

# CHALMERS



## Measurement and communication of environmental performance of products

Deliverable from IMPRESS sub project 7

Markus Erlandsson  
Karolina Flemström

*IMI - Industrial Environmental Informatics  
for*

*CPM - Centre for Environmental Assessment of Product and Material Systems*

CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden 2006

**CPM Report 2006:2**

## **Summary**

This report is the result of a sub project included in the CPM project “Implementation of integrated environmental information systems”, with acronym IMPRESS. The goal of this project is to measure and communicate environmental performance of products within the participating companies in terms of environmental performance indicators (EPIs) according to the RAVEL Design for Environment methodology.

Experiences have shown that the RAVEL methodology, which was developed within the railway industry, also is applicable within the heavy electrical equipment and furniture industries. The collaboration work between Chalmers and the participating companies have resulted in a practical set of EPIs, relevant material data and tools for inserting component and material data and for calculating and communicating EPI results. EPIs, tools and data have been tested and used in practice in the participating companies.

<b>1</b>	<b>INTRODUCTION .....</b>	<b>3</b>
1.1	<i>The IMPRESS project.....</i>	3
1.2	<i>Background in terms of earlier results .....</i>	5
<b>2</b>	<b>WORKING METHOD AND PARTICIPATION .....</b>	<b>7</b>
2.1	<i>Participants .....</i>	7
2.2	<i>The participants roles in the project .....</i>	7
2.3	<i>Working method .....</i>	8
<b>3</b>	<b>IMPLEMENTATION OF THE SELECTED PARTS OF THE RAVEL DFE METHODOLOGY IN COMPANIES .....</b>	<b>10</b>
3.1	<i>Requirements analysis.....</i>	10
3.2	<i>Environmental Performance Indicators .....</i>	13
3.3	<i>Data acquisition.....</i>	18
3.4	<i>DfE Inventory tool.....</i>	25
3.5	<i>Reporting tool .....</i>	27
<b>4</b>	<b>INTEGRATION WITH OTHER INFORMATION SYSTEMS .....</b>	<b>34</b>
4.1	<i>Integration with other information systems within IMPRESS.....</i>	34
4.2	<i>Integration with other information systems within a company .....</i>	34
4.3	<i>Integration of data sources providing support for material selection.....</i>	35
<b>5</b>	<b>EXPERIENCES .....</b>	<b>37</b>
5.1	<i>Experiences from usage of the RAVEL-methodology in general.....</i>	37
5.2	<i>Experiences from usage of the indicators .....</i>	37
5.3	<i>Experiences from usage of the material list and material data .....</i>	38
5.4	<i>Experiences from usage of the CPM Inventory tool and EPI Reporting tool.....</i>	39
5.5	<i>Other experiences from the collaboration .....</i>	39
<b>6</b>	<b>CONCLUSIONS .....</b>	<b>40</b>
	<b>APPENDIX 1: CHECKLIST SUB PROJECT 7 .....</b>	<b>42</b>

<b>APPENDIX 2: TEMPLATES FOR DOCUMENTATION OF EPI AND MATERIAL PROPERTY DATA.....</b>	<b>43</b>
6.1 EPI definition template.....	43
6.2 Material property specification template.....	43
<b>APPENDIX 3: MANUAL FOR CPM INVENTORY TOOL AND EPI REPORTING TOOL.....</b>	<b>45</b>
3.1 Procedure: How to insert data on products into the CPM Inventory tool .....	45
3.2 Procedure: How to calculate EPIs in CPM Inventory tool .....	53
3.3 Procedure: How to define target values for EPIs in CPM Inventory tool.....	54
3.4 Procedure: How to generate EPI Result reports for data inserted into the CPM Inventory tool .....	55

# 1 Introduction

Decisions taken in the development process of a product imply major consequences on the whole life cycle of a product. For that reason it is natural that parameters that control the function, quality, and price etc. of the product, for a long time has been highly prioritized in the design of a product. Environmental consequences related to the production including raw material origin, use, and disposal of the product, has often been an issue neglected in the development of a product. This is now starting to change, as the customers' awareness of environmental issues increase both on a global level (e.g. emissions of green house gases) and local level (e.g. potential emissions of toxic substances). Furthermore, regulations and other means of control used by authorities put environmental requirements on the products which need to be considered in the product development phase.

This report is the result of a sub project included in the CPM project "Implementation of integrated environmental information systems", with acronym IMPRESS. The goal and scope of this project is described below.

## 1.1 *The IMPRESS project*

### 1.1.1 **Goals and objectives**

The IMPRESS project (acronym for IMpLeMentation of integRated Environmental information SystemS) runs 2004 – 2006, and aims at showing how information, methods and tools that supports environmentally related decisions within the industry, can be integrated with each other and with the corporate business processes and also implemented into the organisations.

The companies participating in the project are Akzo Nobel, Bombardier Transportation, Duni, IKEA, ITT Flygt, SCA and Stora Enso. Research and development work is performed together with the research group Industrial Environmental Informatics (IMI) at Chalmers University of Technology. The project is funded by the Swedish competence Center for environmental assessment of Product and Material systems (CPM).

The overall task of IMPRESS is to implement method and tool integration with business processes in a number of industrial companies. The objectives are to:

- Decrease the cost for industrial environmental management.
- Decrease the cost for developing, using and maintaining data, tools and methods for industrial environmental management.
- Facilitate acquisition of environmental information.
- Provide educational tools for industrial environmental management.

The project also aims at investigating possibilities for exploitation and dissemination of previous and new CPM results to enhance the value and increase the usability of the results.

The specific methods and tools studied in this project are design for environment (DfE), environmental risk assessment (ERA), and life cycle assessment (LCA) from a product

perspective, environmental management systems (EMS) and LCA from a process perspective, and CO<sub>2</sub>-emission trading (ET) from a societal perspective. Six industrial application and implementation cases are included in the project:

- Emission trading
- Measurement and communication of environmental performance of products
- Environmental management at site and group level
- Risk management adapted to REACH
- Three tools for IPP
- Integration of experiences and new information

These six cases are studied in detail in close cooperation between Industrial Environmental Informatics (IMI) and the companies in different sub projects, including e.g. market analyses, specific method development, implementation etc. A general integration methodology is regarded in a separate sub-project. Similarly, technical maintenance for integration, commercialization work, and knowledge exchange will be performed in three different sub-projects.

### **1.1.2 Sub project 7 - Measurement and communication of environmental performance of products**

#### **1.1.2.1 Sub project goal**

The main objective of this sub project has been to develop and implement methods for measurement and communication of environmental performance of products in terms of performance indicators e.g. Environmental Performance Indicators (EPIs), Sustainability Performance Indicators (SPIs) or Key Performance Indicators (KPIs). The methods and tools will enable the incorporation of sustainability as one of the relevant decision-factors, comparable to factors as quality and price, in decision-making processes. The needs for environmentally related information on products have been investigated in each participating company. Based on the identified needs, a set of performance indicators have been defined. Tools facilitating measurement and communication of environmental performance in terms of the defined indicators have been identified and a prototype tool demonstrating the DfE methodology has been developed and used in the sub project.

#### **1.1.2.2 Sub project scope**

The sub project scope is design for environment (DfE) in terms of the RAVEL methodology.

This sub project handles both products for the industrial market as well as products for the consumer market. For products in the industrial market the requirements are often quantitative which makes it straightforward to measure the environmental performance in terms of e.g. EPIs. For products in the consumer market the requirements from customers are often more qualitative and dynamic. Differences between these product groups have been noticed but the focus has been on measuring environmental performance in terms of quantitative EPIs.

The participating companies are producing very different products. Bombardier Transportation is manufacturing trains, ITT Flygt is making different types of pumps, and IKEA is making furniture and other products for usage at home. This very wide range of products scope the types of products handled in this sub project. The DfE

methodology which is explored is however suitable for an even larger range of products. IKEA has within this sub project also used the methodology to quantify the environmental performance of whole business units based on the environmental performance of the produced products.

## 1.2 Background in terms of earlier results

### 1.2.1 The RAVEL DfE methodology

The work in the sub project has been based on the Design for Environment (DfE) methodology developed within the Brite-Euram III (EU) project RAVEL (Rail Vehicle Eco-Efficient Design) project running 1998-2001, and implemented within the railway industry in the REPID (Rail sector framework and tools for standardizing and improving usability of Environmental Performance Indicators and Data formats) project running 2002-2004.

The DfE methodology developed in RAVEL makes it possible to measure the environmental performance of a product early in the product development process when it is easy and hence least expensive to introduce changes<sup>1</sup>. The methodology and tools supporting the method provide communication and measurement of environmental performance in the supply chain. The method provides a connection between market requirements and the product design. The communication is based on measurable Environmental Performance Indicators (EPIs), and it is technically facilitated by a common communication format for data exchange. By using the RAVEL method e.g. the customer can communicate environmental requirements and targets to the manufacturing companies. The manufacturers can calculate the actual environmental performance in terms of the defined EPIs, and communicate the results back to the customers. The manufacturers can also utilize the same language when communicating environmental performance with their sub-suppliers.



**Figure 1:** The RAVEL methodology and tools provide communication and measurement of environmental performance

In the REPID project, the method and tools from RAVEL were further developed and implemented within the railway industry<sup>2</sup>. REPID was co-ordinated by the railway operators trade organization UIC (International Union of Railways) and the European railway manufacturers organization UNIFE (the Union of European Railway Industries). It resulted in a practical agreement on a set of EPIs, a practically useful and common material list, and an open data format. Based on the material list, the data format and the standardised EPIs software has been developed for analysis and communication of eco-efficiency data of the design of train vehicles or train-components.

<sup>1</sup> Ander, A, Duflou, J., Dewulf, W., et al, Integrating Eco-efficiency in Rail Vehicle Design, Leuven University Press, 2001

<sup>2</sup> Bergendorff, M. (Editor) et al, Final report for the EU funded REPID project, 2004

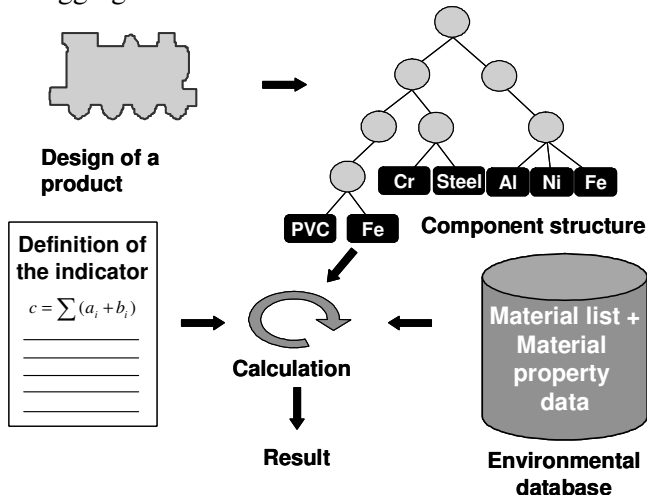
The RAVEL DfE method was developed together with the railway industry and has been implemented within this industry, but it is designed to be generally applicable to any other business where products are developed. The research group IMI – Industrial Environmental Informatics at Chalmers University of Technology participated in both RAVEL and REPID projects. In this sub project in IMPRESS, selected parts of the method have also been tested in companies producing pumps and furniture.

### 1.2.1.1 Environmental Performance Indicators

The most important building brick in the common language are the Environmental Performance Indicators (EPIs) which are quantitative expressions of the environmental performance for a product design. Important characteristics for EPIs that are used in a DfE-system are that the indicators are measurable, able to be controlled by the DfE-process and address important and well defined environmental issues. Another important aspect to consider in the indicator definition process is that the EPIs have to be understandable, as they are going to be used to communicate aggregated information both internally in a company as well as externally between different companies. Within REPID a set of 21 EPIs for energy, noise, materials and recycling etc. was defined based on the environmental policy of rail operators and manufacturers and in accordance with ISO 14031<sup>3</sup>. These definitions were a result of a consensus process within the railway industry which started in the RAVEL project.

### 1.2.1.2 Measurement of environmental performance

The measurement of environmental performance is based on a material list, material property data for each material in the list, and calculation rules for each EPI. To be able to analyze a specific design, a component structure consisting of all the components and materials in the component is needed for the design. The calculation rules define how the material property data, for the materials found in the component structure, shall be aggregated to reach a result for each EPI.



**Figure 2:** Calculation of environmental performance indicators

<sup>3</sup> ISO 14031:1999 (E) Environmental management - Environmental performance evaluation - Guidelines



## 2 Working method and participation

### 2.1 Participants

The following persons have actively participated in the work connected to this sub project (in parentheses the abbreviations used in this report is found):

- Markus Erlandsson, Industrial environmental informatics (IMI)
- Karolina Flemström, Industrial environmental informatics
- Carina Andersson, IKEA of Sweden AB (IKEA)
- Gunilla Clancy, IKEA of Sweden AB
- Evamay Lawson, IKEA of Sweden AB
- Ylva Roos, IKEA of Sweden AB
- Christian Wiklund, ITT Flygt AB (ITT Flygt)
- Ylva Bergkvist, Bombardier Transportation Sweden AB (Bombardier Transportation)
- Sara Paulsson, Bombardier Transportation Sweden AB
- Ronny Öhman, Bombardier Transportation Sweden AB

In addition, persons with expert knowledge regarding e.g. materials, product development, information systems, etc. have contributed to the results from this sub project.

### 2.2 The participants roles in the project

#### 2.2.1 Bombardier Transportation, IKEA and ITT Flygt

The companies' specific role in this subproject has been to explore how the RAVEL methodology can support the company to measure and communicate environmental performance of products. This has included tasks such as:

- Test the indicators with relevant and realistic data. Investigate how useful the indicators are for measurement and communication of environmental performance,
- Develop company specific indicators.

#### 2.2.2 Industrial environmental informatics (IMI)

The specific role of the scientific part IMI in this subproject has been to support and guide the companies when testing the RAVEL methodology, and learn from these experiences on how the method is best implemented within different kinds of industries. This has included tasks such as:

- Develop prototype tool which can be used by the companies when exploring the DfE methodology
- Support the companies when testing the indicators
- Search for other relevant data source and investigate how these data source can be related to the EPI results
- Acquire and maintain basic material data needed for the calculation of the defined EPIs

#### 2.2.3 All

In addition to the specific roles, all parts in the project have participated in tasks such as:

- Agree on the definitions of the common indicators
- Develop an EPI reporting format which facilitates communication of EPI results.
- Discuss level of detail of material lists and environmental data and how this affects the outcome of the measurement of environmental performance in terms of EPI results.

### **2.3 Working method**

The activities performed in this sub project can be summarised by first structuring specific requirements from the participating companies, identify stakeholders and their requirements within e.g. purchasers and outside the companies e.g. from customers. The next step was to define a set of environmental performance indicators (EPIs) based on the requirements and also to build systems or tools facilitating measurement of environmental performance in terms of the defined EPIs. The last steps consisted of implementing the method e.g. acquiring relevant data, performing the actual calculations of the EPIs and to communicate the indicator results etc.

In detail the activities performed are presented in the following list:

- Identify, analyse and structure specific requirements from the different companies
- Identify stakeholders of environmentally related information, their requirements and needs within each company
- Define a first set of common indicators (quantifiable and qualitative) for measurement and communication of environmental performance. Iterative work in meetings. If needed, company specific indicators are also developed with support from IMI.
- Develop a methodology for integrating the needed tools and methods with the existing systems within the company.
  - Analyse which other systems that are being used at the companies
- Develop prototype that implements the RAVEL methodology based on the identified requirements
  - Prototype based on the CPM Inventory Tool with evaluation functionality to perform calculation and set target values.
- Implement the set of indicators in the participating companies
  - Educate employees on how environmental performance can be measured and communicated
  - Establish data quality foundation to assure reliable indicator results etc.
  - Acquisition of relevant data to exemplify the method – environmental data, component data etc.
  - Identify connections and applications for e.g. Idemat (for material substitution).
- Analysis of mapping of material lists, analysis of level of detail in material lists and other related tasks etc.

- Calculate the selected EPIs for a set of test products using the developed prototype
- Communicate the EPI results to the identified stakeholders and analyse the results
- Test how the implemented methodology and prototype fulfils the identified requirement

## **3 Implementation of the selected parts of the RAVEL DfE methodology in companies**

### ***3.1 Requirements analysis***

In the beginning of the sub project IMI compiled a checklist which was used by the companies when collecting company requirements and important background information for the work with implementing the methodology, e.g. regarding existing databases, list of relevant indicators, and identification of stakeholders of the DfE method. This checklist can be found in Appendix 1 in this report. The analysis of the checklists complemented with discussions on project meetings resulted in a description of the current situation at each participating company, together with a set of identified, analysed and structured requirements on measurement and communication of environmental performance of products. A summary of the current situation and the requirements expressed as the main interest from each participating company is provided below.

#### **Bombardier Transportation**

##### ***Current situation***

Bombardier Transportation participated in the RAVEL and REPID projects where the DfE methodology which is studied in this IMPRESS sub project was developed and implemented. Bombardier Transportation has continued the implementation of the RAVEL methodology, and they are developing a toolbox for work according to the DfE methodology. Included in this toolbox is among others CE-MAT which is a central proprietary database with a user friendly web-based interface, for gathering, storing and tracking the environmental performance and passive fire safety requirements of Bombardier Transportation products. The environmental module of the database continues the work that was started in the RAVEL and REPID EU projects. Bombardier has moreover identified how a lot of the information needed for the EPI-analysis can be extracted from the Bombardier PDM (Product Data Management) system.

Bombardier Transportation are today using environmental information to gather basic data to project management, and to gather material data, analyse and report to customer when required at contract. Lists of prohibited respectively restricted materials are communicated to designers, sub-suppliers and other persons involved in the product development and procurement processes. Some indicators like *Recyclability rate*, *Material inventory degree*, *Prohibited materials*, and *Restricted materials*, have already been used in business relations.

The main stakeholders of the RAVEL methodology which they have identified within their company are the DfE Engineers, project management as well as system and production engineering. External important stakeholders are end customers, suppliers and authorities.

##### ***Main interest***

The main interest of Bombardier Transportation in this sub project has been on how to obtain the right level of detail in the material list, and how to identify the

threshold level defining how small amounts of a substance in a product that needs to be declared in the inventory data. Their interest has also been on how to acquire the data needed for the environmental assessments. Initially they also expressed interest in the identification of new indicators with focus on the social domain. The social domain was however regarded to be outside the core scope of this sub project.

## **IKEA of Sweden**

### ***Current situation***

For all products that are developed at IKEA (around 3000/year), there are checkpoints where among others a risk assessment and an environmental assessment is performed. The purpose of the risk assessment is to make sure that there are no risks associated with the use of the product. This is based on the general product safety directive. The environmental assessment is performed using the *eWheel* method, which is a simplified qualitative life cycle assessment method. The *eWheel* provides recommendations on how to design environmentally friendly products.

IKEA is not manufacturing any of their products. This is instead done by different suppliers. There are often several different producers that are supplying the same article. The suppliers of IKEA receive a requirement specification in a *technical specification*, which among others contains a specification of materials that shall be used in the product, a list of substances which not are allowed in the product, as well as a specification of how the product is to be tested. In addition to this, *E-files* (Electronic Material Fact Sheet) are used to collect data on materials and surface treatments etc from their suppliers.

IKEA is today using KPIs (Key Performance Indicators) on different levels within the company and also a lot of different material related databases. IKEA has a KPI-group aiming at defining indicators in the area of renewable materials, recycling, toxicity and emissions during use. IKEA has a company specific material standard and materialist.

IKEA is today using environmental information externally in for example the IKEA catalogue, information on price tags, and on their public web page<sup>4</sup>. Environmental information is also used internally and in the communication with suppliers as described above.

The main stakeholders of the RAVEL methodology which have identified within IKEA are environmental coordinators and persons responsible for annual reporting to S&E affairs and IKEA of Sweden management.

### ***Main interest***

The main interest of IKEA in this sub project has been on how to measure the improvements in environmental performance of their products e.g. once a year or more often. This includes definition of indicators, calculation of these indicators and communication of the calculated indicators. IKEA also expressed interest in how the method could be used to better communicate and collect information from

---

<sup>4</sup> [www.ikea.com](http://www.ikea.com)

suppliers, and in a longer perspective also be used to better communicate environmental performance to the customers. Another important issue for IKEA was to provide better support for material selection to designers. IKEA moreover expressed interest in exploring the whole RAVEL methodology and use it as inspiration to improve their handling of environmental information on products.

## **ITT Flygt**

### ***Current situation***

ITT Flygt has the policy that all new products shall have an environmental performance that is better than previous versions of comparable products. That the environmental performance is improved is controlled in a streamlined LCA using the EPS method. This is mandatory to perform at an early stage in all product development projects performed at ITT Flygt. The result of the streamlined LCA is also followed up at later stages in all product development projects. In the streamlined LCA the material content of the product shall be provided as well as known use phase characteristics, e.g. data on energy consumption because of that the efficiency of the pump is not 100%. The entered data is connected to ready-made LCI-data and IA-data according to EPS and the total impact of each aspect (expressed in ELU) is presented to the user. In all known cases the result of the assessment is that aspects connected to the energy efficiency are the only things that really matters. This sends the message to the product developers that the pump can contain anything as long as the energy efficiency of the pump is improved.

ITT Flygt is today performing EPDs based on a general LCA and specific material content and energy efficiency data. ITT Industries are using a common black and grey list which shall be used by the procurement function in the contact with the sub-suppliers. ITT Flygt has also a company specific material standard, which defines the materials that the sub-suppliers have to use in each provided part. ITT Flygt is also having their own production within the company, which simplifies the exploration and implementation of the RAVEL methodology.

The potential stakeholders of the RAVEL methodology which have been identified within ITT Flygt are: designers/product developers, material technicians, procurement, persons responsible for requirement specification on business units, product managers, decision-makers responsible for the strategic direction, and environmental coordinators.

### ***Main interest***

ITT Flygt wants to use the same EPIs in different parts of the company and use them for internal communication (manufacture, R&D, environmental department etc), to make sure that they really are improving their environmental performance of their products. ITT Flygt has also expressed interest in using the indicators in external communication, e.g. in communication with suppliers and customers. ITT Flygt wished to work with indicators covering the areas: recyclability, fraction recycled material, weight of product, and some more company specific areas (e.g. energy efficiency).

ITT Flygt has in parallel to the IMPRESS project initiated an internal project where the goal is to reduce the total time spent in the product development process for each product by improving the product documentation. This should be achieved by

creating a new integrated system where all the data and documentation on the product development process is kept together. An interest from ITT Flygt has been to investigate and describe in detail how the RAVEL methodology could be integrated within this new system, and be used to provide instant feed-back of the environmental performance to designers.

**General comment from the requirement analysis:**

“Not another tool” was an expression used in the project to explain that we should not develop a new tool but integrate the methodology into an existing system if possible. A user-friendly prototype to show how to use the method and test the working procedure is however needed.

## **3.2 Environmental Performance Indicators**

### **3.2.1 Scope and selection of the set of measurable indicators**

The criteria for environmental performance indicators (EPIs) to be used in a DfE-system that were developed in the RAVEL project are also used in this project i.e.:

- The indicators are measurable
- The indicators are able to control and can be influenced by the DfE process
- The indicators address important and well defined environmental issues
- The indicators are well defined and easy to understand
- The indicators are easy to communicate

The indicators shall be used when setting environmental targets, when measuring the environmental performance, when calculating an environmental baseline i.e. an acceptable level of performance, and when evaluating environmental performance. Each indicator is a quantifiable representation of one or several impact categories. Examples of impact categories are global warming, acidification, eco-toxicological and human toxicological impacts. See also section *1.3.1 The RAVEL DfE methodology*.

A pragmatic selection of EPIs was performed in this project based on the results from the checklists, discussions within the project team, company focus areas and environmental policy and also on the list of general applicable EPIs from earlier projects where IMI participated. For each relevant EPI, the data requirements were analyzed and an overview of available databases at IMI matching these explicit requirements was performed. All these aspects together with the project budget formed a first set of EPIs, consisting of five measurable DfE indicators to be applied for products at ITT Flygt, IKEA and Bombardier Transportation. It was agreed that the indicators that we should focus on and jointly work with should cover the areas *recycling* and *material content* of products.

The defined set of common indicators is naturally not sufficient to monitor all relevant environmental requirements for all different products within the companies. Company specific indicators such as energy efficiency for pumps and odour emissions from furniture were also discussed and these could be used as a complement to the common list of EPIs for each company. A template for definitions of new indicators and related material property data was compiled by IMI, based on earlier project results, to support the companies in their work to define more company- and product-specific indicators, see Appendix 2.

When the definitions of the common list of EPIs were set, these were implemented in the Inventory tool to enable the companies to perform a first test of the indicators using real data for a few products. The first set of EPI definitions was later enhanced several times within the project based on discussions after tests performed.

### **3.2.2 Set of indicators**

Below the short definitions of the set of EPIs in this project is presented. In addition, relevant issues to consider for each of these are included. Full definitions can be found in the report *Definitions of first set of EPIs for SP 7 in the IMPRESS project, Project internal report, 2005*.

#### **EPI 1: Fraction renewable material**

**Unit:** kg and weight-%

Monitor the weight/fraction of renewable materials in the product.

Definition of renewable materials: Renewable are materials coming from living organisms, meaning materials that can be grown or extracted from grown substances. Examples are vegetable oils, wood, cellulose material such as paper and plants fibres.

It is suggested that the material property data on renewability shall be in percent of the material e.g. if construction materials such as Particle boards consist of about 90% wood and 10% glue, then only 90% of the board is a renewable material.

#### **EPI 2: Fraction recycled material**

**Unit:** kg and weight-%

Monitor the weight fraction of recycled materials in the product, in kg and %.

The term "Recycled material" in this indicator is defined as if the material has been recycled through material recycling. Material recycling is defined as the reprocessing in a production process of the waste material for the original purpose or for other purposes but excluding energy recovery. Fraction of recycled materials include post consumer scrap, post industrial scrap in another company's manufacturing unit and also to some extent internal post industrial scrap.

World average values, European average values or Swedish average recycling values can be used but which is the most appropriate for the different companies need to be decided.

In the *CPM Inventory tool* functionality is implemented which enables the user to insert if the materials and components in the product can be separable or not, this information is used in this EPI. Actual fraction of recycled materials in a specific material in a specific component could also be inserted and used instead of the default value in the database.

#### **EPI 3: Can be material recycled**

**Unit:** kg and weight-%

Monitor the fraction of materials in the product that can be material recycled, in kg and %. Material recycling, often called recycling, means the reprocessing in a production process of the waste material for the original purpose or for other purposes but excluding energy recovery. The fraction of materials in the product that in the end of life phase can be material recycled is dependent on waste collection infrastructure,



available recycling plants, if the materials or components are separable, market demand for recycled materials etc.

In the *CPM Inventory tool* functionality is implemented which enables the user to insert if the materials and components in the product can be separable or not. Actual recycling values for a specific material in a specific component could also be inserted and used instead of the default value in the database.

**EPI 4: Can be incinerated with energy recovery**

**Unit:** kg and weight-%

Monitor the amount of material that can be incinerated with energy recovery, in kg and %. Energy recovery means the use of combustible waste as a means to generate energy through direct incineration with recovery of the heat. Properties of the product and of the included materials such as toxicity, thermal value, if the materials are separable, requirements on material recycling, available incineration plants etc., has an impact on the value of this indicator.

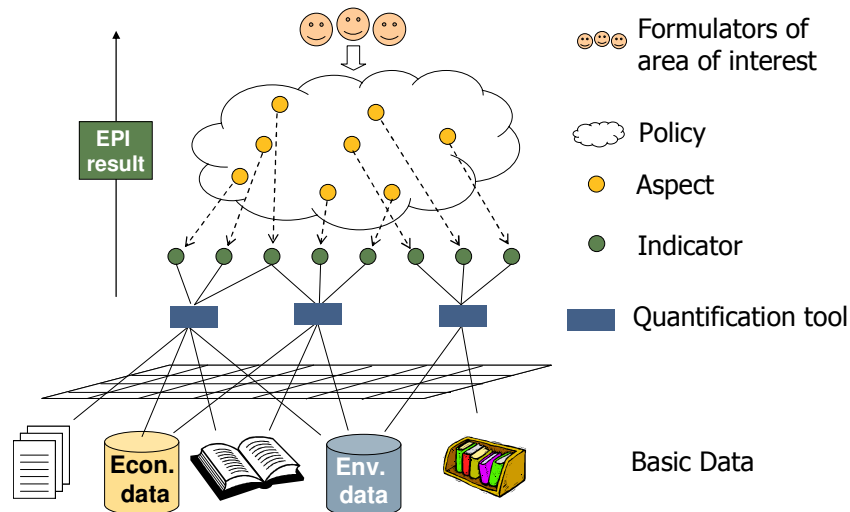
**EPI 5: Materials inventory degree and product weight**

**Unit:** % and kg

Monitor the degree of declaration of materials in a product and also the product weight. The material should be declared by with name and weight. See discussion on detail level of the material list and threshold values of inventory in section 3.3.1 *The material list*.

**3.2.3 How to find the right indicators?**

The policy of a company is formulated based on the area of interest of the company. The RAVEL methodology describes how the policy can be analysed and aspects that together span up the policy are identified. These aspects are then connected to measurable and well-defined indicators, which can be quantified from basic data to an acceptable cost using some kind of quantification tool. For the material related indicators which are calculated directly from the properties of the materials in the analysed product, the quantification tool is simply an implementation of the algorithm that describes how this material related data shall be aggregated to find the result of each indicator. For the indicators that not can be calculated from an assessment of the material content and component structure, some other kind of quantification tool need to be identified. Indicators regarding energy efficiency and length of life of a product can for example be simulated in an external tool, measured on a prototype of the product, guesstimated based on deep knowledge and experience from similar products, etc. Indicators concerning the use phase can also be quantified by sending out questionnaires to customers and then analyse the result etc.



**Figure 3:** Indicators can be identified from the policy of a company or organisation. It must however always be checked that the defined indicators can be quantified to an acceptable cost using some kind of quantification tool.<sup>5</sup>

### 3.2.4 Company and product specific indicators

For companies producing and/or selling products used by end-consumers, aspects such as emissions of chemical substances from products and potential content of toxic substances in different materials in the product are very important. The pre-defined version of the indicators “Amount of prohibited materials” and “Amount of restricted materials” from the RAVEL and REPID projects did not suit the needs of the participating companies. One reason for this is that these EPIs is dependent on high resolution and accurate information on the content of chemical substances in the product e.g. detailed information on flame retardants and other additives used in the materials need to be provided by suppliers and sub-suppliers.

The product specific indicators in the area of questionable substances and emissions from products during usage phase were discussed a lot in the project. Also an indicator for energy loss during usage relevant for heavy electrical equipment such as pumps was briefly discussed. No suitable indicators have been found in other related systems and a summary of the findings in this project has resulted in draft versions of three EPIs. Each of these need to be detailed defined to be able to measure and communicate.

#### 3.2.4.1 Indicator for questionable substances

**Name:** Fraction of potential health risk materials

**Unit:** Weight-% and kg

**Description:** Monitor the weight fraction of potential health risk substances in the product. Potential health risk substances or questionable substances are substances used in the company’s products that cause risk to human health or nature. This EPI could be based on the customer requirements on health e.g. allergy and carcinogenic materials.

<sup>5</sup> Erlandsson, M., Flemström, K., Manual on environmental decision making, Background report, DANES project, 2005

Suppliers and sub-suppliers do not always have knowledge on the content of questionable substance in the parts they deliver, but often assume that the parts are free from any of the questionable substances on the company's restriction lists. Therefore tests of products need to be performed, to check if the products contain any of the questionable substances covered in restrictions at the company today. As these kinds of tests are very expensive it is important that the tests and test results are documented in a thorough way.

If a questionable substance is found in a material delivered from a specific sub-supplier it should furthermore be possible to find other products containing the same material delivered from the same sub-supplier. It is recommended that this indicator is based on these test results. For example could this indicator look for materials in the design product that in any of these tests has contained high rates of questionable substances. A clear definition of the concepts "questionable substance" and "potential health risk substance" need to be set and agreed on.

The indicator materials inventory degree was also discussed as an indicator that could be used in the search for questionable substances. If several levels of detail are used in the material list, an indicator connected to the search for questionable substances could measure the total weight of the materials which is specified at one of these more detailed levels.

#### **3.2.4.2 Indicator for emission from products**

**Name:** Emissions from products

**Unit:** µg/m<sup>3</sup> or high/low based on limit values

**Description:** Monitor the emission from products during usage phase and also give and indicator on occurrence of high or low emissions.

This indicator can be divided into sub parts to measure and control such as the amount of Volatile Organic Compounds (VOC), level of smell from product (high/low) and existence of hazardous substances based on EU classification. Formaldehyde is also one compound often discussed and of high concern in this area and should be included in this indicator. Requirements on the amount of formaldehyde emitted from a product are often separated from other hazardous substances. Each of these parts: the amount of VOC, smell, hazardous substances and formaldehyde can be measured in laboratories (e.g. in microgram/cubic metre)

Surface of emitting product, size of the room, ventilations and other properties are important to consider in this emission indicator as well as to define what is meant with low emission and compared to high emission i.e. that is the limit value, depending on which substance etc.

Typical emissions from different product or material groups are rather well known as well as the amount of emission from some product. There are also generic emission data from some materials that can be used but health or risk data is often missing.

#### **3.2.4.3 Indicator for energy efficiency**

**Name:** Energy loss during operation

**Unit:** kWh

**Description:** Monitor the energy loss during operation phase of the product.

Only energy loss caused by the separate product should preferably be included. The operation phase needs to be explicitly defined in accordance with the intended use of the indicator. Energy loss during operation can be calculated based on energy efficiency of the product.

### **3.2.5 How to define target values**

According to the RAVEL methodology target values for each EPI shall be defined. These represent environmental requirements that the designer shall strive to fulfil. Discussions have been on how to set target values on each indicators, how to document target values and how to use target values. It was found that it is hard to reach an agreement on target values. Furthermore, target value should be defined for each product group, as products with different functions have different environmental performance which not is comparable.

Target values can be based on company policy, laws and regulations, agreements, experiences and conclusions from e.g. LCA studies etc. If no legal requirements exist for a specific EPI and product group, then an appropriate level of target value for this product group can be found through studying calculated EPI values within the group and also for similar products. Estimations can then be made based on experiences on similarity within the product group and by studying the values calculated.

## **3.3 Data acquisition**

As described in section 1.3.1 *The RAVEL DfE methodology* a database containing a common material list and acquired material property data or environmental data is required for calculation of the defined EPIs. The material list and the material data have been the main issues for the data acquisition tasks in this work.

Early in the project it was decided that the material list and data from earlier projects should be used for testing the RAVEL methodology within the IMPRESS project (where relevant for the participants).

### **3.3.1 The material list**

A common material list is one of the main concepts in the RAVEL method and an important part to enable calculation of EPIs since material properties are acquired and stored for the materials in the list. The EPI results for different designs can therefore be compared and analysed based on the same basic data.

In this project an already existing material list was used for the EPI calculations based on findings in the REPID project. Each participating company used another material standard which therefore was compared to the one used in the project. There were two main questions in focus in this project concerning the material list; *How to obtain the right level of detail in the material list and inventory?* and *How to deal with extensions of the material list?* The results are described below.

#### **3.3.1.1 How to obtain the right level of detail in the material list and inventory?**

The participating companies expressed an interested in the issue regarding what level of detail that is needed in the material list to make the indicators sufficiently

accurate, and where the threshold should be defining how small amounts of a substance in a product that needs to be declared.

There are two different resolution levels which need to be considered in the issue regarding which level of detail that is needed in the material list:

- Level of detail in the specification of the material list
  - How detailed materials should be specified in the list e.g. atoms, ions etc.
  - Should additives, lacquers, flame retardants etc. be included as separate materials in the list
- Threshold value for material weights that need to be declared
  - Different threshold values for different material groups may be relevant
  - Should also minor occurrences of additives, lacquers, flame retardants etc. be declared?

For both these cases the appropriate level of detail is determined by the purpose, scope and intended usage of the material list. This means that if the goal is to use it for EPI-calculations then the level of detail should be adapted to these EPIs. It is also important to consider that different EPIs require different level of detail in data and hence also in the material list.

The needs for information determine the level of detail and the list should be adapted to the usage and the intended users. In addition, different level of detail in different material groups exists. In the compilation of a material list there may also be other requirements to consider but the resolution, e.g. existing material lists and user requirements from other existing areas/processes in the company.

Regarding which threshold value for material weights that need to be declared a relevant and appropriate value can be found by performing a sensitivity analysis. A general value can not be given since the threshold value depends on which indicators and materials used. In addition, the inventoried data can be gathered for many different purposes and not only DfE, therefore even small amounts of materials in the product may be relevant.

A trade-off between the level of detail in the material list, accuracy of the environmental analysis and cost of analysis is often needed. A detailed material list and a high inventory degree cause a higher cost.

### **3.3.1.2 How to deal with extensions of the material list?**

Regarding the issue on how to deal with company specific extensions of the material list which is used in the CPM Inventory tool, there are three main options:

1. New materials are added to an unstructured company specific nomenclature. Material property data need to be defined for all new materials.
2. New materials are added to a structured company specific nomenclature. Material property data need to be defined for all new materials.

3. A mapping is created between a structured company specific material nomenclature, and the material list in the database having the material property data needed for the EPI calculations. For those company specific materials that are not matching any material in the EPI material list, material property data need to be collected.

The current version of the Inventory tool is only supporting alternative 1. Functionality to create structured material lists exists in an administrative tool. This functionality is however not very user-friendly. The best alternative is alternative 3, where a structured company specific material list can be used with as little need for new data collection as possible. This is however also the most costly solution. It was decided that the current status of the implementation work at the companies does not require this solution.

IMI has performed a study where the possibilities to map the material list in the IMI material database to the IKEA respectively ITT Flygt material standards was assessed.

### **3.3.2 Material property data**

Calculation of the set of EPIs is based on material list, material property data of each material in the list and also the algorithm for each EPI as shown in figure 2. All data used was acquired and stored in the IMI material database to enable calculations of the EPIs. The material property data required by each EPI is specified in the detailed definitions of the EPIs, see appendix 2.

Early in the project it was decided that the data in IMI databases built up in earlier projects should be used for testing the RAVEL methodology within the IMPRESS project where relevant for the defined EPIs. The first set of EPIs in the project required material recycling data and data on renewability which was available in the IMI material database for a number of materials. Based on new information available and new knowledge in the project team updating and maintenance of this data was also needed. It was also found that EPIs on emissions from products and questionable substances require data that need to be acquired from other databases, both company internal and external.

#### **3.3.2.1 How to find data?**

Data acquisition can be very time consuming and when building the database both the data quality and quantity have to be considered, one thing depending on the other. The cost issue also has to be included in a practical database build up strategy<sup>6</sup>. If the aim is to include a lot of data with good quality, the cost will be higher than if the quality requirements or amount of data is decreased.

The choice of method for data acquisition depends on the scope and purpose of the environmental performance of the product or system. For LCA and Design for Environment (DfE) e.g. there exist a large amount of different methods for data acquisition such as inventories in the supply chain, searches in different types of databases, data modelling, dismantling and analysing products from the supply chain.<sup>6</sup>

---

<sup>6</sup> Erixon M., Carlson R. (2000), Practical Strategies for Environmental Data Acquisition, paper presented at The fourth International Conference on EcoBalance October 31-November 2, Tsukuba, Japan

There is a substantial cost connected to both data acquisition and implementation of basic data. The cost is often difficult to anticipate, since it depends on the access of suitable sources of data and information. One critical aspect of data acquisition is the lack of suitable data and well documented data sources. However it is very important to conduct a quality assessment each time data is inserted in the database. Roughly three steps can be separated in the process of data collection:

- The first step is to thorough defining data needed for the database.
- The second step is to define a list of information sources e.g. reports, other databases, experts etc. In the definition of these sources an explanation is needed to satisfy their reliability and to clear what kind of data it could bring.
- The third step is to comprehend, interpret and transfer data from the source to the database. This also include documentation of the data source, data acquisition process etc.

All three steps need to be systematically documented in the different documentation fields in the database.

Basic environmental and material data needed in DfE for the calculations of quantitative Environmental Performance Indicators (EPIs) can be acquired in a huge amount of ways, for example through interviews with competent people with knowledge in a specific area, literature, internet, specific companies, environmental-, material- and toxicity- databases etc.

### **3.3.2.2 Data documentation**

Data quality may be defined as “characteristics on data that bears on their ability to satisfy stated requirements”. About 10 years experiences from work with data quality and establishing data quality criteria in the Swedish national competence center CPM have shown that the quality of a dataset can only be assessed if the characteristics of the data are sufficiently documented. Data quality does therefore in many respects correspond to documentation quality.<sup>7,8</sup>

Data documentation for material property data consist of information about the data (the value) e.g. which acquisition method and information sources used, assumptions made, who gathered the data and when, conscious lack of knowledge etc. Data is sufficiently documented if the documentation is understood by the user and correctly used, and so that it can easily be improved or update when better data exists, new knowledge is available or better competence is involved in the work.

---

7 Arvidsson, P., Krav på Datakvalitet, CPMs Databas 1997, CPM Report 1997:1, Chalmers University of Technology, Sweden

8 Pålsson A-C., Introduction and guide to LCA data documentation using the CPM data documentation criteria and the SPINE format, CPM Report 1999:1, Chalmers University of Technology, Sweden

To facilitate the data documentation a documentation format called ISO/TS 14048 was used in e.g. the REPID project<sup>9</sup>. The fields used to document each data set of material property data used in EPI calculations are listed in the table below.

**Table 1:** Material property data documentation

<b>Data type</b>	<b>Data field</b>	<b>Description</b>
Depending on the value type	<b>Value</b>	This is the value for a specific property for a given material in the database. A material property value can be of three types: <u>numeric value</u> , <u>range of allowed words (nomenclature)</u> to choose from and <u>free text</u> . The definition of numeric values in the web tool; an integer shall be used, units are specified in <i>material</i> property specification, therefore no unit should be included in this field. If the class of the value type is nomenclature, the value of the property shall be selected from a pre-defined range. For example the nomenclature Boolean has the range Yes/No. The definition of free text in the web tool; maximum 255 characters can be used.
Nomenclature*	<b>Data collection</b>	A short description of the methods used during the data collection e.g. Derived, specified; Derived, legal requirements; Unspecified, expert outspoke; Derived, statistics etc. See below for explanations*
Date interval YYYYMMDD/YYYYMMDD	<b>Collection date</b>	The time period under which the data were acquired.
Free text	<b>Data treatment</b>	A description of the methods, sources and assumption made.
Free text	<b>Reference</b>	All references to data source used e.g. literature, other databases, internet sites, communication with well informed persons etc
Free text	<b>Notes</b>	For further information needed to specify the data, shall also contain name and organization of the person who inserted the data and data documentation

\* **Derived, specified** - Data can be traced to the basic source, from well known sources e.g. reports and articles.

**Derived, unspecified** - Data is based on information from one or more unspecified sources. For example: Internet information without references etc.

**Derived, statistics (unspecified/specified)** - The data can be derived to calculations based on statistical methods.

**Unspecified, expert outspoke** - Data has been acquired through personal communication.

**Derived, legal requirements** - Data is based on legislations

**Derived, estimated** – Data is based on estimations. The basis for estimations made is described in the field Data treatment.

<sup>9</sup> Bergendorff, M. (Editor) et al, Final report for the EU funded REPID project, 2004



*Note: This list can be extended based on the data acquisition procedures used.*

### **3.3.3 How to establish the inflow of data needed to perform the assessments?**

To establish a more or less continuously inflow of data to the information system used for assessments is a crucial task. The discussions on this issue within the project can be summarized in the following recommendations:

- Do not design an information system which requires more data than it is worth to maintain
- Use information in existing information systems
- Coordinate data acquisition with other company functions

These recommendations are described in more details below.

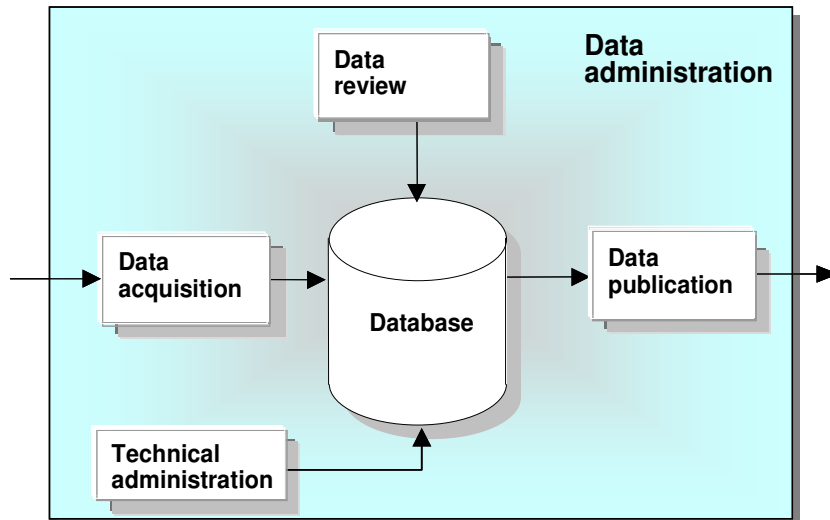
#### **3.3.3.1 Do not design an information system which requires more data than it is worth to maintain**

The establishment of the inflow of data into an information system, which is required to be able to use the information for assessments, is not an issue that can be separated from the information system. Every information system is designed for a specific context. If the information system does not contain data that fulfill the requirements of this context, the information system is useless even if it is technically working perfectly. The establishment of organisational functions for data quality maintenance of an information system must be part of the design of the information system.<sup>10</sup> This means that if it is not decided how the information system will be kept updated you do not have any information system at all.

Data sources of a good quality call for organisational functions for maintenance of the data quality. One example is CPM, responsible for the maintenance of the national Swedish LCI database. The picture below illustrates the different organisational functions which are involved in the data administration of the Swedish LCI database. The data acquisition function makes it possible to insert data into the system. All data that is inserted into the system is reviewed by a data review function. The review function makes sure that the data quality requirements of the system are fulfilled. The data publication function makes sure that the data in the system is available through a standard communication format. The system does also need technical administration to make sure that the system is available and is working properly.

---

<sup>10</sup> Carlson R. Erixon M, Pålsson A-C.; "Establishment of Trade Structures for LCI Data", CPM-rapport 2000:3



© Carlson, Ericsson and Pålsson, 1999, CPM, CTH

**Figure 4:** Illustration of the data administration of CPM LCI database.

### 3.3.3.2 Use information in existing information systems

There exists a vast set of different management tools which may contain design-related information like for example

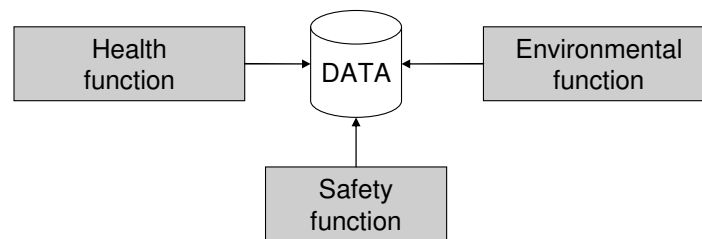
- ERP (Enterprise Resource Planning)
- SCM (Supply Chain Management)
- CAD (Computer-aided design)
- CAM (Computer-aided manufacturing)
- PDM (Product Data Management)
- PLM (Product Lifecycle Management)

Check what type of information that is available at your company or organisation. Do however not expect to find all the information needed for the environmental assessments in the existing information systems. The resolution of the information you will find in the different information systems depends on the requirements of the usage domain the system is designed for. For example from a design perspective the important thing is that the product complies with the specifications. The exact material content and how products are produced are not in focus, and detailed information on material contents and component structures for products delivered from sub-suppliers is hence generally not available in these kinds of systems. On the other hand, from a risk perspective exact information on content of certain materials is essential.

### 3.3.3.3 Coordinate data acquisition with other company functions

Functions such as safety and health often need the same type of detailed information on material content which is needed for environmental issues. Economical gains may be achieved by coordinating inventory systems for different company functions that call for similar information. The persons responsible for providing the information will only have to provide the information once, and a better data quality can hence be required. Furthermore, when the information is updated it only needs to be changed in on place. Integrated systems do however

require material nomenclatures and other important concepts to be harmonized. When different material names and material properties are used in different usage domains with different requirements on the resolution etc., it is of vital importance that common agreements are reached on the definition of these names and properties. Common nomenclatures are often costly to achieve but economical gains from a common understanding of the meaning of the data will be achieved in many different areas.



**Figure 5:** Health, safety and environmental functions at a company often have a common data need.

## 3.4 DfE Inventory tool

### 3.4.1 Overview

The goal of this sub project was to enhance the measurement and communication of environmental performance of products within the participating companies, by implementing the RAVEL methodology within the companies. Early in the project it was stated that the outcome of this sub project should not be just another specialized tool, as new tools are not welcome in the daily work of the designers and other stakeholders of the DfE methodology. Instead focus should be put on integration and operationalizing of the DfE method within existing systems and working processes in the companies.

Even though it was decided not to develop any new specialized DfE tool within the sub project, a user-friendly prototype was needed to demonstrate how to use the method and test the working procedure. Early in the project it was decided that the *CPM Inventory tool* should be further developed and used as prototype. The *CPM Inventory tool* is a web-based application where suppliers can submit data about their components and directly get a measure of the environmental performance of the components by calculating Environmental Performance Indicators. The application also supports a review procedure where data submitted by the suppliers is reviewed by administrators which guarantee that only data of a good quality is imported into an internal environmental database. The tool was developed by Bombardier and Chalmers after the RAVEL project, and it is implementing parts of the RAVEL methodology.

By using the tool it is possible to declare the structure and material content of products, and use this information to calculate the environmental performance of the products in terms of a set of Environmental Performance Indicators. Detailed information on how to work with the *CPM Inventory tool* is provided in Appendix 3.

### **3.4.2 Extended functionality**

The IMPRESS edition of the CPM Inventory tool has extended functionality compared to the original version of the tool, as the scope of the original version was to collect data from sub-suppliers rather than demonstrating the RAVEL methodology.

### **3.4.3 Addition of new materials**

The original version of the CPM Inventory tool contained a material list with material property data that was developed within the railway industry. This material list did naturally not contain all materials used in products at neither IKEA nor ITT Flygt. For that reason, functionality to make a company specific extension to the material list was implemented, as it is important to use realistic examples when exploring a method. For each material that is added a name and material property data shall be provided. For the common EPIs used in the sub-project, data is needed for the properties *Rate of recycled material*, *Renewable*, *Can be incinerated*, and *Material recycling* for each material. In addition to a value for each property the users should also provide documentation of how each property value was acquired when adding a new material. More information on extensions of the material list can be found in 3.3.1.2.

### **3.4.4 Definition of target values**

Environmental requirements of products are in the RAVEL methodology expressed by the selection of EPIs that are relevant for a product and target values for these selected indicators. Environmental requirements are typically defined by customers, an environmental coordinator, or other roles involved in the requirements specification process. The fulfilling of these requirements is typically the task of a designer, a sub-supplier or other roles involved in the product development or procurement processes.

The original version of the *CPM Inventory tool* used in the sub project does not contain any support for the requirements specification process. This functionality was instead included in a tool for administration of the data from the CPM Inventory tool. In this sub project of the IMPRESS project, the CPM Inventory tool alone was used to demonstrate the RAVEL methodology. To make it possible to test and explore the important target value concept, functionality was hence added to define target values on the EPIs for an article. Furthermore, functionality to provide documentation of each target value was implemented. See Appendix 3.2 for more information on how to define target values.

### **3.4.5 Calculation of the selected EPIs**

Functionality for calculation of the indicators which were selected within this subproject has been implemented in the *CPM Inventory tool*. This functionality was also updated several times as the definitions of the indicators changed when the EPIs were tested in the companies.

One of the defined indicators requires additional data to be collected in the tool. The EPI *Can be material recycled* was assigned a definition which needs information on if a component is separable or not. This was implemented as a check box on component level. For components that are defined as separable, also the sub-components are assumed to be separable if the sub-components are not

explicitly marked as non-separable. See Appendix 3.3 for more information on how to calculate EPIs.

#### **3.4.6 Generation of EPI result reports**

Functionality for generation of Excel reports for communication of the EPI results was also integrated within the IMPRESS edition of the *CPM Inventory tool*. See Appendix 3.4 for more information on how to generate the reports, and see chapter 3.5 below for more information on how to understand and interpret the EPI result reports.

### **3.5 Reporting tool**

#### **3.5.1 Overview**

An important focus of the sub project was how to communicate the EPI results calculated in the tool in the best way. It was decided that transparent and understandable reports which easily could be distributed to the decision makers was needed. Functionality for generation of these reports from the data inserted in the *CPM Inventory tool* was implemented in a *Reporting tool*. The reporting tool is an Excel file with so called macros, which are retrieving selected data from the database connected to the *CPM Inventory tool* and is formatting and inserting the data into different sheets of the Excel file. The resulting Excel file is referred to as an *EPI result report* where information on indicators, analysis results, component structures, and material property data is presented in a way that is understandable for the different stakeholders of the EPI results.

The reporting tool is developed based on the principle of *Everyday technology solutions*, which makes it possible for any user to access and assess data using tools that they are familiar with, such as Excel and Word. The principle of *Everyday technology solutions* is further investigated in sub project “Maintenance of integration” in the IMPRESS project. The fact that Excel is used to generate and communicate reports from the Inventory tool makes it easy for each user to modify and extend the report so that it suits the user's specific needs e.g. different types of graphical presentations can be made by using Excel or any other simple to use tool. The results should then be in a form suitable for the specific decision-maker or receiver of the results.

#### **3.5.2 Understanding the EPI result report**

An EPI Result Report is a report on the environmental performance of products, expressed in terms of Environmental Performance Indicators (EPIs). In the report EPI results for different products or alternative designs can be compared both in an aggregated form as well as for each EPI. The information has been formatted to facilitate communication of the results.

The EPI results reports need to be easy to communicate (understandable for a decision-maker) but still transparent. This is achieved by using different sheets with different level of aggregation of the data. The first sheet defines how to use the tool, the second describes the indicators, the third provides the EPI results in an understandable way to decision-makers, the fourth provides the material inventory with material property data that was used in the calculation of the EPIs, and the

fifth sheet provides the documentation of the material property data. A more detailed description of the different fields in an EPI result report is provided here:

- **Overview**  
This sheet contains a short overview of the tool
- **EPI definitions**  
This sheet contains short definitions of the Environmental Performance Indicators (EPIs). The full definitions of the indicators can be found in the document "Definitions of EPIs for SP 7 IMPRESS project.doc" which is available on the internal web site of the IMPRESS project.
- **EPI results**  
This sheet contains quantitative measures of the environmental performance of the analysed products in terms of the agreed EPIs. The results are presented both in tables as well as in graphs. This sheet hence contains the most vital information when communication with indicators.
- **Material inventory**  
This sheet contains the complete list of all materials that are declared in each analysed product. It furthermore contains the complete list of all material property data that is used when analysing the environmental performance of the selected products in terms of the selected EPIs.
- **Meta data**  
This sheet contains transparent documentation of all used material property data that is used when analysing the environmental performance of the selected products in terms of the selected EPIs.
- **Help**  
This sheet contains help on how to use and understand the EPI result report.

The sheet "EPI result" is the sheet that provides most vital information as it contains the calculated indicator results. All the information that is needed for the calculation of the indicators can be found in the "Material inventory" sheet. Information on how and where the material property data of the "Material inventory" sheet was collected can be found in the "Meta data" sheet. The aggregation of information that is performed when calculating the indicators can hence be traced in the EPI result report. The sheet "EPI result" can also be extended with more indicators which then are included in the graphical presentation.

### **3.5.2.1 Target values and tolerance**

Target values can be defined for each indicator, either in the CPM Inventory tool as described in Appendix 3.2, or in a template for the EPI result report which is stored on a server at Chalmers. The target values facilitate the interpretation of indicator results as it may be hard to understand if an indicator value is good or bad for an assessed product. Colour codes are used to make it possible to get a quick overview of which indicator results that are above respectively below the target value. A tolerance was also introduced to make it possible to highlight those indicator results that were close to the target value. A tolerance value can be defined for each indicator and it specifies the interval below the target value for which the indicator values are printed on a yellow background. Values below these are printed on a red background as these values are deviating a lot from the target. Values above the target value are printed on a green background. The tolerance values for the indicators can be changed by defining a new template on the server. The target

values can also be changed manually in the generated reports, but then the background colours must be updated manually.

### **3.5.2.2 Interpretation of the EPI results**

Another issue which was discussed in the sub project regarding communication of EPI results was how to interpret the EPI results. To be able to make any decisions using the EPI results the user at least need to know:

- what environmental issue each indicator is monitoring
- whether the EPI result preferably should be high or low
- the possible range of values for each EPI
- the seriousness of deviations from the target value

The environmental issue which each indicator is monitoring should be identified from the name of the indicator, and described in detail in the definition of the indicator. To make it easier for the decision-makers the indicators should be defined in a way so that an increase of an indicator result is good and a decrease is bad.

Furthermore, when a decision calls for compromises between several indicators the relative importance of the involved indicators should be communicated to the decision-maker. One way of providing guidance to the decision-makers on this issue is by defining a weighting for the different indicators. This weighting need to be based on a quantitative prioritization among the environmental issues related to each indicator (see next section for more information).

### **3.5.3 Weighting**

To achieve even further aggregation and simplification of the EPI results, the relative importance of the different EPIs could be stored in terms of a weighting. The weighting makes it possible to express the environmental performance of the assessed product or system in a single number. Weighting of indicators could be needed when several indicators have been calculated for one product and a decision based on these results need to be taken. Weighting could then facilitate the decision making by resulting in a weighted i.e. aggregated value of the EPI results. The problem or difficulties with this approach is however to find a relevant weighting, and to cope with the major simplification which this high level of aggregation leads to.

Different ways to perform weighting have been discussed in the project. An overview of different methods for weighting can be found in the next section. Further, it was decided that no “advanced” weighting will be applied in the project. The weighting was therefore based on each company’s policy or key areas instead of LCA or EMS methods, described in the next section. A possibility for the user to add a weighting was added to the CPM Inventory tool in terms of scaling and prioritisation but this was later removed since it was too difficult to prioritise and weight between the set of defined EPIs in a “simple” way, a more advanced approach was needed to make a correct weighting. A new approach was therefore suggested, which is presented in the section *Practical prioritization and weighting* below. However, this has not been implemented in the CPM Inventory tool yet and should be seen as a method or framework for practical weighting.

The weighting of EPI results needs to be performed in a structured way and it is important to document how the weighting was performed to be able to make the same type of weighting each time etc. In addition, weighting need to be performed on the environmental level e.g. what has the highest priority 10 dead species/year or global warming of 0.1 degrees Celsius?

### 3.5.3.1 Different weighting methods

Weighting of EPIs can be performed based on company policy, national or international laws and regulations, experiences and conclusions from e.g. LCA studies etc. Weighting of EPIs can also be performed based on the product's life cycle and scientific LCA weighting methods as presented in the article *Transparent translation of design data to environmental impact data*<sup>11</sup> where life cycle models for a normal and a ideal scenario for each EPI is used. The study described in this article is based on a translation of design data to environmental impact data by linking the RAVEL method to the LCIA method EPS. The result demonstrates that it is in principle possible to transparently prioritize between different EPIs by using different LCIA methods. There are many examples of weighting methods used in LCA that can be used for prioritise between EPIs e.g. EPS (ELU/kg), EcoIndicator99 (ECO99 unit/DALYS or /PDF m2 yr or /MJ) and EDIP/1997/(kg or m3).

In addition, weighting of EPIs can be based on methodologies used in EMS. There are as many schemes for evaluating environmental impact as there are companies with evaluating procedures. Marilyn R Block<sup>12</sup> is of the opinion that each organisation should choose or modify a method for evaluation that is appropriate for them. The impacts are evaluated according to different criteria e.g. severity, likelihood, frequency, consequence etc.

Impacts	Likelihood	Severity	Significance
Addition:			
Impact 1	3	3	3 + 3 = 6
Impact 2	5	1	5 + 1 = 6
Multiplication:			
Impact 1	3	3	3 * 3 = 9
Impact 2	5	1	5 * 1 = 5

**Table 2:** Impacts evaluated according to the criteria severity and likelihood (Block).

Most evaluation criteria employ a three-or five-point rating scale. The drawback to such scales is the tendency for evaluators to select the mid-point. A solution to this problem can be to create a four-point scale and force evaluators to either the harmful or harmless side. When an impact has been given a rate for all the criteria,

11 Carlson, R., Flemström, K., Häggström, S., Transparent translation of design data to environmental impact data, 13<sup>th</sup> CIRP International Conference on Life Cycle Engineering, Leuven, 2006

<sup>12</sup> Block, Marilyn R., "Identifying Environmental Aspects and Impacts", American Society for Quality (ASQ), Wisconsin, 1999



the results can either be added or multiplied, with very different outcome. Block suggests that if the values assigned to the measured attributes are unrelated to each other, as in this example with likelihood and severity, then the scores should be multiplied. Scores should be added when the values are related to each other.

### 3.5.3.2 Practical prioritisation and weighting

To enable an accurate weighting of EPIs in the project we propose a modular definition of prioritisation, which explicitly gives room for example different local, regional or global prioritizations for products, projects, markets etc. The terms *Policy prioritisation* and *Practical prioritisation* is introduced. The concept of “practical prioritisation” support inclusion of technical, economical and environmental considerations, defined as below.

$$\text{Practical prioritisation} = \text{Weighted environmental impact model factor} * \text{Policy prioritization}$$

Where the “**Weighted environmental impact model factor**” can be the total improvement potential (further described in the article *Transparent translation of design data to environmental impact data*.<sup>13</sup>), a weighted environmental impact model factor received by using an impact assessment model e.g. EPS or EcoIndicator99.

The **policy prioritisation** depends on technology, economy, marketing and the environmental policy of the company. Each of these factors has an influence on which of the EPIs that the designer should in practice choose to optimize. Thus the **practical prioritisation** can differ from the weighted environmental impact model factor.

#### Environmental performance of product

The product’s environmental performance is the sum of weighted EPI-results or weighted score of a reference product in a product group:

$$\text{Environmental performance} = \sum (\text{Practical prioritisation} * \text{EPI result for the reference product})$$

To be able to use the same practical prioritization for all products in a product group, the product scaling factor is introduced. The product scaling factors are used to scale the practical prioritization up and down based on the characteristics of a reference product and other products in the same product group. Such characteristics can e.g. be total weight, energy efficiency etc.

The environmental performance of an optional product in a product group:

$$\text{Total environmental performance} = \sum (\text{Practical prioritisation} * \text{Product scaling factor} * \text{EPI result for optional product in the product group})$$

The proposed modular definition of practical prioritisation and weighting of EPIs have not been implemented in the tools developed within this sub project and should be seen as a framework which should be further specified.

---

<sup>13</sup> Carlson, R., Flemström, K., Häggström, S., Transparent translation of design data to environmental impact data, 13th CIRP International Conference on Life Cycle Engineering, Leuven, 2006

### **3.5.4 Development of the reporting format**

The need for simple and efficient communication of the EPI results called for the development of a reporting format. Two different versions of the format were drafted by IMI, and these were later enhanced through discussions at project meetings. The first one of these formats was optimized for comparison of a few products, while the second version was optimized for comparison of a large number of products. When an agreement had been reached on the content and layout of the report formats, functionality for generation of these EPI result reports was implemented.

In the first version of the reporting tool, the reports were generated using macros in Excel directly on the users' computers. This version was working perfectly when tested at Chalmers. It was however not working at all when testing it at IKEA and ITT Flygt. The problem is that clients within the networks of these companies are not allowed to establish a direct connection to a remote database, which is needed when generating the reports directly from Excel. For that reason support was also implemented to generate the reports on one of IMI's servers from the *CPM Inventory tool*. The reports in this second version of the tool are generated in Excel on this server, and the resulting EPI result report can be downloaded from the CPM Inventory tool. All choices performed by the users are carried out in the CPM Inventory tool and then communicated to Excel on invocation of the macros. This new way of generating reports called for some changes of the Excel macros. The biggest challenge was however to run Excel on the server from a web application, as Excel is not designed to be run on servers with users that access the application from a web interface. Excel does not support more than one concurrent user, and if a user does not terminate their session before leaving the application, an instance of the application will remain on the server. This instance might make it hard to use the Excel for other users. Moreover, the usage of macros in Excel require some user privileges on the server which for security reasons call for an extra Windows login that the users have to perform to gain access to the report generation functionality.

#### **3.5.4.1 Handling of target values**

The first versions of the *Reporting tool* contained default target values for the EPIs which could not be changed before the reports were generated. The target values could be changed manually in the generated reports. The color codes of the EPI results are however not updated when the target values are changed in a generated report. In the third release of the *Reporting tool* target values for the EPIs could be stored on product level in the *CPM Inventory tool* and used instead of the default target values on report generation. The definition of target values should preferably be performed in a separate application dealing with requirement specifications, as targets normally are not defined by the same persons who shall fulfill them. The inclusion of this functionality in *CPM Inventory tool* was however motivated as the setting of targets is a vital part of the RAVEL methodology and hence needed to be demonstrated. A known limitation of the *Reporting tool* is that when a report including many articles is generated, the target values for the first article with target values defined are used. A new reporting format should be defined where one set of target values is assigned to each assessed article. This was however excluded from the scope of this project as this can be achieved by manually merging reports for single articles.

#### **3.5.4.2 Graphical presentation of EPI results**

The EPI results are presented both in tables and graphs. In the version of the Reporting tool optimized for comparison of several products, there is one graph containing data for all products for each indicator. In the version of the Reporting tool optimized for comparison of a few products, all EPI results are presented in a single graph. When presenting different indicators in the same diagram, it has to be assured that the indicators really are comparable. This both involves that the indicators need to be transferred to the same unit, as well as scaled to the same range of the possible values. For the current set of indicators used in IMPRESS this is not a problem, as all indicators are expressed in weight-% where a high value is preferred. It is however recommended to use one graph for each indicator.

The implemented graphical presentation of the EPI results was very appreciated in the participating companies.

## **4 Integration with other information systems**

### **4.1 Integration with other information systems within IMPRESS**

In another sub project in the IMPRESS project “General method development” a method for integration of environmental information systems has been developed, described in the report *Method for integration of industrial environmental information systems*<sup>14</sup> The dimensions for integration in focus for this method are gaps and overlaps in primary data need, gaps and overlaps in tasks and gaps and overlaps in communication in terms of controllability.

The sub project where this report is developed is one of six industrial case studies in environmental information areas. The case study areas are Life Cycle Assessment (LCA), Design for Environment, Environmental Management System, emission trading, risk assessment and knowledge management. The relationship between this sub project (DfE) and the other sub project areas can be analysed in terms of differences and similarities of policy, indicators, data, methods etc. The most evident relationship between the work in IMPRESS with DfE and LCA on a methodological level is that DfE can be regarded as a simplified LCA. Regarding relationship on the data level, EPIs shall be defined so that they represent different or several part of a products or materials life cycle, from cradle to grave. Life cycle inventory and impact assessment data on materials, products and processes can be used as data sources for material property data used for calculating EPIs. This is practically demonstrated in VIEWS (Visualisation of integrated environmental work spaces) which is a demonstration result from the IMPRESS project.

Risk assessment and the coming EU chemical legislation REACH is closely related to indicators in the risk area e.g. content of toxic substances in a product and emissions of toxic substances from products etc. We have had common discussions on risk associated with chemicals in products and related areas in the IMPRESS project. There is a need for relevant risk assessment data in DfE and further cooperation in terms of sharing of data e.g. substance property data, classification and labelling and user scenarios and knowledge, could improve EPIs in these areas.

### **4.2 Integration with other information systems within a company**

When implementing the RAVEL methodology it is important to investigate connections to other existing internal and external data sources. Both data needed for the current set of indicators, as well as data in existing systems that the users of the indicators want to see together with the indicator results are important to consider.

---

<sup>14</sup> Erixon, M., Tivander, J., Pålsson, A-C., Carlson, R., Method for integration of industrial environmental information systems Deliverable from IMPRESS sub project 2, IMI - Industrial Environmental Informatics, CPM report, Chalmers University of Technology, Sweden 2006

An extensive study of existing and future information systems at ITT Flygt was performed within this sub project in cooperation with the sub project “General method development”. The goal of the study was to find out how the information systems shall be adapted to best support measurement and communication of environmental performance to different stakeholders which were identified at ITT Flygt. In parallel to this IMPRESS project, ITT Flygt initiated an internal project where the goal was to reduce the total time spent in the product development process for each product by improving the product documentation. This should be achieved by creating a new integrated system where all the data and documentation on the product development process is kept together. This tool or integrated system will e.g. integrate CAD-systems with their PDM-system and material list. Minor changes of designs of existing products would then be possible to manage in a more cost-efficient way than is the case today. In the IMPRESS study it was found that the data model and system design of the new integrated system could be adapted to also support the RAVEL methodology.

The study performed in this sub project moreover identified an interesting connection between LCA and DfE. As the study related to several information handling areas within IMPRESS, the study continued as a case study within the IMPRESS sub project “General method development”, where the IMPRESS integration method was applied to the case study. The results from the whole study can be found in the report Method for integration of industrial environmental information systems<sup>15</sup>.

### **4.3 Integration of data sources providing support for material selection**

A major part of the environmental load associated with the production, use and disposal of most products is related to the materials in the product. It is for that reason important that materials which lead to a lower environmental load are selected. The RAVEL methodology can be extended with material selection methodology that supports the designer in the selection of materials, by providing well-founded information on relevant environmental properties of each material that the designer can understand and make use of in the product development process in combination with other more traditional design parameters. The methodology also consists of procedures to build up and maintain this knowledge of environmental loads associated with the use of materials in different contexts.

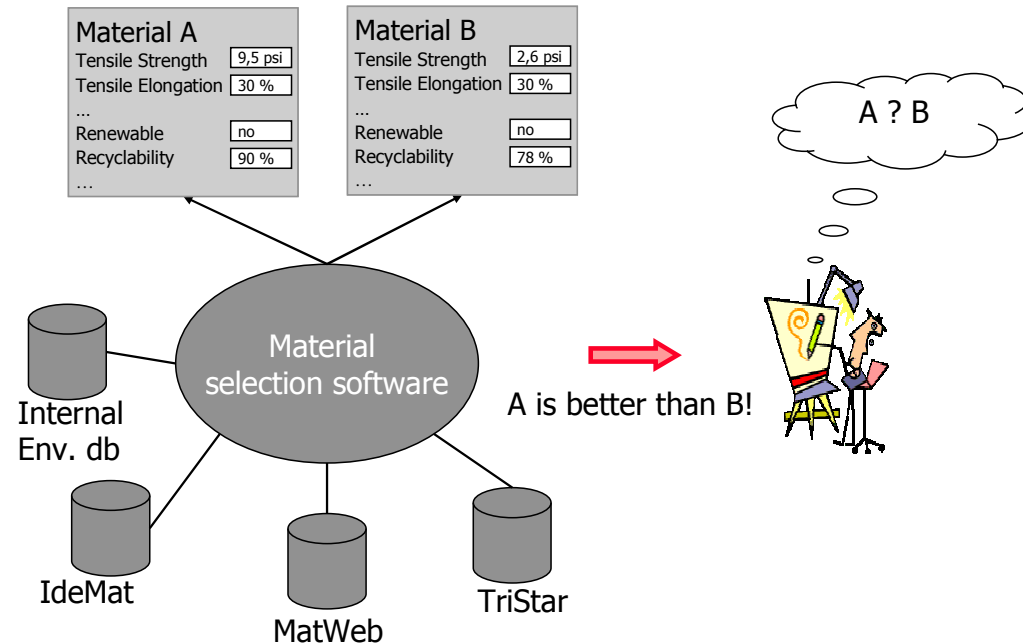
#### **4.3.1 Method for material selection**

Designers and other persons making material choices in the product development and procurement processes need support for making as good selections of materials as possible in their daily work. To achieve this, all relevant knowledge on materials needs to be made available to the designers. This can be realized by connecting several databases containing material property data in a *Material selection software* as described in figure 6 below. One of these databases could be the IMI Environmental database which contains environmental material property data that has been used to calculate the indicators within this sub project. The software could provide information on engineering properties as *Tensile strength* and *Tensile elongation*, as well as

---

<sup>15</sup> Erixon, M., Tivander, J., Pålsson, A-C., Carlson, R., “Method for integration of industrial environmental information systems” Deliverable from IMPRESS sub project 2, CPM-report, Chalmers, 2006

information on price and availability together with information on environmental properties as *Renewability rate* and *Recyclability rate*. The software could be used to present all relevant parameters on some selected materials when choosing among two or more alternative materials which have been identified by the designer. The software could also be used to search for alternative materials with better environmental performance based on the property data of a selected material.



**Figure 6:** Material selection software enabling the designer to get all relevant material data needed when deciding on which material is the most appropriate.

When making a choice of material it is important to also document the decision criteria which resulted in the choice of a specific material. This documentation should be attached to the documentation of the designed product. By analysing and structuring information on performed material selections, knowledge is gained which both aids in the redesign of existing products as well as in the development of new products.

#### 4.3.2 Strategy for material selection

A practical strategy for how companies should deal with material selection issues could be formulated as follows:

- Act now based on the best available knowledge. New knowledge is often very expensive to acquire.
- Document and store experiences when making material choices
- Structure and generalize experiences
- Support long term knowledge acquisition e.g. by supporting research that acquire new property data on materials and future scenarios.

Knowledge management on a more general level has been studied in the sub project “Integration of experiences and new information” in the IMPRESS project.

## **5 Experiences**

Overall, the inventory tool and the implemented graphical presentation of the EPI results were very appreciated in the participating companies. In addition, the defined EPIs and material data in the database were suitable for analysing environmental performance of real products.

Maintenance of the database, tools and the selected EPIs used for analyses is crucial for the reliability of the results. This includes e.g. continuously updating the database used and checking for new legislations and policies related to the EPI area to include in the definitions. A structured handling of extensions of the material list is needed i.e. new materials need to be included in the hierarchy otherwise it will be hard to find them during the inventory. When inserting new materials in the database new material property data need to be acquired and inserted in to the database. Experiences have shown that it is very important to document the origin of the data and to document how the data was treated. This information shall be written in the meta data documentation fields in the CPM Inventory tool. In addition, the work in the sub project have shown that common EPIs for different product groups can be used, as a complement a set of EPIs specific for each product group is also needed.

More general experiences from the project are described in earlier sections of this report. Below is a list of company specific experiences.

### ***5.1 Experiences from usage of the RAVEL-methodology in general***

The RAVEL methodology suits Bombardier Transportation and the rail industry very well as a base for the indicators and communication of the environmental performance. The methodology is well suited also to fit ITT Flygt needs for eco design. The rail industry is in some way similar to the pump industry, complex products with many different materials and an environmental performance that is very dependent on the usage phase.

IKEA was looking for Environmental Performance Indicators, EPIs, to steer the business when they joined CPM in 2004. This sub project in IMPRESS and the RAVEL method have shown to fit this purpose very well, from defining the set of EPIs to communicating the results.

### ***5.2 Experiences from usage of the indicators***

The indicators have been further developed and adjusted to Bombardier Transportation specific processes. The indicators that they use most are; amount of restricted substances and recyclability. Reporting of amounts of different material groups are also in focus for rail vehicles. The detailed material information is the base for the LCAs and the EPDs that are produced at Bombardier Transportation. The results from these projects are communicated both internally and externally and have been very appreciated. DfE information is often asked for by internal

departments, customers, suppliers and authorities.

From the set of indicators that was agreed upon in the project, three of them was suitable for ITT Flygt needs; Fraction recycled material, Can be material recycled and Materials inventory degree and product weight. Since the products constitutes of metals, mainly iron and steel, but also scarcer metals like copper and wolfram it is very important that the products are being recycled after usage. The environmental impact connected to the materials in the pump can be reduced if ITT Flygt is aiming to in greater extent use recycled materials.

Increasing the amount of renewable and recyclable materials are part of IKEAs strategy, hence, the indicators in this project fits them very well. IKEA started with measuring EPIs for the top 10 products at each Business Area (BA), and now they are working with measuring EPIs for 20% of the sales FY05 at each BA and also 20% of the sales FY05 for total IKEA of Sweden AB. IKEA have communicated the EPI results internally at the different business areas. The EPIs showed to be easy to explain and understood by everybody, also by those who do not work with environment issues at the company.

### ***5.3 Experiences from usage of the material list and material data***

An important part of the methodology is the "pre-defined" material tree with material details in different levels, according to Bombardier Transportation. The DfE properties for a material are predefined and this simplifies for their suppliers and increases the harmonisation in the DfE reporting.

The rail industry is similar to the pump industry regarding materials used in the products. Therefore the material database used in this sub project is compatible with the materials that are used by ITT Flygt.

During the work in this sub project IKEA used the material database as far as possible. Thereafter they added materials which were needed to the database. It is easy to add material into the database, but some material is difficult to get recycling data for or even to decide how deep to define them. For example a particle board, is it 100% wood or 90% wood and 10% glue and is a tissue material recyclable? Another discussion IKEA had was about marking the box 'possible to separate'. They decided that if there is a system where they know their product can be material recycled then they tick the box.

In addition, IKEA use other words for some materials compared to the nomenclature use in the material list in the IMI material database. It would be good to have the same material vocabulary in the data base as we use at IKEA. Regarding the definitions of the material property data and the actual data, it was very good to start with. After some work IKEA noticed that for some materials it would be good to have renewable in percent and maybe also add compostable as a new indicator and/or new material property.



#### **5.4 Experiences from usage of the CPM Inventory tool and EPI Reporting tool**

IKEA participants are very glad to have a tool they can use now at IKEA. In addition, it would be good if the following was added to the Inventory tool.

- the materials with the same name as we have in IKEA's *Materialregister*. This includes changing names of materials and to add some materials.
- to change the criteria for renewable yes/no to percent renewable and maybe also add compostable.

ITT Flygt finds the CPM Inventory tool to be a good system to calculate the EPIs, and using the reporting tool is a good way to communicate the results. The tools will probably not be used by ITT Flygt as it is today. Nevertheless, it will act as a good example when the new tool is developed at ITT Flygt.

#### **5.5 Other experiences from the collaboration**

Below are a few quotations on other experiences from the collaboration in this sub project.

*From Bombardier Transportation:*

“The project has met our expectations and the participants from CoC DfE at Bombardier Transportation have given a lot of input into the project, regarding our work experiences and methods and tools. The output from the project that we have appreciated the most is the contacts with other companies and the competence at IMI regarding material properties (e.g. recycling), programming skills and a good lead of the project.”

*From IKEA:*

“We have had good possibility to exchange idea with other companies and IMI, which have made this job very interesting, increased our knowledge and also benchmarked the result.”

*From ITT Flygt:*

“The collaboration with IMI and the other participating companies have been very fruitful and interesting. The knowledge and expertise at IMI is IMPRESSive, the support that they have given us companies have been very appreciated and needed. The meetings we have had in the project have been profitable and have acted as source for new inspiration for working with environmental issues.”

## 6 Conclusions

The focus of the work performed in this sub project has been to enhance the measurement and communication of environmental performance of products within the participating companies, by implementing the RAVEL methodology within the companies. Experiences have shown that the method, which was developed within the railway industry, also is applicable within the heavy electrical equipment (e.g. pumps) and furniture industries.

A requirement analysis performed early in the sub project indicated that the participating companies had different needs regarding measurement and communication of environmental performance of products, due to the fact that all the companies are active in different industry sectors with different requirements and working methods. However, a common agreement on the focus of the sub project could be reached. A pragmatic selection of Environmental Performance Indicators (EPIs) was performed based on the results from the requirement analysis and available data. This resulted in the definition of a set of indicators covering the areas *recycling* and *material content* of products. These indicators have been calculated for a wide range of different products in the companies. The EPIs showed to be easy to explain and understood by everybody, also by those who do not work with environmental issues.

Each EPI constitute a simplified description or model of the real world. The EPIs should be based on best available data and knowledge and should be revised when new relevant information exists. The simplifications on model level e.g. to not include scenario data for recycling of a product, need to be understood by the user of the RAVEL method to avoid misinterpretations. The cost for data acquisition is connected to this since site or product specific data is often associated to a higher cost than general data. In this project more general data has been used. In addition, more specific data can be inserted into the database by the user when available. To increase data quality in terms of e.g. reusability and transparency of data and facilitate interpretation of EPI results all data acquired should be detailed documented.

The interpretation of the calculated EPI result is facilitated by using target values, which are representing environmental requirements that the designer shall strive to fulfil. Experiences from this work show that it is hard to define relevant target values. Furthermore, target value should be defined for each product group, as products with different functions have different environmental performance which not is comparable.

A user-friendly prototype was needed to demonstrate how to use the method and test the working procedure. The *CPM Inventory tool* developed in earlier CPM projects has been further developed and used to insert the product data, set target values and to calculate the EPI results for all products.

An important focus of the sub project was how to communicate the EPI results calculated in the tool in the best way. It was decided that transparent and understandable reports which easily could be distributed to the decision makers was

needed. Functionality for generation of these reports from the data inserted in the *CPM Inventory tool* was implemented in the Excel based *Reporting tool*. Reports from this tool have been generated for the products inserted into the *CPM Inventory tool*.

A general comment from the requirement analysis was that we should not develop a new tool but integrate the RAVEL methodology into existing systems. The work has shown that the functionality of the *CPM inventory tool* and *Reporting tool* is needed and can be integrated into each company's systems. In addition, the calculation of EPIs and reporting of EPI results can also be made manually using e.g. Excel or other technology.

Results from this sub project are also material supporting e.g. the definition of new indicators, tools and basic data. This will facilitate a continued implementation of the RAVEL methodology also after the IMPRESS project.

Knowledge exchange has been an appreciated part of the work, which increased the participants' knowledge on DfE work and also benchmarked the result.

## Appendix 1: Checklist sub project 7

1. Which are the driving forces and requirements to communicate environmental information today
  - a. with customers
  - b. with suppliers
2. How do you work with product related environmental information today?
3. How could the RAVEL methodology be implemented in your organisation?
4. Which parts are the most interesting?
5. Who are the potential stakeholders that could use the method at your company?
  - a. Which of these should be involved in the implementation work of SP 7?
6. Which indicators (EPIs, SPIs, KPIs etc) do you use today? Do you have ongoing work in the indicators area?
  - a. Which indicators do you want to work with in this project?
  - b. Which persons should be involved in the definition of a set of indicators in the SP 7 work?
7. Which relevant databases are used at your company today?
8. What do they contain?
  - a. product and component data
  - b. material data
  - c. environmental data (e.g. LCA data)
9. Details on technical aspects:
  - a. data format
  - b. nomenclature
  - c. technical platforms for databases and for working with data (e.g. Microsoft, Java)
10. Other relevant information

## Appendix 2: Templates for documentation of EPI and material property data

### 6.1 EPI definition template

Documentation Field	Explanation
<b>Name</b>	The name of the EPI should be explanatory as far as possible.
<b>Description of function</b>	A short description, in words, of the function of the EPI. The explanation of the EPI shall be easy to understand. Definition of relevant words and concepts should also be given here. A reference to the material property definition shall also be included when relevant.
<b>Formula</b>	Algorithm showing how the EPI will be calculated.
<b>Unit</b>	Unit of the EPI; specified if needed.
<b>Input – User input</b>	Specification of input needed from the user to calculate the EPI. It is very important that the user input is well specified to avoid misunderstandings.
<b>Input – Material specific properties for this indicator</b>	Specification of the material property data needed as input to the calculation. Specification of each material property is given in a separate document.
<b>Output</b>	Specification of the output in terms of name and unit.
<b>Comments</b>	Extra comment to the defined indicator e.g. knowledge of how the EPI was developed can be given here as well as name of the person(s) written the definition.

### 6.2 Material property specification template

Documentation Field	Explanation
<b>Default name</b>	The default name is the most common used and easily comprehensible name for the material property.
<b>Alternate name</b>	Relevant alternative names improving the understanding.
<b>Use in calculation of EPI</b>	Name of the EPI the material property is used in.

<b>Property method description</b>	Explanation of the material property, how it is defined in detail and how to find data for this material property.
<b>Value type</b>	Description of the value type e.g. numeric value, range of allowed words (nomenclature) and free text.
<b>Unit</b>	The property's unit is written here. Write 'Dimensionless' if numeric value without unit and 'Not applicable' if text.
<b>Unit specification</b>	Explanation of the unit including why it is dimensionless if so. References should be written in the reference field.
<b>Property reference</b>	References to the sources used for the material property specification. It should be a numbered reference list with complete references. A complete reference is described so that a different person can easily find the data source.
<b>Modeller</b>	Name, organization and address of the person(s) documented the property specification.

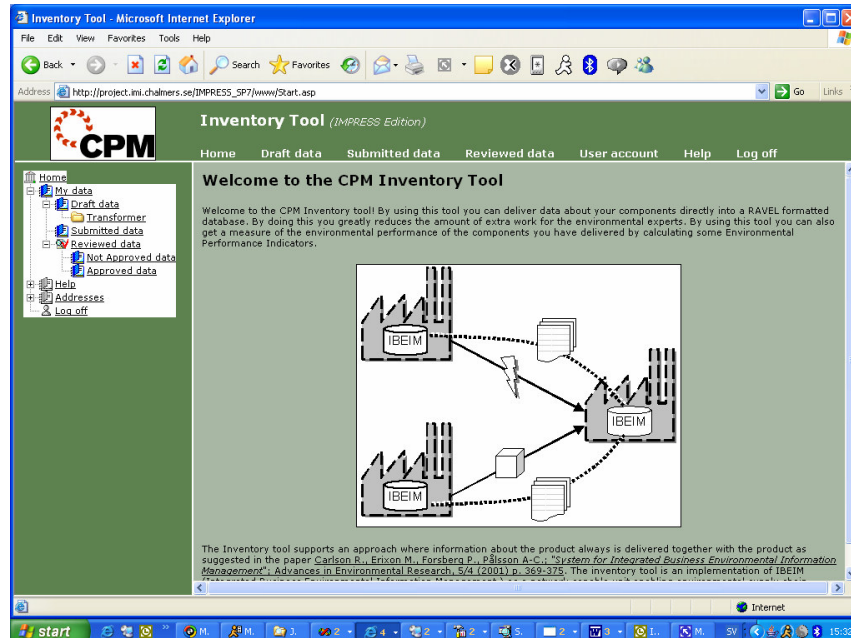
## Appendix 3: Manual for CPM Inventory tool and EPI Reporting tool

### 3.1 Procedure: How to insert data on products into the CPM Inventory tool

This is a step by step description on how to insert products, material and material property data into the CPM Inventory tool which has been used and further developed within sub project 7 “Measurement and communication of environmental performance of products” of the IMPRESS<sup>16</sup> project.

1. Log in to [http://project.imi.chalmers.se/IMPRESS\\_SP7](http://project.imi.chalmers.se/IMPRESS_SP7) and enter your username and password, which has been sent to you by email. Please contact Johan Tivander at IMI, if you do not have access to any valid username.

You will then see this user interface:

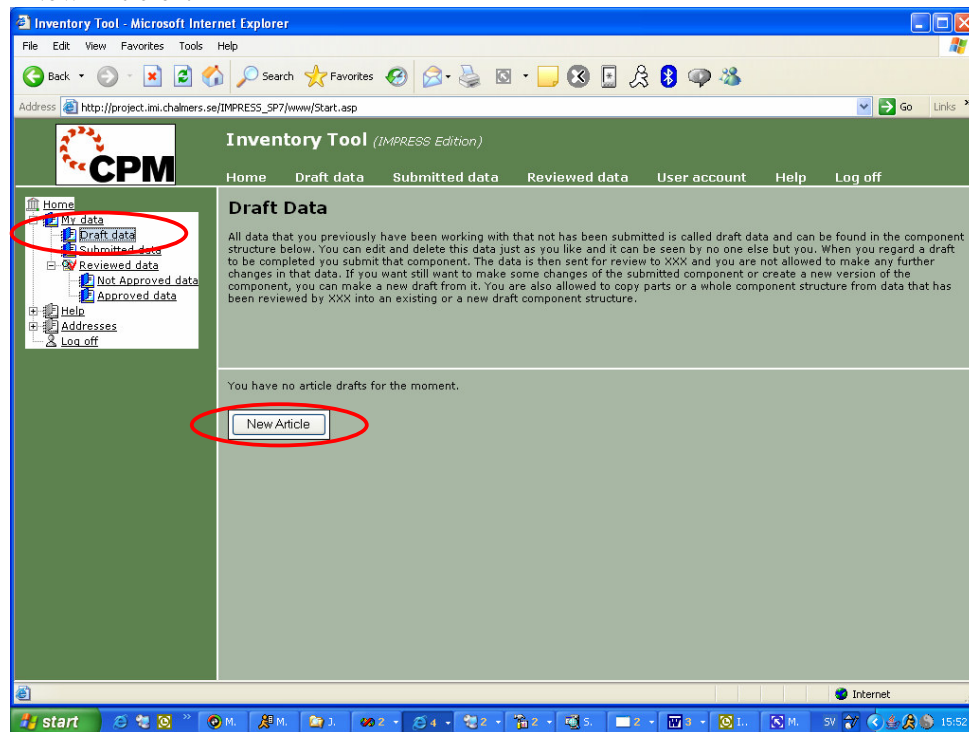


In the top of the page some links are provided which among others makes it possible to edit your password (click on “User account”). These links are always available in the tool. On the left hand side of the page a tree menu is provided which also always is accessible. This menu contains all articles which you have entered into the tool and also some help links. As the tool originally was developed as an inventory tool to collected data from sub-suppliers for Bombardier Transportation, the articles have different states depending on if the suppliers are working with the data (“Draft”), the suppliers has sent the data for review (“Submitted data”) or if the data has been reviewed (“Reviewed data”). We will not use these different states for our application of the tool and we are

<sup>16</sup> IMPRESS (Implementation of integrated environmental information systems) project is funded by CPM and runs 2004-2006. more information is found at [www.cpm.chalmers.se](http://www.cpm.chalmers.se)

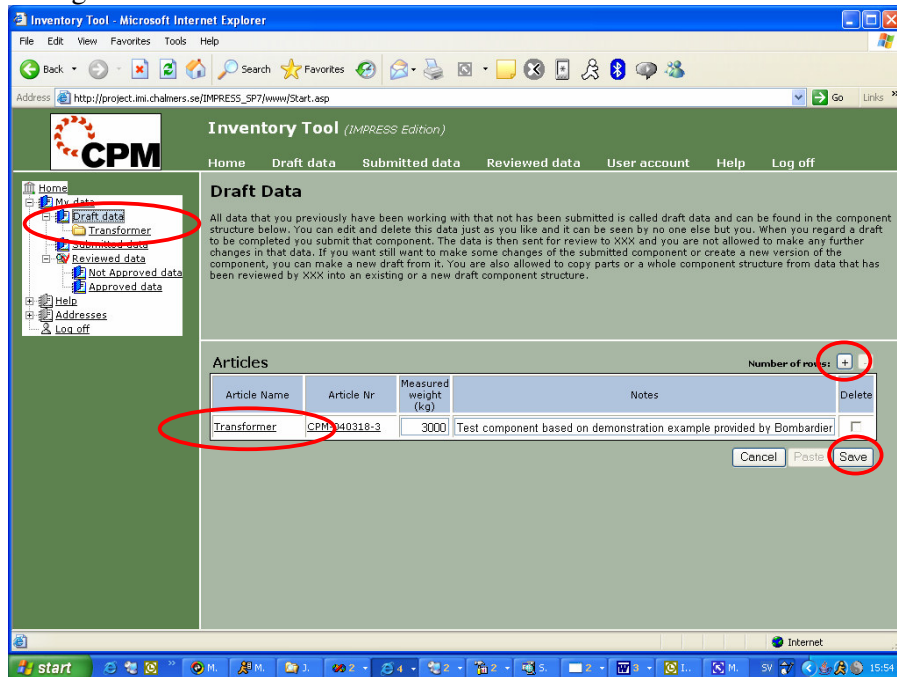
hence only focusing on the Draft data which we can enter and edit.

2. Choose “Draft data” in the left hand menu in the tool. Then click on the button “New Article”.





- Enter values in the fields “Article Name”, “Article Nr”, “Measured weight (kg)”, and “Notes”. Click on Save. The article is now added to the tree menu on the left. If you want to create more articles you can click on the “+” button on the right which adds more rows where article data can be entered.



- Add data to the created article by clicking on the name of the article in the left hand menu or in the articles table. The following user interface is loaded:

**Table containing information on the currently selected component or article in the article tree**

**Article tree containing all components and materials of the selected article**

**Table containing information on all subcomponents and materials of the currently selected component or article in the tree**

Component Name	Article Nr	Quantity in super component	Measured weight (kg)	Notes	Delete
Coil	CPM-040318-3-1	1	749		<input type="checkbox"/>
Coils	CPM-040318-3-2	1	978		<input type="checkbox"/>
Enclosure	CPM-040318-3-3	1	380		<input type="checkbox"/>
Bushings	CPM-040318-3-4	1	4		<input type="checkbox"/>
Winding isolation	CPM-040318-3-5	1	160		<input type="checkbox"/>
Active parts details	CPM-040318-3-6	1	134		<input type="checkbox"/>
Oil	CPM-040318-3-7	1	370		<input type="checkbox"/>

- If no data has been defined for the article, both the article tree and containing subcomponents and materials in the article of course are empty.

Click on the buttons “Add SubComponent” or “Add Material” to get a table where you can enter data on sub-components or materials.

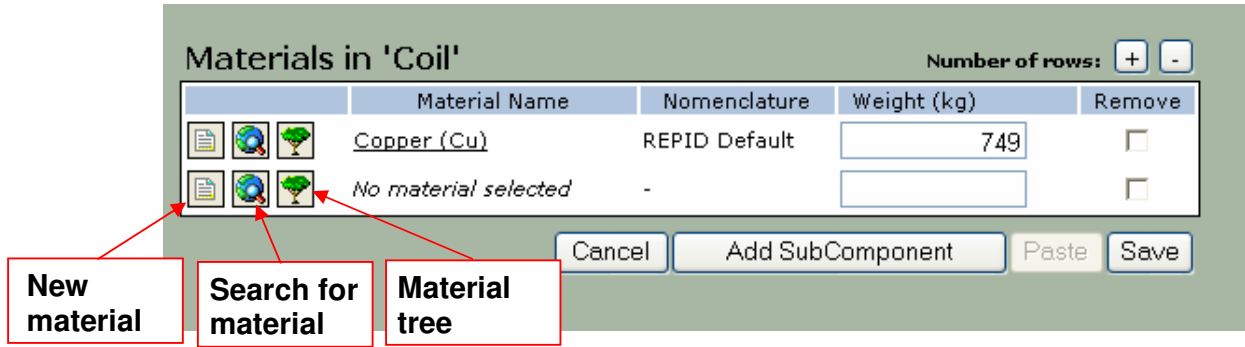
The set of indicators which we currently have defined are mainly based on material properties. The component structure is however used to define a component or article as possible to separate or not. This property on component level is used in the calculation of the indicator “[Can be material recycled](#) “. Only articles and components which are defined as separable can contribute to raise the value of this indicator. The component structure is also useful if we want to analyse different parts of a product separately.

6. Add subcomponents of the article by clicking on the button “Add SubComponent”. The following data can be added:
  - Component Name
  - Component Nr
  - Quantity in superior component (The quantity of this subcomponent which is used in the parent component)
  - Measured weight (kg)
  - Notes (Any additional information)

Save the information. The component is added to the article tree. You can add more subcomponents by clicking on the “+” button

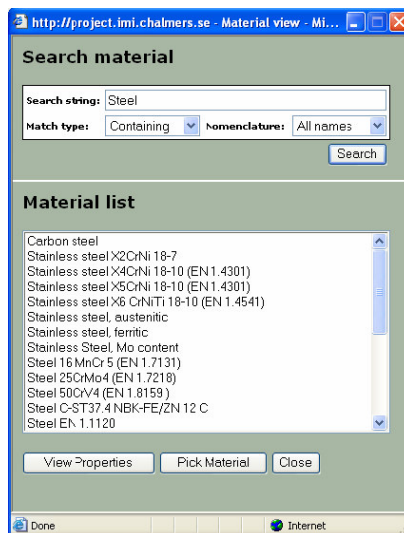
Subcomponents to 'Transformer'					
Component Name	Component Nr	Quantity in super component	Measured weight (kg)	Notes	Delete
Coil	CPM-040318-3-1	1	749		<input type="checkbox"/>
Core	CPM-040318-3-2	1	978		<input type="checkbox"/>
Enclosure	CPM-040318-3-3	1	380		<input type="checkbox"/>
Bushings	CPM-040318-3-4	1	4		<input type="checkbox"/>
Winding isolation	CPM-040318-3-5	1	160		<input type="checkbox"/>
Active parts details	CPM-040318-3-6	1	134		<input type="checkbox"/>
Oil	CPM-040318-3-7	1	370		<input type="checkbox"/>

7. You can add subcomponents to subcomponents by selecting a subcomponent in the article tree and perform step 6.
8. Add materials to the subcomponents (or directly to the article) by selecting the subcomponent in the article tree and click on the button “Add Materials”. The following data can be added:
  - Material name
  - Nomenclature
  - Weight (Weight of the specified material used in each occurrence of the superior component)

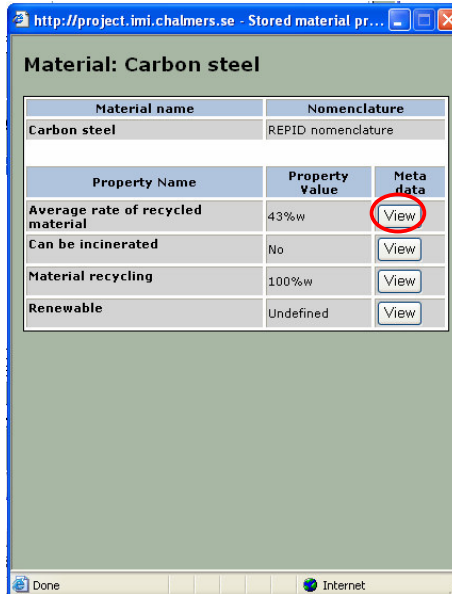


The IMI material database connected to this tool contains the material list and the material property data which was collected by IMI in earlier projects. This data are used for test and demonstration in this sub-project. You can select these materials either by clicking on the search button or the material tree button. You can also add new materials to the database by clicking on the left button on each row. These new materials are only available to you (or anyone else logged in using the same user name).

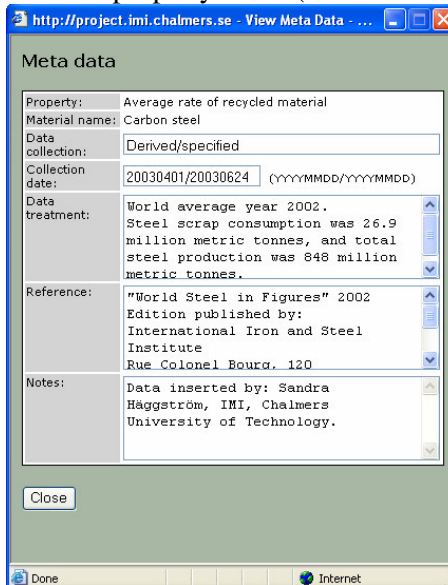
- a. Search for material:
  - i. Enter a Search string select a nomenclature and define how the search function shall use the search string by selecting a match type. Then click on Search.
  - ii. All materials in the database matching your search criteria are displayed in the material list.
  - iii. If you find matching materials either double-click on that material in the material list, or select the material and click on "Pick Material" to use this material in your component.



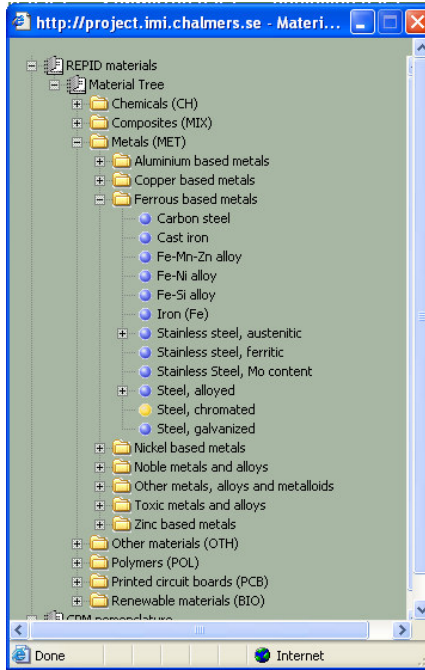
- iv. When you have selected a material you can also view the documented material properties which are stored for this material in the database, by clicking on "View properties". The following window appears.



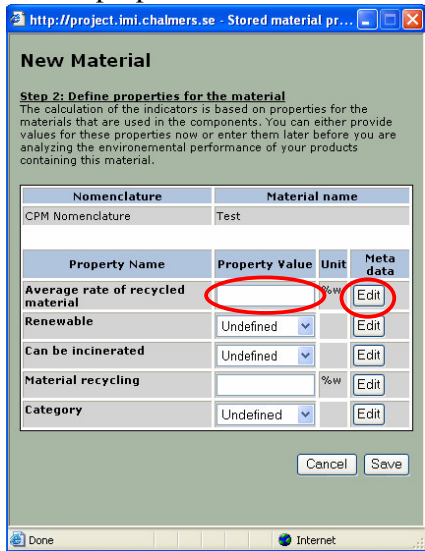
- v. By clicking on the button “View” you can view the documentation which is available in the database for the selected material property value (see section Data documentation above)



- b. Find material in tree
  - i. The material list has been categorized in different material groups to facilitate the selection of materials. Expand material groups until you find the material you want to use.
  - ii. The materials which you have added are available in the branch “User-defined materials”.



- c. Add a new material
  - i. Define a name for your material and click on “Continue”
  - ii. Define properties for the created material



- iii. You should document how each data value was acquired. Documentation can be provided for each value by clicking on the

button “Edit”. In the window that opens you can enter documentation of each value as described in the section “Data documentation” above.

The screenshot shows a web browser window with the following content:

- Address bar: <http://project.imi.chalmers.se> - Edit Meta Data - M...
- Form Title: Meta data
- Property: Average rate of recycled material
- Material name: Steel, low alloyed
- Data collection:
- Collection date:  (YYYYMMDD/YYYYMMDD)
- Data treatment:
- Reference:
- Notes:
- Buttons: Save, Close

### 3.2 Procedure: How to calculate EPIs in CPM Inventory tool

An *Environmental Performance Indicator (EPI)* is a quantitative expression of environmental performance. EPI results of a product are the values of the calculated set of EPIs. You can calculate the defined EPIs for the articles you have inserted data for in the CPM Inventory tool by:

1. Log in to the CPM Inventory tool and select the article or component that you want analyse in terms of the defined EPI.
2. Click on the link “EPI results”

Indicator Name	Relative value (%)	Absolute value (kg)	Target value (%)
Amount of restricted materials	0	0	0
Can be incinerated with energy recovery	16.838	427.398954	10
Can be material recycled	99.9212	2536.2998196	90
Fraction recycled material	43.3048	1099.2057384	85
Fraction renewable material	11.4407	290.3992881	30
Materials inventory degree	84.61	-	100

3. The indicators are automatically calculated in accordance with the calculation formulas which have been drafted for each indicator
4. Relative and absolute values are provided for each indicator. You can also get an explanation of each indicator by clicking on the name of an indicator.



### 3.3 Procedure: How to define target values for EPIs in CPM Inventory tool

Quantitative target values are often set before the actual design of a product starts. The environmental performance of a product is decided in terms of target values for a set of chosen EPIs. The targets should be set based on policies and specific market needs i.e. according to requirements within or outside the company. Set target values form the control value, which the design subsequently should aim at.

Functionality for setting of target values was not included in previous versions of the CPM Inventory tool. This functionality was instead included in a tool for administration of the data from the CPM Inventory tool. Functionality for setting of target values was however added as the CPM Inventory tool alone was used to demonstrate the RAVEL methodology in subproject 7 of the IMPRESS project, and target values is a vital concept of this methodology.

1. Log in to the CPM Inventory tool and select the article or component, for which you want to set target values.
2. Click on the link “Targets”

Indicator Name	Target value (%)	Meta data
Amount of restricted materials	0	Edit
Can be incinerated with energy recovery	10	Edit
Can be material recycled	90	Edit
Fraction recycled material	85	Edit
Fraction renewable material	30	Edit
Materials inventory degree	100	Edit

3. Define relative target values for each indicator and click on “Save” to store the values. You can get an explanation of each indicator by clicking on the name of an indicator.

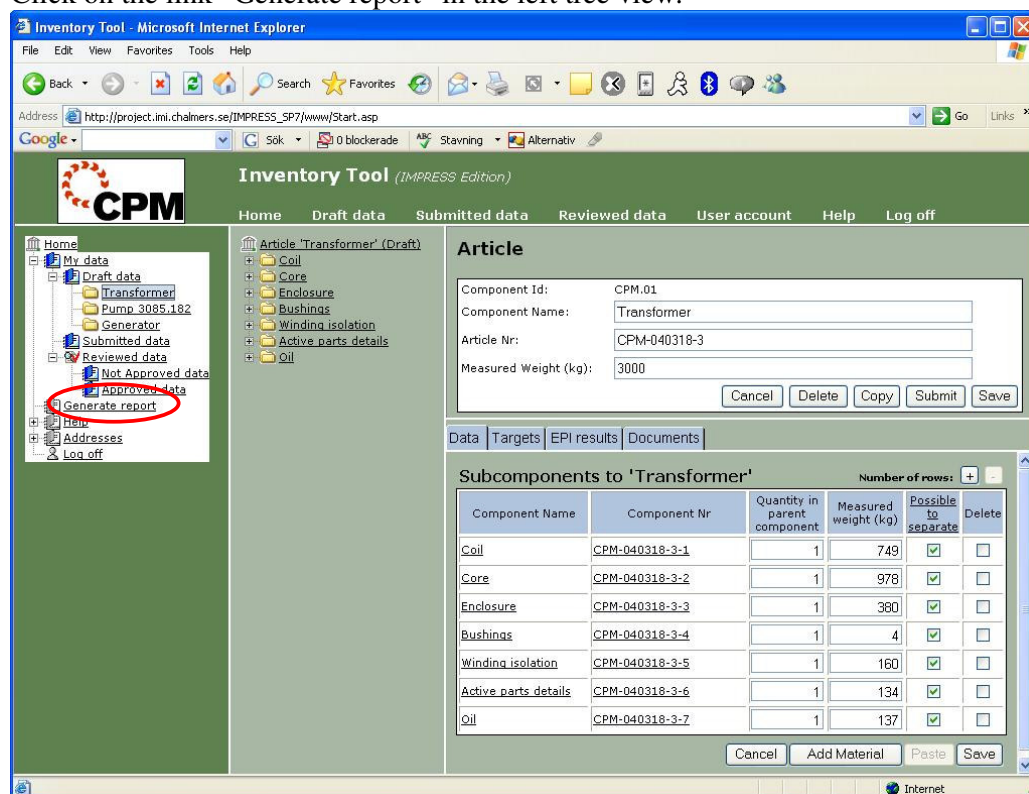
*Important:* Document what your target value is based on as meta data for the target value. If you are only taking the value out of the blue, then document that.



### 3.4 Procedure: How to generate EPI Result reports for data inserted into the CPM Inventory tool

This is a step by step description on how to generate an EPI result report from the CPM Inventory tool. An EPI Result Report is a report on the environmental performance of products, expressed in terms of Environmental Performance Indicators (EPIs). In order to generate a report, data for the product first need to be inserted into the CPM Inventory Tool.

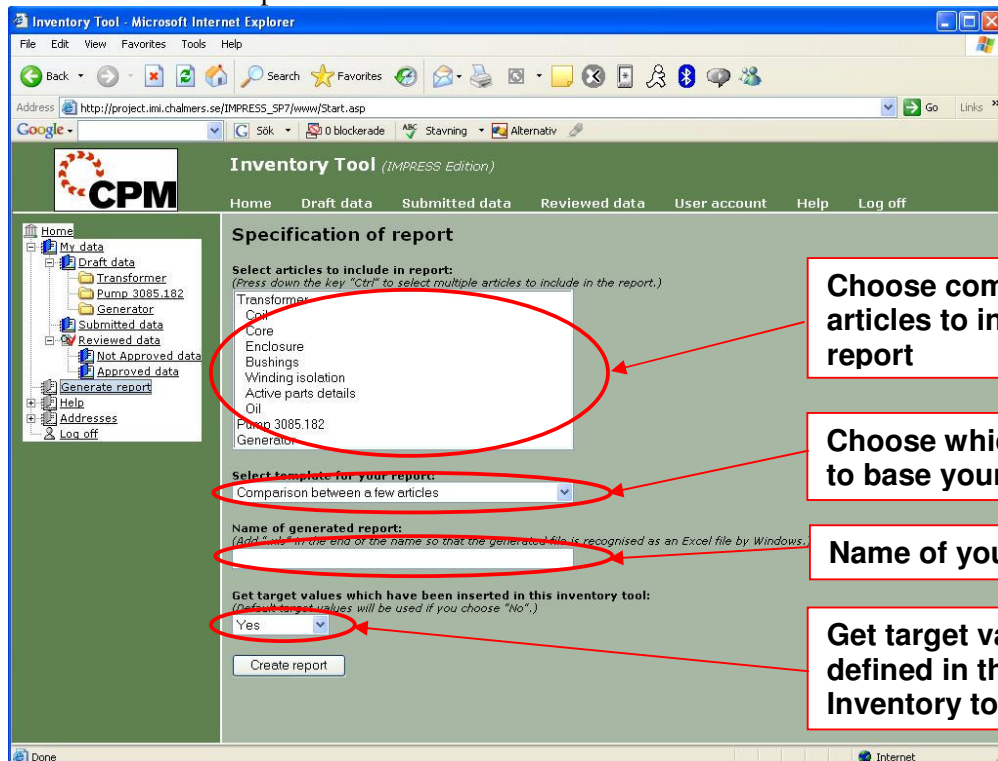
1. Log in to the CPM Inventory tool
  - a. Insert data that is to be included in the report as described in the procedure [How to insert data on products into the CPM Inventory tool](#).
  - b. You may also define target values for the EPIs to be used in the report as described in the procedure [How to define target values for EPIs in CPM Inventory tool](#).
2. Click on the link “Generate report” in the left tree view.



3. For security reasons you need to provide the Windows username and password which has been provided to you.



4. You can now in the form “Specification of report”:
  - a. Choose which articles or components to include in the report
  - b. Choose which template to base your report upon
    - i. Report template suitable for comparison between a few articles
    - ii. Report template suitable for comparison between many articles
  - c. Provide a name of the report which is to be generated. It is important that you end the name with the suffix “.xls”. The report will otherwise not be recognized as an Excel report on the server, and you will not be able to view or download the generated report.
  - d. Choose if target values inserted into the CPM Inventory tool shall be used in the report or if the default target values shall be used. It is important to know that if you are including many articles with defined target values in your report, only one of these sets of target values can currently be included in the report. The target values from the first selected article or component with at least one defined target value is used in the report.



**Choose components or articles to include in the report**

**Choose which template to base your report on**

**Name of your report**

**Get target values defined in the CPM Inventory tool?**

5. Click on the button “Create report”. The EPI report for the selected articles and components is generated on the server.
6. The generated report can now be viewed on the server or downloaded to your computer (right-click on the link and choose “Save target as..”). We highly recommend you to download it to your own computer.