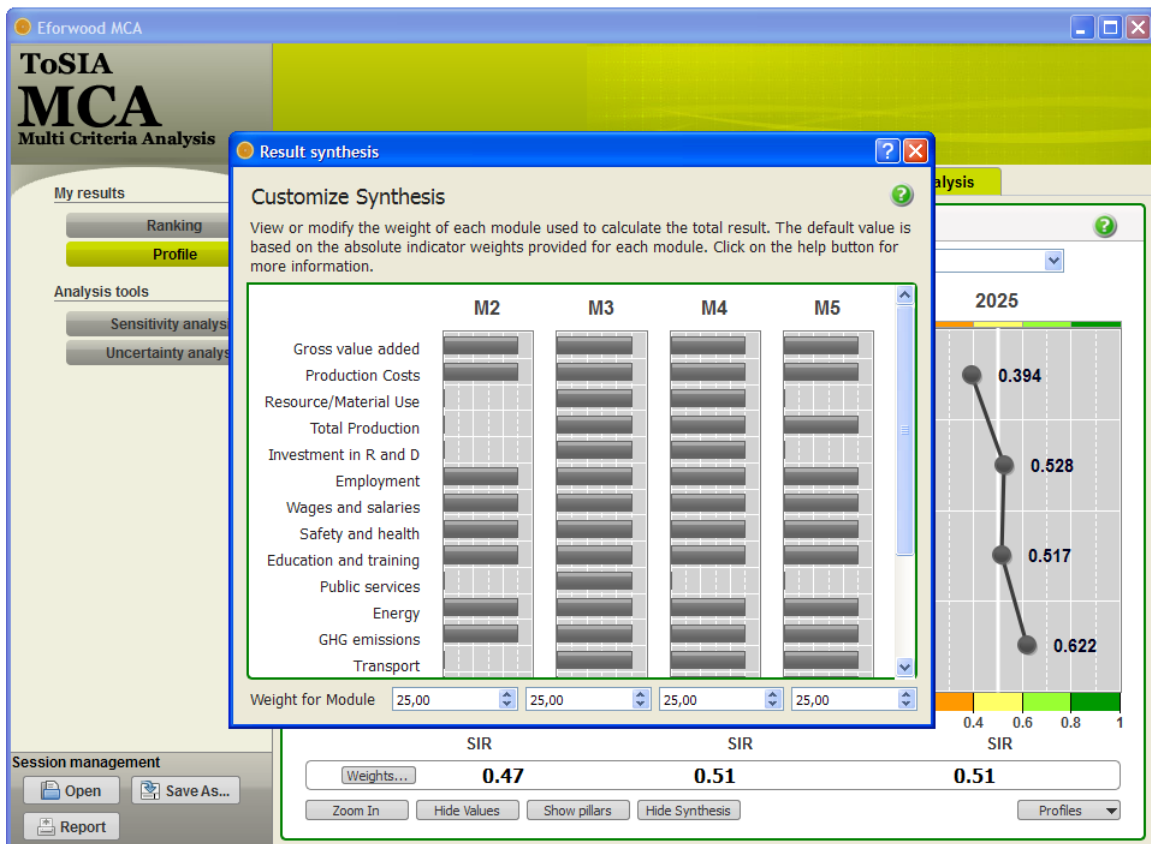


Figure 21: Customizing synthesis of SIR by assigning weights on the contribution of FWC stages for the aggregation of the profile

For comparison of the current cardinal preference profile with previously generated or external profiles as additional functionality is offered. In a scroll-down menu (“Profile”) on the bottom right profiles can be saved, reselected, and managed. Profiles contain cardinal ranking results of different sessions. They can be used to compare ranking results with those of the current session for each step of alternatives and stages along the FWC (Figure 22). Up to six different profiles can be displayed in the graph indicated by different colours.

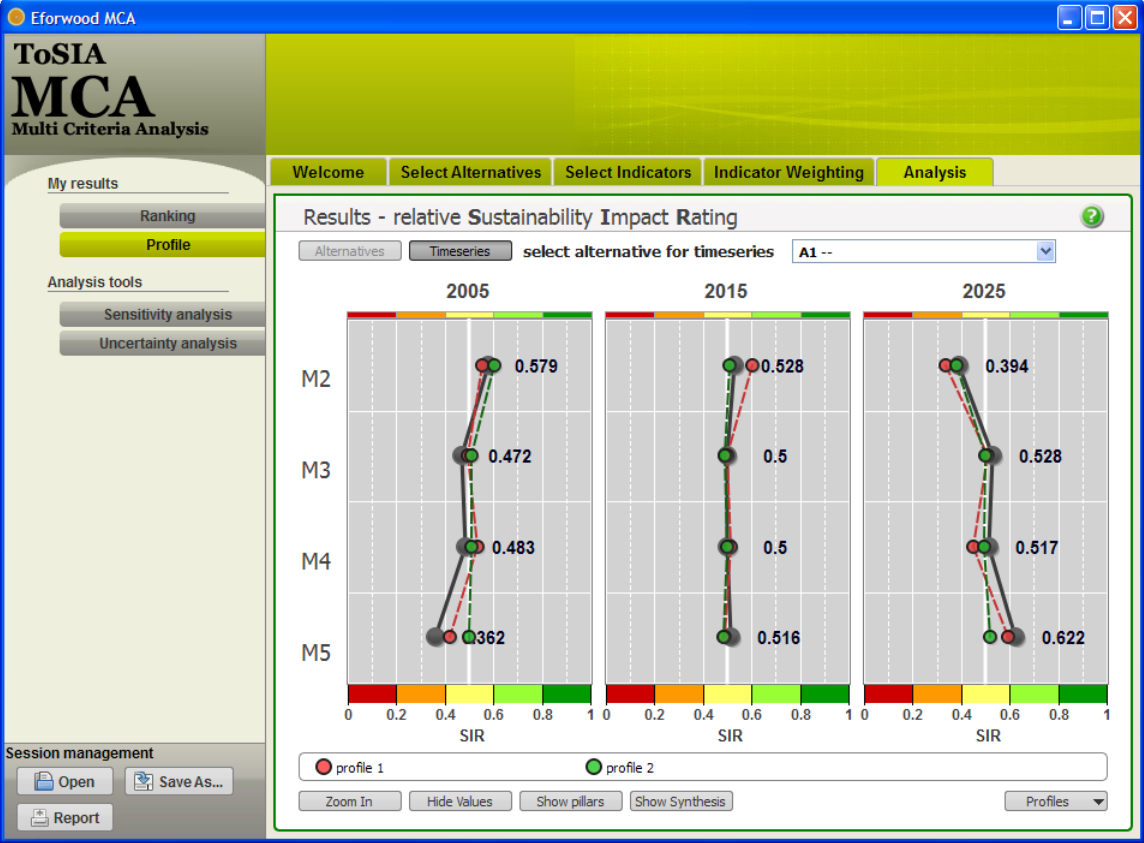


Figure 22: Comparison of the current preference file with previous or external profiles

3.3.6 Sensitivity analysis

Beyond creating ranking results, ToSIA-MCA provides two additional analysis tools. Sensitivity analysis is designed to test how sensitive cardinal ranking are to changes in the weights. Activated in the left frame a pop-up window opens containing sliders to change weights of any of the indicators. The tool grants simultaneous recalculation of SIR values when weights are changed leaving a blue dot for the original SIR behind and creating a new for the recalculated SIR (Figure 23). When closing the pop-up the original SIR profile will be displayed.



Figure 23: Interactive change of indicator weights for sensitivity analysis in ToSIA-MCA.

3.3.7 Uncertainty analysis

The second analysis tool is designed for uncertainty analysis. In contrast to user input analysed in the sensitivity analysis, this tool is dealing with uncertainty of data aimed at estimating the impact of changing data on the overall ranking results.

Activated in the left frame a pop-up window opens where the setting for uncertainty analysis can be defined for each main indicator and each stage as a plus/minus range around the original value. Minimum and maximum indicator values are displayed to adumbrate to occurring range of values. Uncertainty analysis is then performed in a Monte Carlo simulation that can be defined by the number of repetitions (1000 by default, Figure 24).

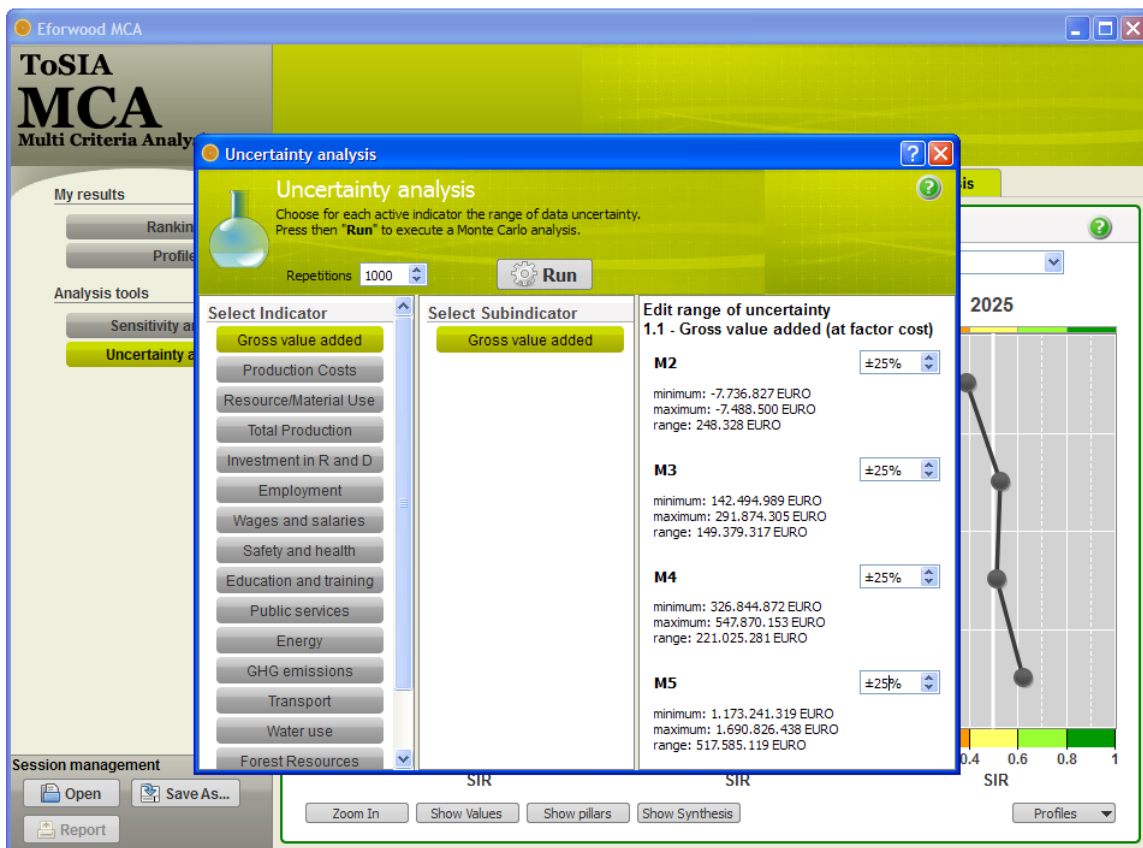


Figure 24: Setting uncertainty analysis in a Monte Carlo simulation

As a result, two uncertainty analyses are obtained (the category “uncertainty results” appears after the Monte Carlo calculation in the left-hand frame). In the cardinal profile, uncertainty results are shown as boxplots indicating median, minimum and maximum values, as well as the quartiles. Uncertainty intervals are dependent within one stage, i.e., M2, M3 or M4 but independent among them. (Figure 25). At the ordinal scale, uncertainty is mapped as a probability distribution for each rank (Figure 26).

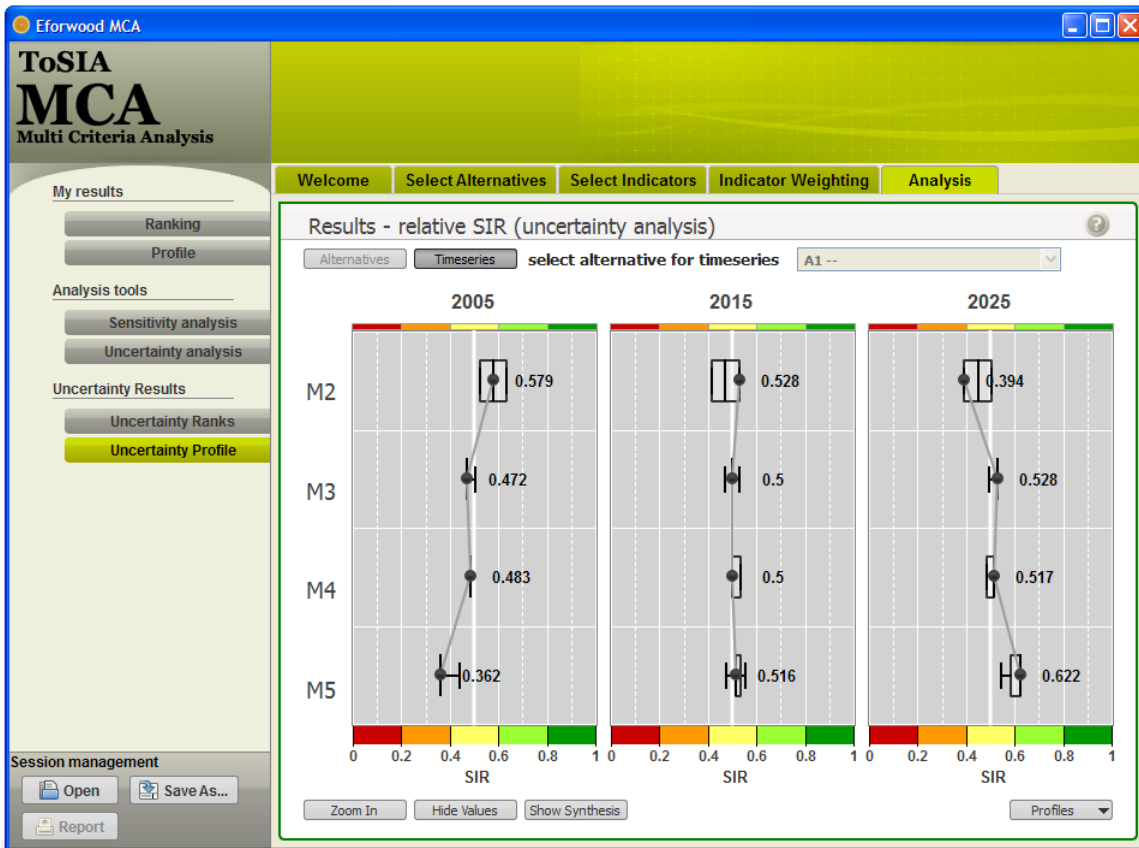


Figure 25: Representation of uncertainty analysis in the cardinal profile by means of boxplots

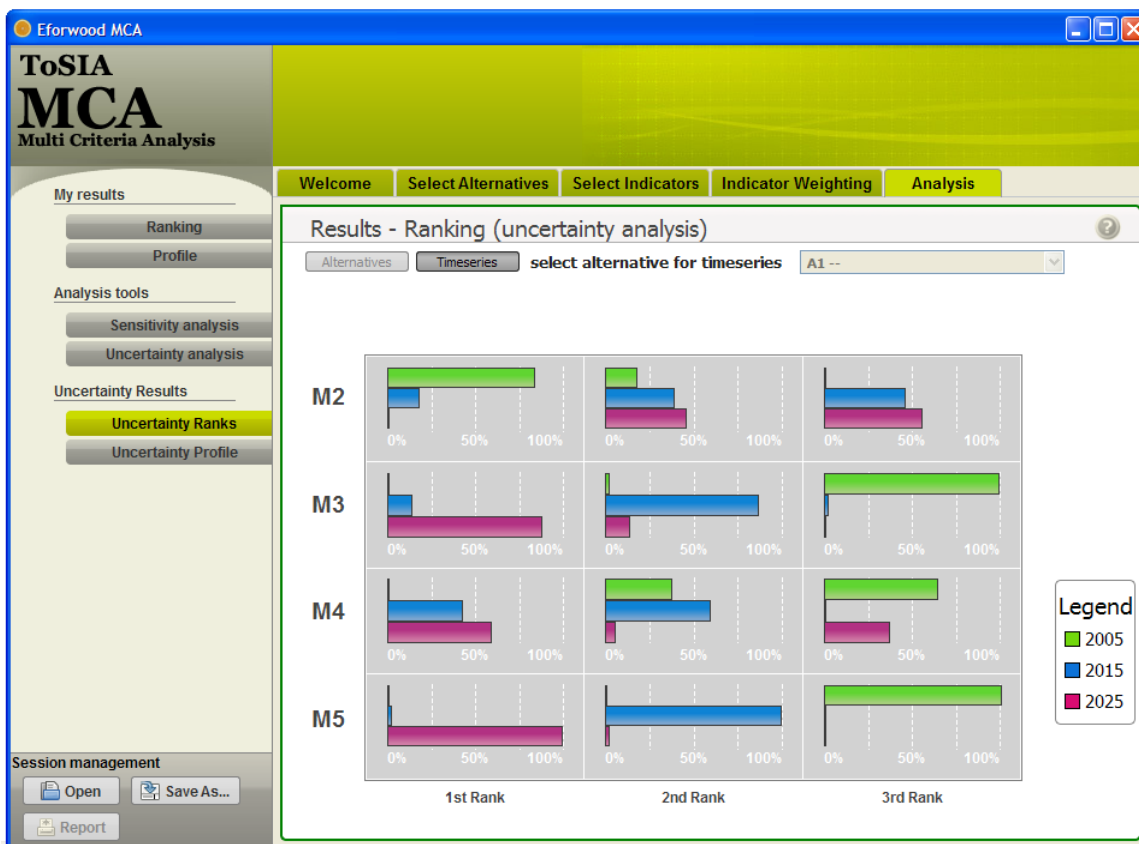


Figure 26: Ordinal ranking probability for 1st, 2nd, and 3rd ranks of timesteps in uncertainty analysis

3.3.8 Constraints

The constraints functionality refers directly to advanced thresholds options in section 3.3.3. Recalling that for each indicator a consistency threshold may be set the results of the check are represented in a dialogue window giving warning about indicators that have been exceeding thresholds (Figure 27).

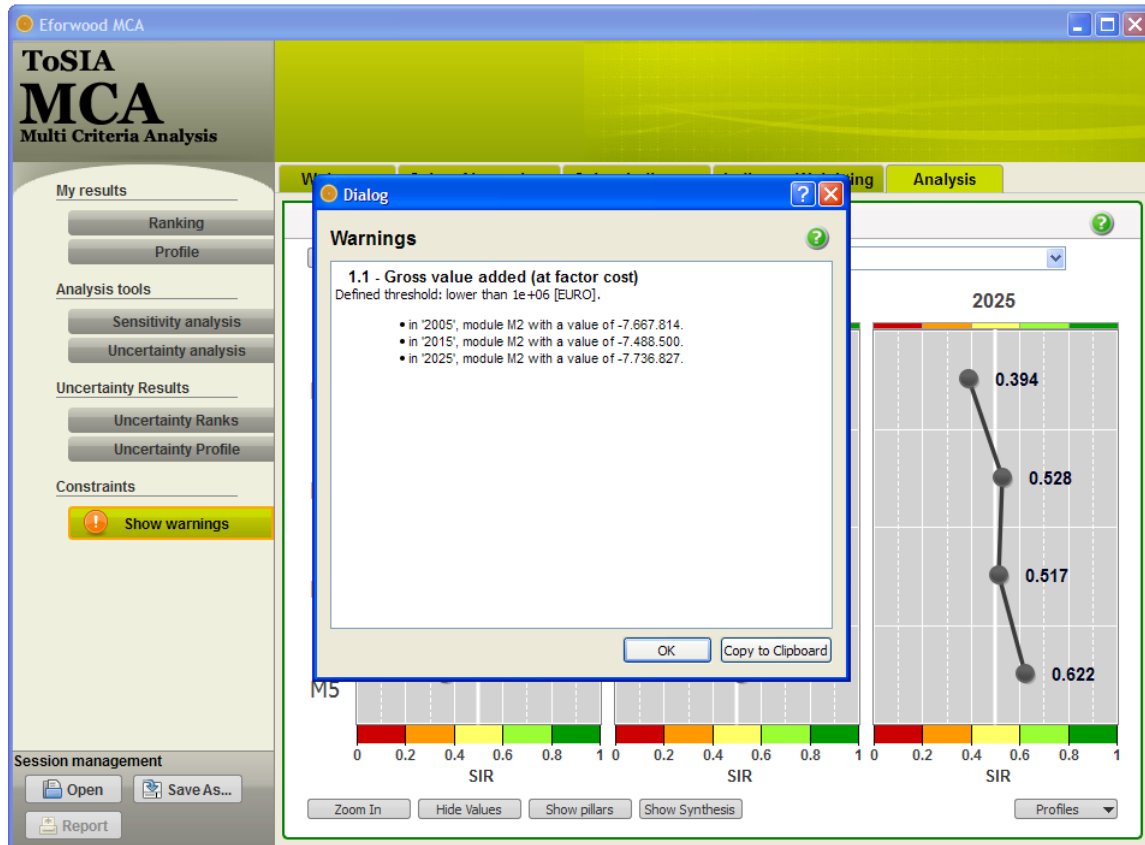


Figure 27: Warning function if data consistency thresholds are exceeded

3.3.9 Reporting function

One of the basic features of any MCA is a proper documentation of the results to secure transparency and traceability of the results. Also, it might be desirable to reproduce the results and compare it to others, which can be handled in the session management after having completed the MCA procedure. On the one hand, the user can save the session and his personal setting in a session's xml-file (as indicated in section 3.3.1). On the other hand, an extensive reporting instrument has been implemented for ToSIA-MCA. In contrary to the "Save As..." button that allows handling at any time the reporting functionality is only available in the analysis section.

The session report is generated as a HTML-file and is saved with an arbitrary name in the export folder in the TOSIA-MCA main folder (Figure 28). The HTML allows then for reading, exporting, and printing the required information. The full report of the exemplified session underlying the screenshots is attached in the Annex. Please note that the input data generated by ToSIA are preliminary ones and should be put at stake for this demonstration of the MCA tool.

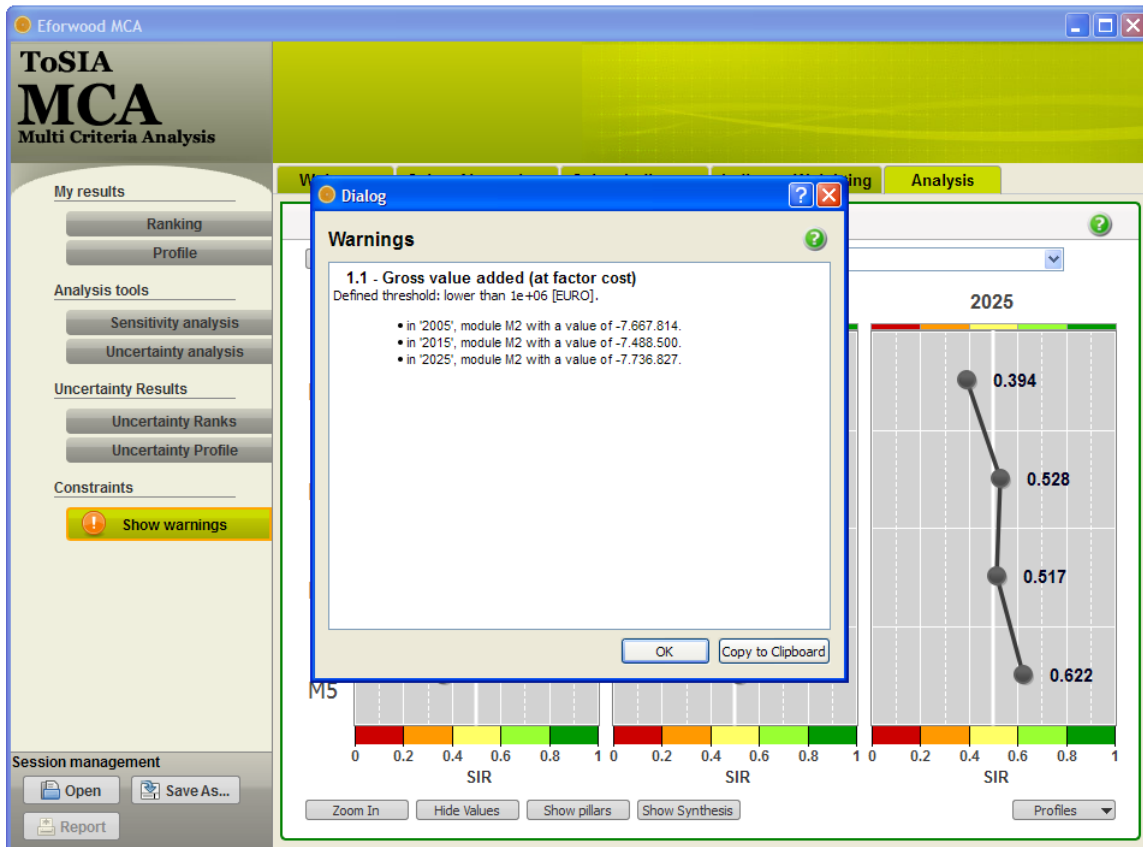


Figure 28: Reporting function of ToSIA-MCA

4 Conclusions

Due to the complexity of the problem, i.e. to evaluate entire FWCs at regional and European scale, MCA is a challenging task. There is a notion that assessment tools are often too simple to make reliable statements or too technical and so they are scarcely used in actual decision- and policy making (Nilsson et al., 2008). MCA is expected to integrate and communicate a huge amount of data but still has to take psychological capacities of users into account for a consistent decision support. Key issues which are essential in implementing EFORWOOD MCA include inter alia (i) the need to consistently and flexibly structure a set of indicators and to aggregate preferences for indicators and indicator values at different aggregation levels (i.e., modules, whole FWC), (ii) the demand to be suitable for an objective-driven sustainability assessment (i.e., absolute evaluation of indicator values), and (iii) the consideration of uncertainty in data and preferences (Wolfslehner et al., 2007).

Based on analysis of existing methods, a new MCA software tool was developed that has been tailored to the structural and analytical needs within the EFORWOOD project. The tool ToSIA-MCA can be used as ToSIA add-on or as a stand alone tool which makes it flexible for different forms of use. The methodological cornerstones and innovations of ToSIA-MCA are:

- a hierarchical re-organisation of the original PROMETHEE organisation according to the indicator/subindicator structure
- an advanced thresholds section that allows for implicit definition of preference functions and a set up for consistency check
- providing a choice among different weighting modes acknowledging different psychological approaches for preference statements
- extending analysis functionalities by adding Monte Carlo-based uncertainty analysis of input data in addition to sensitivity analysis of weights
- an extended facility for session management and reporting

ToSIA-MCA in its current implementation is a single user version which allows a decision maker to explore the implications of different preferences on trade-offs and rankings of alternative FWCs.

Huge potential for MCA in EFORWOOD is the explicit involvement of stakeholders and their preferences in an evaluation process of FWCs. One stakeholder workshop was conducted primarily for testing applicability of the general approach and the MCA software component. Feedback showed that the acceptance of ToSIA-MCA would strongly depend on the user-friendliness of the tool in terms of intuitive and accommodate ways of using it as well as manageable efforts both from the intellectual and time-consuming point of view. This calls for some simplifications in the MCA procedure but does not absolve from the call for distinct transparency when addressing decision-makers and stakeholders regarding the evaluation

process and the generation and interpretation of results. In ToSIA-MCA, these needs are already considered through the use of comprehensible procedures, clear communication of preference elicitation and aggregation principles, emphasis of interactive components and future facilitation of group decision analysis. Within EFORWOOD first attempts were explored to extend the current single user version of ToSIA-MCA to a multi-stakeholder variant which could be operated via the worldwide web or a local network. Such a group decision making version of ToSIA-MCA sets an array of challenges regarding to transparency and communication. A group-mode prototype is currently under development and foreseen to be tested in follow-up activities of EFORWOOD.

One of the issues that remains crucial for EFORWOOD and the application of ToSIA is data management. Meta-information shall be available at any stage where needed to grant an informed decision-making process and to avoid judging black-boxes during the MCA procedure (Wolfslehner and Seidl, 2009). While this demand was taken seriously in the conceptualisation of ToSIA MCA compromises had to be made in the implementation to prevent information overload for a MCA user. Experiences of a stakeholder workshop revealed the huge potential of ToSIA MCA but also the trade-offs between applicability and loss of information in the process (Prokofieva et al., 2008). Data quality issues as well as the communication thereof will be a serious challenge for further stakeholder acceptance of ToSIA and ToSIA-MCA.

5 References

- Bäcklund, A.K. (2009): Impact assessment in the European Commission – a system with multiple objectives. *Environmental Science & Policy* 12(8): 1077-1087.
- Berg, S. et al. (2008): Manual for data collection for Regional and European cases. EFORWOOD Project Deliverable PD 0.0.16. Skogforsk, Sweden.
- Bouyssou, D., Marchant, T., Pirlot, M., Tsoukias, A., Vincke, P. (2006): Evaluation and decision models with multiple criteria. *Stepping stones for the analyst*. Springer, New York, USA.
- Brans, J.P., Vincke, P., Mareschal, B. (1986): How to select and how to rank projects: The PROMETHEE method. *European Journal of Operation Research* 24: 228-238.
- Brouwer, R., Van Ek, R. (2004): Integrated ecological, economic and social impact assessment of alternative flood control policies in the Netherlands. *Ecological Economics* 50: 1-21.
- Brunner, N., Starkl, M. (2004): Decision aid systems for evaluating sustainability: A critical survey. *Environmental Impact Assessment Review* 24: 441-469.
- Colorni, A., Laniado, E., Muratori, S. (1999): Decision support systems for environmental impact assessment of transport infrastructures. *Transportation Research Part D: Transport and Environment* 4: 1-11.
- Esteves, A.M. (2008): Evaluating community investments in the mining sector using multi-criteria decision analysis to integrate SIA with business planning. *Environmental Impact Assessment Review* 28: 338-348.
- French, S., Geldermann, J. (2005): The varied contexts of environmental decision problems and their implications for decision support. *Environmental Science and Policy* 8: 378-391.
- Gamper, C.D., Turcanu, C. (2007): On the governmental use of multi-criteria analysis. *Ecological Economics* 62: 298-307.
- Gasparatos, A., El-Haram, M., Horner, M. (2008): A critical review of reductionist approaches for assessing the progress towards sustainability. *Environmental Impact Assessment Review* 28: 286-311.
- George, C., Kirkpatrick, C. (2003): Sustainability Impact Assessment of World Trade Negotiations: Current practice and lessons for further development. Institute for Development Policy and Management, University of Manchester, UK. Conference paper, New directions in impact assessment for development, University of Manchester, November 2003, 30 p.
- Hayez, Q., De Smet, Y., Mareschal, B. (2009): D-sight: a new promethee-based software. 23rd European Conference on Operational Research. Bonn, July 5-8, 2009. Book of Abstracts, 286.

- Hermann, B.G., Kroeze, C., Jawjit, W. (2007): Assessing environmental performance by combining life cycle assessment, multi-criteria analysis and environmental performance indicators. *Journal of Cleaner Production* 15: 1787-1796.
- Journel, C.M., Duchene, F., Coanus, T., Martinais, E. (2003): Devising local sustainable development indicators: From technical issues to bureaucratic stakes. The Greater Lyons experience. *Local Environment* 8: 615-626.
- Kirkpatrick C., Lee N. (2002): Further development of the methodology for a sustainability impact assessment of proposed WTO negotiations. Final Report to the European Commission. Manchester/ IDPM, University of Manchester.
- Lee, N. (2006): Bridging the gap between theory and practice in integrated assessment. *Environmental Impact Assessment Review* 26, 57-78.
- Lindner, M., Suominen, T., Paluoso, T., Garcia-Gonzalo, J., Verweij, P., Zudin, S., Päivinen, R. (2009): ToSIA- A tool for sustainability impact assessment of forest-wood-chains. *Ecological Modelling*, in press. doi:10.1016/j.ecolmodel.2009.08.006
- Lootsma, F.A. (1999): Multi-Criteria Decision Analysis via Ratio and Difference Judgments. Dordrecht: Kluwer Academic. *Applied Optimization* Vol. 29.
- Munda, G. (2004): Social multi-criteria evaluation: Methodological foundations and operational consequences. *European Journal of Operational Research* 158: 662-677.
- Ness, B., Urbel-Piirsalu, E., Anderberg, S., Olsson, L. (2007): Categorising tools for sustainability assessment. *Ecological Economics* 60: 498-508.
- Nilsson, M., Jordan, A., Turnpenney, J., Hertin, J., Nykvist, B., Russel, D. (2008): The use and non-use of policy appraisal tools in public policy making: an analysis of three European countries and the European Union *Policy Science* 41: 335-355.
- Päivinen, R., Lindner, M. (2008): Assessment of sustainability of forest-wood chains. In: L. Cesaro, P. Gatto and D. Pettenella, Editors, *The Multifunctional Role of Forests—Policies, Methods and Case Studies*. *EFI Proceedings* 55, European Forest Institute, Joensuu (2008), 153–160.
- Prabhu, R., Colfer, C.J.P., Venkateswarlu, P. et al. (1996): Testing Criteria and Indicators for the sustainable management of forests. Phase I. Final Report. Jakarta: CIFOR special publication.
- Prokofieva I., Masjuan R., Wolfslehner B., Lexer M.J., Rammer W., Bosselmann A.S., Thorsen B.J. (2008): EFORWOOD - A technical report documenting the results of the MCA and CBA procedures for the demonstration case study Baden-Württemberg. EFORWOOD Project Deliverable 1.5.5, CTFC, Spain.

Rabl, A., Holland, M. (2008): Environmental assessment framework for policy applications: Life cycle assessment, external costs and multi-criteria analysis. *Journal of Environmental Planning and Management* 51: 81-105.

Ramanathan, R. (2001): A note on the use of the analytic hierarchy process for environmental impact assessment. *Journal of Environmental Management* 63: 27-35.

Seppälä, J., Basson, L., Norris, G.A. (2002): Decision Analysis Frameworks for Life-Cycle Impact Assessment. *Journal of Industrial Ecology* 5(4): 45-68.

Wolfslehner, B., Seidl, R. (2009) Harnessing Ecosystem Models and Multi-Criteria Decision Analysis for the Support of Forest Management. *Environmental Management*, in press. doi: 10.1007/s00267-009-9414-5

Wolfslehner B., Rammer, W., Lexer M.J. (2009): Multi-criteria analysis (MCA) of a Scandinavian forest-wood chain in EFORWOOD. Presentation given at the FTP C Conference 2009, NOV 9-10, 2009, Stockholm.

Wolfslehner B., Lexer M.J., Vacik H., Thorsen B.J., Vedel S. (2007): Protocol for the evaluation of Multi-Criteria Analysis methods for use within EFORWOOD. EFORWOOD Project Deliverable 1.5.2, BOKU University, Austria.

6 Annex - Reporting

Data Export

The following annex gives a preview on what a typical ToSIA report looks like. In this report base settings, underlying data, preference statements done by the user and result displays are listed.

Table of contents

- [Overview Alternatives](#)
- [Results](#)
- [Result Images](#)
- [Result Tables](#)
- [Weighting of indicator groups](#)
- [Indicator data](#)
- [Indicator settings](#)

Export created: Mi 10. Feb 11:36:58 2010

Alternatives

2005

Alternative **2005**

of chain Scandinavian General Structure Case Study.

Details:

- Year: **2005**
- Reference Future: --
- Scenario: --
- Id: **10000002**

Description:

2015

Alternative **2015**

of chain Scandinavian General Structure Case Study.

Details:

- Year: **2015**
- Reference Future: **A1**
- Scenario: --
- Id: **10000003**

Description:

2025

Alternative **2025**

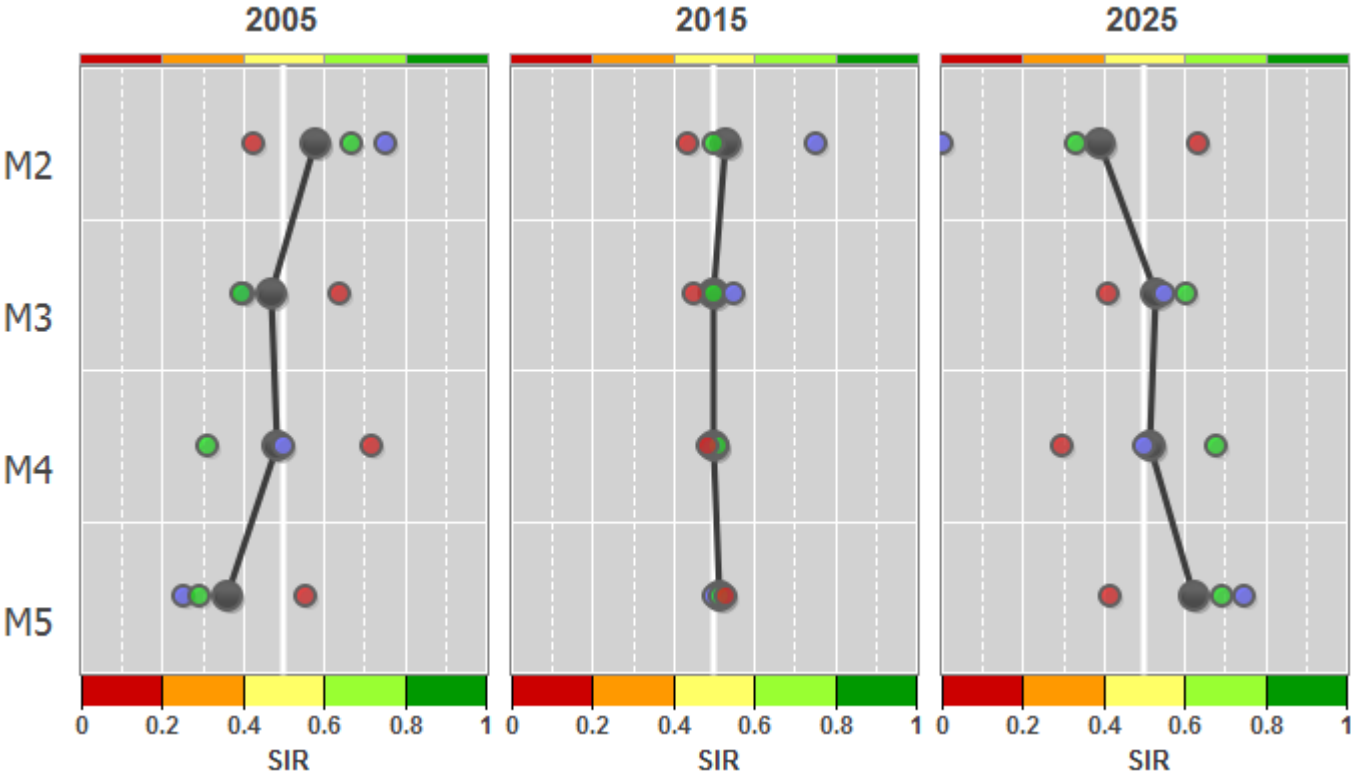
of chain Scandinavian General Structure Case Study.

Details:

- Year: **2025**
- Reference Future: **A1**
- Scenario: --
- Id: **10000004**

Description:

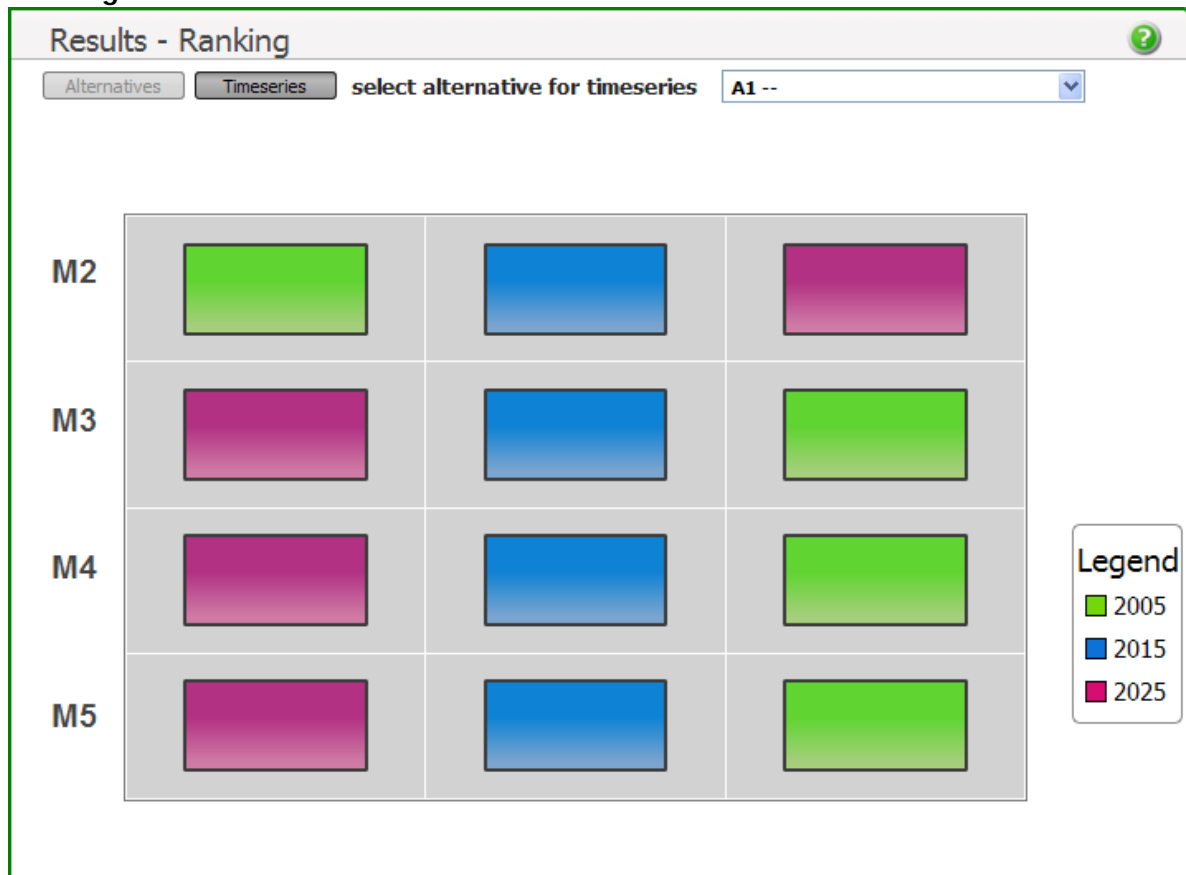
Results Profile



Details



Ranking



Result table

Module	2005	2015	2025
M2	0.578704	0.527778	0.393519
M3	0.472396	0.5	0.527604
M4	0.483333	0.5	0.516667
M5	0.361888	0.516171	0.621941
Synthesis	0.47408	0.510987	0.514932

Weights for the calculation of the total result (Synthesis)

- M2: 25%
- M3: 25%
- M4: 25%
- M5: 25%

Detailed results (by pillar)

	2005			2015			2025		
	Economic Indicators	Ecological Indicators	Social Indicators	Economic Indicators	Ecological Indicators	Social Indicators	Economic Indicators	Ecological Indicators	Social Indicators
M2	0.75	0.666667	0.427083	0.75	0.5	0.4375	0	0.333333	0.635417
M3	0.4	0.395833	0.636667	0.55	0.5	0.45	0.55	0.604167	0.413333
M4	0.5	0.3125	0.71875	0.5	0.510417	0.484375	0.5	0.677083	0.296875
M5	0.25	0.291035	0.552083	0.5	0.514205	0.53125	0.75	0.69476	0.416667

Weighting of indicator groups

Indicator	Type	Enabled	M2	M3	M4	M5
Gross value added	Economical	yes	0.5	0.5	0.5	0.5
Production Costs	Economical	yes	0.5	0.5	0.5	0.5
Resource/Material Use	Economical	yes	-	0.5	0.5	-
Total Production	Economical	yes	-	0.5	0.5	0.5
Investment in R and D	Economical	yes	-	0.5	0.5	-
Employment	Social	yes	0.5	0.5	0.5	0.5
Wages and salaries	Social	yes	0.5	0.5	0.5	0.5
Safety and health	Social	yes	0.5	0.5	0.5	0.5
Education and training	Social	yes	0.5	0.5	0.5	0.5
Public services	Social	yes	-	0	-	-
Energy	Environmental	yes	0.5	0.5	0.5	0.5
GHG emissions	Environmental	yes	0.5	0.5	0.5	0.5
Transport	Environmental	yes	-	0.5	0.5	0.5
Water use	Environmental	yes	-	-	0.5	0.5

Forest Resources	Environmental	yes	0	0	-	-
Pollution	Environmental	yes	-	0.5	0.5	0.5
Generation of waste	Environmental	yes	-	0.5	0.5	0.5

Data 2005

Name	Unit	M2	M3	M4	M5
Gross value added	EURO	-7667814	142494989	326844872	1173241319
Production cost	EURO	10328822	145518376	891963480	4757402938
Material costs in FWC	EURO	-	0	375635920	1669565777
Material costs outside FWC	EURO	-	0	217082268	2451550937
Labour costs	EURO	3264953	54996987	112281417	349114051
Energy costs	EURO	420611	35544143	86591334	47570162
Other costs	EURO	6472412	36483269	69293740	85747413
Non-productive costs	EURO	-	18482479	31078765	154301329
Share wood-based costs	%	-	-	-	-
Wood Imports - Volume	m ³	-	30350	0	-
Wood Imports - Value	EURO	-	-	0	-
Import Share	%	-	-	-	-
Wood Exports - Volume	m ³	-	-	0	-
Wood Exports - Value	EURO	-	-	0	-
Export Share	%	-	-	0	-
Net trade - volume	m ³	-	-	0	-
Net trade - value	EURO	-	-	0	-
Other renewable	m ³	-	0	0	33460612
Renewable-virgin	m ³	-	458103	0	33460612
Renewable-recycled	m ³	-	0	0	-
Non-renewable	m ³	-	30083883	0	383
Non-renewable-virgin	m ³	-	30102247	0	383
Non-renewable-recycled	m ³	-	8802	0	-
Enterprises	total number	-	-	-	-
Public	total number	-	-	-	-
Private	total number	-	-	-	-
Size	ha	-	-	-	-
Public	ha	-	-	-	-
Private	ha	-	-	-	-
Small	total number	-	-	-	-

Medium	total number	-	-	-	-
Large	total number	-	-	-	-
Investment	EURO	-	29818362	36059655	-
Machines	EURO	-	13564491	36059655	-
Vehicles	EURO	-	10202855	0	-
Land	EURO	-	1310236	0	-
Buildings	EURO	-	5117	0	-
R and D	EURO	-	2036068	0	-
Private	EURO	-	1020757	0	-
Public	EURO	-	2295454	0	-
Goods	%	-	-	-	-
Processes	%	-	-	-	-
Products	%	-	-	-	-
Total Employment	total number	76	2410	2963	4930
Employment male	total number	-	88	-	-
Employment female	total number	-	12	-	-
Rural areas	total number	-	0	-	-
Urban areas	total number	-	100	-	-
Wages and salaries	EURO	2184120	30206909	77330004	276920732
Wages male	EURO	1759739	27352858	46536510	120247948
Wages female	EURO	448625	5690605	8753112	9137619
Country-compared	%	-	64	-	-
Compared purchasing power	%	246619373	40403813	44047559	217710918
Total accidents	total number	6	130	309	527
Accidents (non-fatal)	total number	6	129	309	542
Accidents (fatal)	total number	-	1	0	16
Diseases	number per 1000	13	103	8	0
Education low	total number	1315	3297477	71	23
Education high	total number	470	16828702	1270	147
Training time per employee	hours	-	7979791	209	74279722
Certified holdings	total number	-	-	-	-
Forest certification	total number	-	-	-	-
EMS	total number	-	-	-	-
Certified wood	%	-	-	-	-
Limited-total	total number	-	-	-	-
Limited-male	total number	-	-	-	-

Limited-female	total number	-	-	-	-
Self-employed	total number	-	-	-	-
Recreational use	ha	-	-	-	-
Protective services	ha	-	52	-	-
Visitors	total number	-	-	-	-
Wood consumption	m ³	-	-	-	-
Forest area	%	-	-	-	-
Biodiversity	%	-	-	-	-
Forest health	%	-	-	-	-
Env. friendly	%	-	-	-	-
Employer	%	-	-	-	-
Onsite generation	MJ	-	-	861166201	4041405801
Heat from residues	MJ	-	-	1241017039	1161853464
Heat from other wood	MJ	-	-	371572881	4572699100
Heat non-wood	MJ	-	-	0	0
Electricity from residues	MJ	-	-	0	1379050735
Electricity from other wood	MJ	-	-	404616889	0
Electricity non-wood	MJ	-	-	0	0
Fuel from residues	MJ	-	-	0	0
Fuel from other wood	MJ	-	-	0	0
Fuel non-wood	MJ	-	-	0	0
Energy use	MJ	-	-	-	-
Heat renewable	MJ	-	-	22301958748	49758
Heat fossil	MJ	-	-	3027810787	41442011
Fuel renewable	MJ	-	0	0	0
Fuel fossil	MJ	24940799	1300263205	121917084	4161070170
Electricity renewable	MJ	-	-	0	0
Electricity fossil	MJ	-	-	0	0
Electricity from grid	MJ	-	9434060	1285353825	3862715857
Self-sufficiency	%	-	-	-	-
Greenhouse gas emission	kg CO2 equivalents	1738702	120302160	2915107424	5657169616
GHG from machinery	kg CO2 equivalents	256484	120302160	238392288	160470577
GHG from combustion	kg CO2 equivalents	8722776	-	2676106762	4473263386
Carbon stock	kg CO2 equivalents	-	-	-	-
Carbon above ground	kg CO2 equivalents	305895072	-	-	-
Carbon below ground	kg CO2 equivalents	76473768	-	-	-

Carbon dead wood	kg CO2 equivalents	8752358	-	-	-
Carbon soil	kg CO2 equivalents	-	-	-	-
Carbon wood products	kg CO2 equivalents	-	-	-	-
Road transport (loaded)	km	-	691108674	565814075	3127628940
Rail transport	km	-	209009525	997534531	232877082
Water transport (inland)	km	-	0	0	0
Water transport (sea)	km	-	0	0	6790453791
Air transport	km	-	0	0	0
Road transport (unloaded)	km	-	691108674	216665004	531427519
Freight volume road	t	-	230220619	94039726	284890610
Freight volume rail	t	-	548292110	203428074	0
Freight volume water	t	-	0	0	0
Freight volume sea	t	-	0	0	93685496364
Freight volume air	t	-	0	0	0
Water use - industry	m ³	-	-	64453755	1064656
Water use - forest	m ³	-	-	-	-
Evapotranspiration	m ³	-	-	-	-
Groundwater	m ³	-	-	-	-
FOWL	ha	3182607	30350	-	-
Growing stock above ground	m ³	-	-	-	-
Commercial volume	m ³	-	-	-	-
Net annual increment	m ³	-	-	-	-
Age classes	total number	-	-	-	-
Age variation	coefficient of variation	-	-	-	-
Diameter classes	total number	-	-	-	-
Diameter variation	coefficient of variation	-	-	-	-
Soil properties	-	-	-	-	-
pH	pH classes	-	-	-	-
CEC	cmol/ha	-	-	-	-
C/N ratio	ratio per ha	-	-	-	-
Organic carbon	g/ha	-	-	-	-
Base saturation	%s	-	-	-	-
Nutrient budget	% per ha	-	-	-	-
Soil compaction	%	-	-	-	-
Water pollution - organic	kg	-	-	2717684	3596

Water pollution - nutrients	kg	-	-	363550	124989
CO into air	kg	-	14349	2966	12264158
NOx into air	kg	-	939591	2238086	36163601
SO2 into air	kg	-	2089	1277095	3342260
NM VOC into air	kg	-	14366	0	96240
Forest biodiversity	-	-	-	-	-
Tree species	total number	-	-	-	-
Introduced species	total number	-	-	-	-
Standing deadwood	m ³ /ha	-	-	-	-
Lying deadwood	m ³ /ha	-	-	-	-
Protected area	%	-	-	-	-
Biotic	ha	-	-	-	-
Insects/diseases	ha	-	-	-	-
Wildlife/grazing	ha	-	-	-	-
Abiotic	ha	-	-	-	-
Fire	ha	-	-	-	-
Storm	ha	-	-	-	-
Snow/others	ha	-	-	-	-
Human	ha	-	-	-	-
Damage-induced wood	m ³	-	-	-	-
Waste generation	kg	-	335306	807791579	571619128
Waste not hazardous	kg	-	118727	803408553	230338292
Hazardous waste	kg	-	263748	874570	249978850
Recycling	kg	-	0	83999357	240393366
Incineration	kg	-	-	640610374	17191029
Landfill	kg	-	-	82307278	35724329

2015

Name	Unit	M2	M3	M4	M5
Gross value added	EURO	-7488500	222935730	533598345	1472486835
Production cost	EURO	11785294	187018605	949303170	3940791241
Material costs in FWC	EURO	-	0	417480718	1761860186
Material costs outside FWC	EURO	-	0	220116648	4163315227
Labour costs	EURO	2576073	115135943	115762786	376742398
Energy costs	EURO	443998	25412886	88939758	42122362
Other costs	EURO	8677355	31721369	30606091	96573414
Non-productive costs	EURO	-	14748407	6501979	119217438

Share wood-based costs	%	-	-	-	-
Wood Imports - Volume	m ³	-	30350	0	-
Wood Imports - Value	EURO	-	-	0	-
Import Share	%	-	-	-	-
Wood Exports - Volume	m ³	-	-	0	-
Wood Exports - Value	EURO	-	-	0	-
Export Share	%	-	-	0	-
Net trade - volume	m ³	-	-	0	-
Net trade - value	EURO	-	-	0	-
Other renewable	m ³	-	0	0	33545742
Renewable-virgin	m ³	-	357893	0	33545742
Renewable-recycled	m ³	-	0	0	-
Non-renewable	m ³	-	23217567	0	384
Non-renewable-virgin	m ³	-	23288271	0	384
Non-renewable-recycled	m ³	-	5704	0	-
Enterprises	total number	-	-	-	-
Public	total number	-	-	-	-
Private	total number	-	-	-	-
Size	ha	-	-	-	-
Public	ha	-	-	-	-
Private	ha	-	-	-	-
Small	total number	-	-	-	-
Medium	total number	-	-	-	-
Large	total number	-	-	-	-
Investment	EURO	-	29617952	31552198	-
Machines	EURO	-	13599330	31552198	-
Vehicles	EURO	-	9538819	0	-
Land	EURO	-	1312363	0	-
Buildings	EURO	-	5117	0	-
R and D	EURO	-	2036546	0	-
Private	EURO	-	1020997	0	-
Public	EURO	-	2297821	0	-
Goods	%	-	-	-	-
Processes	%	-	-	-	-
Products	%	-	-	-	-
Total Employment	total number	75	2243	2775	3763
Employment male	total number	-	83	-	-

Employment female	total number	-	17	-	-
Rural areas	total number	-	0	-	-
Urban areas	total number	-	100	-	-
Wages and salaries	EURO	1771559	31943812	100646729	233670570
Wages male	EURO	1457685	26589492	5674475	106453554
Wages female	EURO	488981	5677966	50433	8021772
Country-compared	%	-	64	-	-
Compared purchasing power	%	304893501	80579564	26474563	138816080
Total accidents	total number	5	293	291	419
Accidents (non-fatal)	total number	5	151	291	431
Accidents (fatal)	total number	-	7	0	13
Diseases	number per 1000	16	324	8	0
Education low	total number	1644	4996940	71	23
Education high	total number	587	15793755	1270	148
Training time per employee	hours	-	7993468	209	74478374
Certified holdings	total number	-	-	-	-
Forest certification	total number	-	-	-	-
EMS	total number	-	-	-	-
Certified wood	%	-	-	-	-
Limited-total	total number	-	-	-	-
Limited-male	total number	-	-	-	-
Limited-female	total number	-	-	-	-
Self-employed	total number	-	-	-	-
Recreational use	ha	-	-	-	-
Protective services	ha	-	39	-	-
Visitors	total number	-	-	-	-
Wood consumption	m ³	-	-	-	-
Forest area	%	-	-	-	-
Biodiversity	%	-	-	-	-
Forest health	%	-	-	-	-
Env. friendly	%	-	-	-	-
Employer	%	-	-	-	-
Onsite generation	MJ	-	-	862571662	0
Heat from residues	MJ	-	-	1241017039	0
Heat from other wood	MJ	-	-	372528307	0
Heat non-wood	MJ	-	-	0	0

Electricity from residues	MJ	-	-	0	0
Electricity from other wood	MJ	-	-	448172306	0
Electricity non-wood	MJ	-	-	0	0
Fuel from residues	MJ	-	-	0	0
Fuel from other wood	MJ	-	-	0	0
Fuel non-wood	MJ	-	-	0	0
Energy use	MJ	-	-	-	-
Heat renewable	MJ	-	-	22885344820	49758
Heat fossil	MJ	-	-	2480718031	41442011
Fuel renewable	MJ	-	0	0	327628976
Fuel fossil	MJ	23104365	1015243290	102496610	3788712165
Electricity renewable	MJ	-	-	0	0
Electricity fossil	MJ	-	-	0	0
Electricity from grid	MJ	-	7222281	1188130119	3442338102
Self-sufficiency	%	-	-	-	-
Greenhouse gas emission	kg CO2 equivalents	1629730	94053710	2879891150	926884686
GHG from machinery	kg CO2 equivalents	337327	94053710	196501927	158195279
GHG from combustion	kg CO2 equivalents	10903470	-	686356976	1614574
Carbon stock	kg CO2 equivalents	-	-	-	-
Carbon above ground	kg CO2 equivalents	308648299	-	-	-
Carbon below ground	kg CO2 equivalents	77162075	-	-	-
Carbon dead wood	kg CO2 equivalents	8521915	-	-	-
Carbon soil	kg CO2 equivalents	-	-	-	-
Carbon wood products	kg CO2 equivalents	-	-	-	-
Road transport (loaded)	km	-	692501705	438019970	3044718316
Rail transport	km	-	209009525	997534531	232877082
Water transport (inland)	km	-	0	0	0
Water transport (sea)	km	-	0	0	6808705409
Air transport	km	-	0	0	926653220
Road transport (unloaded)	km	-	692501705	207510248	510000585
Freight volume road	t	-	230605637	94039726	271574893
Freight volume rail	t	-	0	203428074	0
Freight volume water	t	-	0	0	0
Freight volume sea	t	-	0	0	93938225218
Freight volume air	t	-	0	0	7280846729
Water use - industry	m ³	-	-	58459731	999654

Water use - forest	m ³	-	-	-	-
Evapotranspiration	m ³	-	-	-	-
Groundwater	m ³	-	-	-	-
FOWL	ha	3007408	30350	-	-
Growing stock above ground	m ³	-	-	-	-
Commercial volume	m ³	-	-	-	-
Net annual increment	m ³	-	-	-	-
Age classes	total number	-	-	-	-
Age variation	coefficient of variation	-	-	-	-
Diameter classes	total number	-	-	-	-
Diameter variation	coefficient of variation	-	-	-	-
Soil properties	-	-	-	-	-
pH	pH classes	-	-	-	-
CEC	cmol/ha	-	-	-	-
C/N ratio	ratio per ha	-	-	-	-
Organic carbon	g/ha	-	-	-	-
Base saturation	%s	-	-	-	-
Nutrient budget	% per ha	-	-	-	-
Soil compaction	%	-	-	-	-
Water pollution - organic	kg	-	-	2134729	3593
Water pollution - nutrients	kg	-	-	182977	102271
CO into air	kg	-	11193	2428	12232258
NOx into air	kg	-	732628	1833916	35488707
SO2 into air	kg	-	1628	1046396	3302381
NMVOC into air	kg	-	11193	0	76545
Forest biodiversity	-	-	-	-	-
Tree species	total number	-	-	-	-
Introduced species	total number	-	-	-	-
Standing deadwood	m ³ /ha	-	-	-	-
Lying deadwood	m ³ /ha	-	-	-	-
Protected area	%	-	-	-	-
Biotic	ha	-	-	-	-
Insects/diseases	ha	-	-	-	-
Wildlife/grazing	ha	-	-	-	-
Abiotic	ha	-	-	-	-

Fire	ha	-	-	-	-
Storm	ha	-	-	-	-
Snow/others	ha	-	-	-	-
Human	ha	-	-	-	-
Damage-induced wood	m ³	-	-	-	-
Waste generation	kg	-	336363	38468393	227055423
Waste not hazardous	kg	-	118949	34839411	155520223
Hazardous waste	kg	-	264583	120525	466
Recycling	kg	-	0	84230214	263505676
Incineration	kg	-	-	5473041	9371684
Landfill	kg	-	-	10673645	0

2025

Name	Unit	M2	M3	M4	M5
Gross value added	EURO	-7736827	291874305	547870153	1690826438
Production cost	EURO	14226159	196349716	964922889	3431897695
Material costs in FWC	EURO	-	0	460149713	1938122670
Material costs outside FWC	EURO	-	0	198957322	4600930096
Labour costs	EURO	3371701	125805376	113654332	402565987
Energy costs	EURO	558317	28231184	86676422	36882752
Other costs	EURO	10186386	30846978	16390588	99811984
Non-productive costs	EURO	-	13288212	8553869	115428916
Share wood-based costs	%	-	-	-	-
Wood Imports - Volume	m ³	-	30350	0	-
Wood Imports - Value	EURO	-	-	0	-
Import Share	%	-	-	-	-
Wood Exports - Volume	m ³	-	-	0	-
Wood Exports - Value	EURO	-	-	0	-
Export Share	%	-	-	0	-
Net trade - volume	m ³	-	-	0	-
Net trade - value	EURO	-	-	0	-
Other renewable	m ³	-	0	0	33611958
Renewable-virgin	m ³	-	372442	0	33611958
Renewable-recycled	m ³	-	0	0	-
Non-renewable	m ³	-	24133177	0	385

Non-renewable-virgin	m ³	-	24208101	0	385
Non-renewable-recycled	m ³	-	5435	0	-
Enterprises	total number	-	-	-	-
Public	total number	-	-	-	-
Private	total number	-	-	-	-
Size	ha	-	-	-	-
Public	ha	-	-	-	-
Private	ha	-	-	-	-
Small	total number	-	-	-	-
Medium	total number	-	-	-	-
Large	total number	-	-	-	-
Investment	EURO	-	29665565	28046398	-
Machines	EURO	-	13626429	28046398	-
Vehicles	EURO	-	9557677	0	-
Land	EURO	-	1314018	0	-
Buildings	EURO	-	5117	0	-
R and D	EURO	-	2036919	0	-
Private	EURO	-	1021183	0	-
Public	EURO	-	2299663	0	-
Goods	%	-	-	-	-
Processes	%	-	-	-	-
Products	%	-	-	-	-
Total Employment	total number	93	2258	2656	3167
Employment male	total number	-	81	-	-
Employment female	total number	-	19	-	-
Rural areas	total number	-	0	-	-
Urban areas	total number	-	100	-	-
Wages and salaries	EURO	2302715	32125687	114848350	230808198
Wages male	EURO	1884830	25641416	6080510	93367195
Wages female	EURO	595224	6340598	48897	6820360
Country-compared	%	-	64	-	-
Compared purchasing power	%	400074254	28711099	26466104	125058442
Total accidents	total number	6	262	290	347
Accidents (non-fatal)	total number	6	147	290	356
Accidents (fatal)	total number	-	6	0	11
Diseases	number per 1000	21	334	8	0

Education low	total number	2196	5104028	71	23
Education high	total number	784	15768694	1270	148
Training time per employee	hours	-	8004124	209	74632891
Certified holdings	total number	-	-	-	-
Forest certification	total number	-	-	-	-
EMS	total number	-	-	-	-
Certified wood	%	-	-	-	-
Limited-total	total number	-	-	-	-
Limited-male	total number	-	-	-	-
Limited-female	total number	-	-	-	-
Self-employed	total number	-	-	-	-
Recreational use	ha	-	-	-	-
Protective services	ha	-	39	-	-
Visitors	total number	-	-	-	-
Wood consumption	m ³	-	-	-	-
Forest area	%	-	-	-	-
Biodiversity	%	-	-	-	-
Forest health	%	-	-	-	-
Env. friendly	%	-	-	-	-
Employer	%	-	-	-	-
Onsite generation	MJ	-	-	518937917	0
Heat from residues	MJ	-	-	0	0
Heat from other wood	MJ	-	-	373271467	0
Heat non-wood	MJ	-	-	0	0
Electricity from residues	MJ	-	-	0	0
Electricity from other wood	MJ	-	-	496133998	0
Electricity non-wood	MJ	-	-	0	0
Fuel from residues	MJ	-	-	0	0
Fuel from other wood	MJ	-	-	0	0
Fuel non-wood	MJ	-	-	0	0
Energy use	MJ	-	-	-	-
Heat renewable	MJ	-	-	21741363125	49758
Heat fossil	MJ	-	-	2031089619	41442011
Fuel renewable	MJ	-	0	0	592527098
Fuel fossil	MJ	29565778	994905454	12816856	3501220342
Electricity renewable	MJ	-	-	0	0

Electricity fossil	MJ	-	-	0	0
Electricity from grid	MJ	-	7666069	985493937	3172057238
Self-sufficiency	%	-	-	-	-
Greenhouse gas emission	kg CO2 equivalents	2093715	92087398	2853789423	765092336
GHG from machinery	kg CO2 equivalents	466756	92087398	164735685	157189034
GHG from combustion	kg CO2 equivalents	14566985	-	687651207	0
Carbon stock	kg CO2 equivalents	-	-	-	-
Carbon above ground	kg CO2 equivalents	309416105	-	-	-
Carbon below ground	kg CO2 equivalents	77354026	-	-	-
Carbon dead wood	kg CO2 equivalents	8682469	-	-	-
Carbon soil	kg CO2 equivalents	-	-	-	-
Carbon wood products	kg CO2 equivalents	-	-	-	-
Road transport (loaded)	km	-	693585247	0	3048646747
Rail transport	km	-	209009525	0	240595566
Water transport (inland)	km	-	0	0	0
Water transport (sea)	km	-	0	0	6822902065
Air transport	km	-	0	0	928681099
Road transport (unloaded)	km	-	693585247	0	511258992
Freight volume road	t	-	230905116	0	273246801
Freight volume rail	t	-	0	0	0
Freight volume water	t	-	0	0	0
Freight volume sea	t	-	0	0	94134805294
Freight volume air	t	-	0	0	7296780062
Water use - industry	m ³	-	-	52989368	958137
Water use - forest	m ³	-	-	-	-
Evapotranspiration	m ³	-	-	-	-
Groundwater	m ³	-	-	-	-
FOWL	ha	3040182	30350	-	-
Growing stock above ground	m ³	-	-	-	-
Commercial volume	m ³	-	-	-	-
Net annual increment	m ³	-	-	-	-
Age classes	total number	-	-	-	-
Age variation	coefficient of variation	-	-	-	-
Diameter classes	total number	-	-	-	-
Diameter variation	coefficient of variation	-	-	-	-

Soil properties	-	-	-	-	-
pH	pH classes	-	-	-	-
CEC	cmol/ha	-	-	-	-
C/N ratio	ratio per ha	-	-	-	-
Organic carbon	g/ha	-	-	-	-
Base saturation	%s	-	-	-	-
Nutrient budget	% per ha	-	-	-	-
Soil compaction	%	-	-	-	-
Water pollution - organic	kg	-	-	2138943	3593
Water pollution - nutrients	kg	-	-	183338	101889
CO into air	kg	-	9835	2966	12190005
NOx into air	kg	-	643736	1531530	35384477
SO2 into air	kg	-	1431	856800	3291160
NMVOC into air	kg	-	9835	0	66588
Forest biodiversity	-	-	-	-	-
Tree species	total number	-	-	-	-
Introduced species	total number	-	-	-	-
Standing deadwood	m ³ /ha	-	-	-	-
Lying deadwood	m ³ /ha	-	-	-	-
Protected area	%	-	-	-	-
Biotic	ha	-	-	-	-
Insects/diseases	ha	-	-	-	-
Wildlife/grazing	ha	-	-	-	-
Abiotic	ha	-	-	-	-
Fire	ha	-	-	-	-
Storm	ha	-	-	-	-
Snow/others	ha	-	-	-	-
Human	ha	-	-	-	-
Damage-induced wood	m ³	-	-	-	-
Waste generation	kg	-	337186	38535790	187965499
Waste not hazardous	kg	-	119123	34906591	129138408
Hazardous waste	kg	-	265232	120742	416
Recycling	kg	-	0	84409781	288867771
Incineration	kg	-	-	5475329	1499536
Landfill	kg	-	-	10694714	0

Indicator settings

ID	Indicator	Indicator group	Enabled	Pref.Min.Threshold	Pref.Max.Threshold	abs.
----	-----------	-----------------	---------	--------------------	--------------------	------

						Value Warning
1000	Gross value added	Gross value added	yes	0.03	0.1	1e+06
2000	Production cost	Production Costs	yes	0.03	0.1	
2010	Material costs in FWC	Production Costs	no	0.03	0.1	
2020	Material costs outside FWC	Production Costs	no	0.03	0.1	
2030	Labour costs	Production Costs	no	0.03	0.1	
2040	Energy costs	Production Costs	no	0.03	0.1	
2050	Other costs	Production Costs	no	0.03	0.1	
2060	Non-productive costs	Production Costs	no	0.03	0.1	
2070	Share wood-based costs	Production Costs	yes	0.03	0.1	
3010	Wood Imports - Volume	Resource/Material Use	yes	0.03	0.1	
3020	Wood Imports - Value	Resource/Material Use	yes	0.03	0.1	
3030	Import Share	Resource/Material Use	yes	0.03	0.1	
3040	Wood Exports - Volume	Resource/Material Use	yes	0.03	0.1	
3050	Wood Exports - Value	Resource/Material Use	yes	0.03	0.1	
3060	Export Share	Resource/Material Use	yes	0.03	0.1	
3070	Net trade - volume	Resource/Material Use	yes	0.03	0.1	
3080	Net trade - value	Resource/Material Use	yes	0.03	0.1	
4040	Other renewable	Total Production	yes	0.03	0.1	
4050	Renewable-virgin	Total Production	no	0.03	0.1	
4060	Renewable-recycled	Total Production	no	0.03	0.1	
4070	Non-renewable	Total Production	yes	0.03	0.1	
4080	Non-renewable-virgin	Total Production	no	0.03	0.1	
4090	Non-renewable-recycled	Total Production	no	0.03	0.1	
5010	Enterprises	Forest Enterprises	yes	0.03	0.1	
5020	Public	Forest Enterprises	no	0.03	0.1	
5030	Private	Forest Enterprises	no	0.03	0.1	
5040	Size	Forest Enterprises	yes	0.03	0.1	
5050	Public	Forest Enterprises	no	0.03	0.1	

5060	Private	Forest Enterprises	no	0.03	0.1	
5070	Small	Forest Enterprises	yes	0.03	0.1	
5080	Medium	Forest Enterprises	yes	0.03	0.1	
5090	Large	Forest Enterprises	yes	0.03	0.1	
6010	Investment	Investment in R and D	yes	0.03	0.1	
6021	Machines	Investment in R and D	no	0.03	0.1	
6022	Vehicles	Investment in R and D	no	0.03	0.1	
6023	Land	Investment in R and D	no	0.03	0.1	
6024	Buildings	Investment in R and D	no	0.03	0.1	
6030	R and D	Investment in R and D	yes	0.03	0.1	
6040	Private	Investment in R and D	no	0.03	0.1	
6050	Public	Investment in R and D	no	0.03	0.1	
7210	Goods	Innovation	yes	0.03	0.1	
7220	Processes	Innovation	yes	0.03	0.1	
7230	Products	Innovation	yes	0.03	0.1	
8010	Total Employment	Employment	yes	0.03	273.17	
8020	Employment male	Employment	yes	0.03	0.1	
8030	Employment female	Employment	yes	0.03	0.1	
8040	Rural areas	Employment	yes	0.03	0.1	
8050	Urban areas	Employment	yes	0.03	0.1	
9000	Wages and salaries	Wages and salaries	yes	0.03	0.1	
9010	Wages male	Wages and salaries	yes	0.03	0.1	
9020	Wages female	Wages and salaries	yes	0.03	0.1	
9030	Country-compared	Wages and salaries	yes	0.03	0.1	
9040	Compared purchasing power	Wages and salaries	yes	0.03	0.1	
10005	Total accidents	Safety and health	no	0.03	0.1	
10010	Accidents (non-fatal)	Safety and health	yes	0.03	0.1	
10020	Accidents (fatal)	Safety and health	yes	0.03	0.1	
10025	Diseases	Safety and health	yes	0.03	0.1	

11010	Education low	Education and training	yes	0.03	0.1	
11020	Education high	Education and training	yes	0.03	0.1	
11030	Training time per employee	Education and training	yes	0.03	0.1	
11110	Certified holdings	CSR	yes	0.03	0.1	
11120	Forest certification	CSR	no	0.03	0.1	
11130	EMS	CSR	no	0.03	0.1	
11140	Certified wood	CSR	yes	0.03	0.1	
11210	Limited-total	Employment quality	yes	0.03	0.1	
11220	Limited-male	Employment quality	no	0.03	0.1	
11230	Limited-female	Employment quality	no	0.03	0.1	
11240	Self-employed	Employment quality	yes	0.03	0.1	
11310	Recreational use	Public services	yes	0.03	0.1	
11320	Protective services	Public services	yes	0.03	0.1	
11330	Visitors	Public services	yes	0.03	0.1	
11410	Wood consumption	Consumer behaviour	yes	0.03	0.1	
11420	Forest area	Consumer behaviour	yes	0.03	0.1	
11430	Biodiversity	Consumer behaviour	yes	0.03	0.1	
11440	Forest health	Consumer behaviour	yes	0.03	0.1	
11450	Env. friendly	Consumer behaviour	yes	0.03	0.1	
11460	Employer	Consumer behaviour	yes	0.03	0.1	
12000	Onsite generation	Energy	no	0.03	0.1	
12010	Heat from residues	Energy	yes	0.03	0.1	
12020	Heat from other wood	Energy	yes	0.03	0.1	
12030	Heat non-wood	Energy	yes	0.03	0.1	
12040	Electricity from residues	Energy	no	0.03	0.1	
12050	Electricity from other wood	Energy	no	0.03	0.1	
12060	Electricity non-wood	Energy	no	0.03	0.1	
12070	Fuel from residues	Energy	no	0.03	0.1	

12080	Fuel from other wood	Energy	no	0.03	0.1	
12090	Fuel non-wood	Energy	no	0.03	0.1	
12100	Energy use	Energy	yes	0.03	0.1	
12110	Heat renewable	Energy	no	0.03	0.1	
12130	Heat fossil	Energy	no	0.03	0.1	
12135	Fuel renewable	Energy	no	0.03	0.1	
12140	Fuel fossil	Energy	no	0.03	0.1	
12150	Electricity renewable	Energy	no	0.03	0.1	
12160	Electricity fossil	Energy	no	0.03	0.1	
12170	Electricity from grid	Energy	no	0.03	0.1	
12200	Self-sufficiency	Energy	yes	0.03	0.1	
13010	Greenhouse gas emission	GHG emissions	yes	0.03	0.1	
13011	GHG from machinery	GHG emissions	no	0.03	0.1	
13012	GHG from combustion	GHG emissions	no	0.03	0.1	
13015	Carbon stock	GHG emissions	yes	0.03	0.1	
13020	Carbon above ground	GHG emissions	no	0.03	0.1	
13030	Carbon below ground	GHG emissions	no	0.03	0.1	
13040	Carbon dead wood	GHG emissions	no	0.03	0.1	
13050	Carbon soil	GHG emissions	no	0.03	0.1	
13060	Carbon wood products	GHG emissions	no	0.03	0.1	
14010	Road transport (loaded)	Transport	yes	0.03	0.1	
14020	Rail transport	Transport	yes	0.03	0.1	
14030	Water transport (inland)	Transport	yes	0.03	0.1	
14040	Water transport (sea)	Transport	yes	0.03	0.1	
14050	Air transport	Transport	yes	0.03	0.1	
14060	Road transport (unloaded)	Transport	yes	0.03	0.1	
14070	Freight volume road	Transport	yes	0.03	0.1	
14080	Freight volume rail	Transport	yes	0.03	0.1	
14090	Freight volume	Transport	yes	0.03	0.1	

	water					
14100	Freight volume sea	Transport	yes	0.03	0.1	
14110	Freight volume air	Transport	yes	0.03	0.1	
15010	Water use - industry	Water use	yes	0.03	0.1	
15015	Water use - forest	Water use	yes	0.03	0.1	
15020	Evapotranspiration	Water use	no	0.03	0.1	
15030	Groundwater	Water use	no	0.03	0.1	
16100	FOWL	Forest Resources	yes	0.03	0.1	
16210	Growing stock above ground	Forest Resources	yes	0.03	0.1	
16250	Commercial volume	Forest Resources	yes	0.03	0.1	
16430	Net annual increment	Forest Resources	yes	0.03	0.1	
16510	Age classes	Forest Resources	yes	0.03	0.1	
16515	Age variation	Forest Resources	yes	0.03	0.1	
16520	Diameter classes	Forest Resources	yes	0.03	0.1	
16525	Diameter variation	Forest Resources	yes	0.03	0.1	
17010	Soil properties	Soil condition	no	0.03	0.1	
17020	pH	Soil condition	yes	0.03	0.1	
17030	CEC	Soil condition	yes	0.03	0.1	
17040	C/N ratio	Soil condition	yes	0.03	0.1	
17050	Organic carbon	Soil condition	yes	0.03	0.1	
17060	Base saturation	Soil condition	yes	0.03	0.1	
17070	Nutrient budget	Soil condition	yes	0.03	0.1	
17080	Soil compaction	Soil condition	yes	0.03	0.1	
18010	Water pollution - organic	Pollution	yes	0.03	0.1	
18020	Water pollution - nutrients	Pollution	yes	0.03	0.1	
18030	CO into air	Pollution	yes	0.03	0.1	
18040	NOx into air	Pollution	yes	0.03	0.1	
18050	SO2 into air	Pollution	yes	0.03	0.1	
18060	NMVOC into air	Pollution	yes	0.03	0.1	
18100	Forest biodiversity	Forest biodiversity	no	0.03	0.1	
18110	Tree species	Forest biodiversity	yes	0.03	0.1	
18120	Introduced species	Forest	yes	0.03	0.1	

		biodiversity				
18130	Standing deadwood	Forest biodiversity	yes	0.03	0.1	
18140	Lying deadwood	Forest biodiversity	yes	0.03	0.1	
18150	Protected area	Forest biodiversity	yes	0.03	0.1	
18210	Biotic	Forest damage	yes	0.03	0.1	
18220	Insects/diseases	Forest damage	no	0.03	0.1	
18230	Wildlife/grazing	Forest damage	no	0.03	0.1	
18240	Abiotic	Forest damage	yes	0.03	0.1	
18250	Fire	Forest damage	no	0.03	0.1	
18260	Storm	Forest damage	no	0.03	0.1	
18270	Snow/others	Forest damage	no	0.03	0.1	
18280	Human	Forest damage	yes	0.03	0.1	
18290	Damage-induced wood	Forest damage	yes	0.03	0.1	
19000	Waste generation	Generation of waste	yes	0.03	0.1	
19005	Waste not hazardous	Generation of waste	no	0.03	0.1	
19010	Hazardous waste	Generation of waste	no	0.03	0.1	
19030	Recycling	Generation of waste	yes	0.03	0.1	
19040	Incineration	Generation of waste	yes	0.03	0.1	
19050	Landfill	Generation of waste	yes	0.03	0.1	