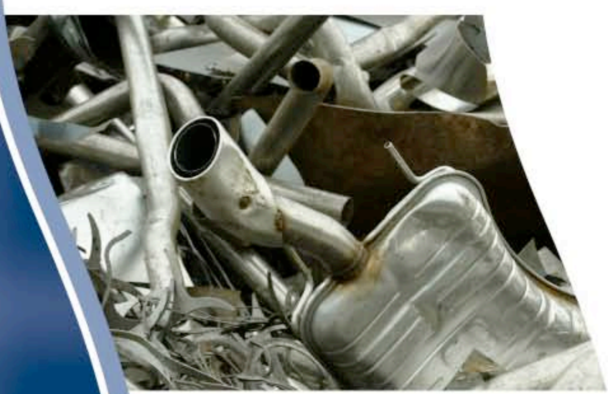
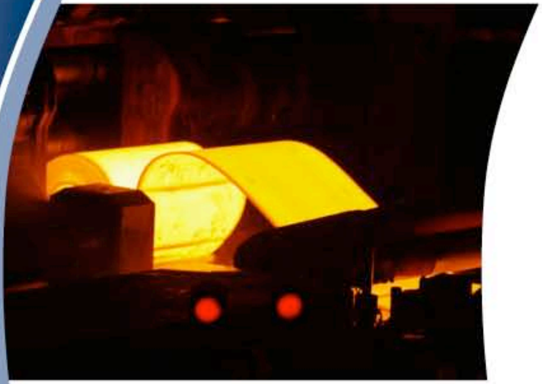
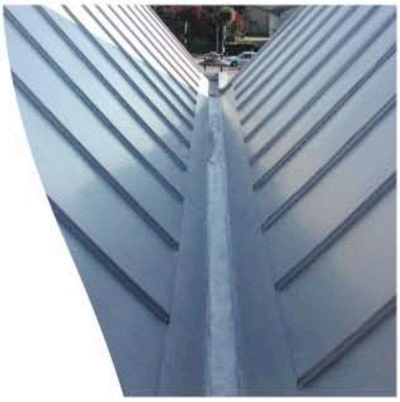
THE EUROPEAN STEEL INDUSTRY'S CONTRIBUTION TO AN INTEGRATED PRODUCT POLICY





FINAL REPORT



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4. EXECUTIVE SUMMARY

In response to the European Commission's communication on Integrated Product Policy, IPP, released in June 2003, the European Steel Industry, EUROFER, undertook a project to look at the implications of IPP and to contribute to the discussions with the European Commission. The aim of IPP is to identify and minimise environmental impacts caused by products and services, which occur throughout the phases of their life cycle, whether from manufacture, use or disposal.

There is an ever-increasing volume of product-related material available, for designers, consumers and end of life recyclers, be it technical data or general information. The demand of legislative requirements is also growing, which requires that industry produces similar information in many different formats, for different regulatory bodies. IPP aims to consolidate these requirements rather than developing any new legislation.

The project consists of three main parts:

- The development of product-specific eco-design packages to be used throughout the supply chain which are based on the requirements of key steel industry customers. These requirements were determined through a number of face-to-face interviews with the customers, initiating an open dialogue between the steel producers and product manufacturers. Current and future desired practices and information requirements were discussed so as to establish the most appropriate content and format of the eco-design packages. Packages were developed for a number of case study products in different market sectors, namely:

    - Automotive – a tailor welded blank (TWB), comprising electro-galvanised carbon steel

    - Construction – carbon steel: a composite flooring system, comprising steel sections (beams), hot dip galvanised steel (decking), reinforcement bars and electro-galvanised steel (studs)

    - Construction – stainless steel: a roofing system, comprising 304 2B cold rolled coil

    - White goods – a dishwasher casing, incorporating both carbon and stainless steel, comprising organic coated carbon steel and 304 2B cold rolled stainless steel coil.

  The design of these packages is shown in Figure 1.

ECO-DESIGN PACKAGE

COMPOSITE FLOORING SYSTEMS

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ECO-DESIGN PACKAGE

TAILOR WELDED BLANKS

ECO-DESIGN PACKAGE

STAINLESS STEEL ROOFING SYSTEMS

ECO-DESIGN PACKAGE

CONSUMER PRODUCT DISHWASHER CASING

Figure 1: Product Specific Eco-Design Packages

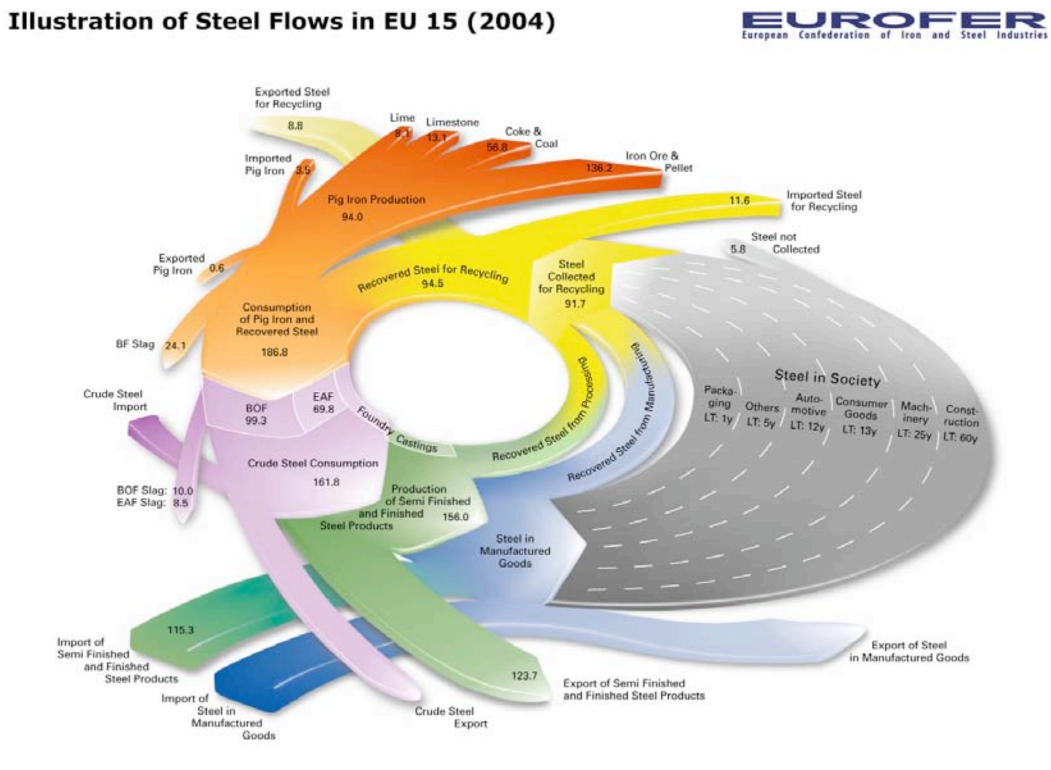
- The development of a cradle to grave (excluding use phase) steel industry Life Cycle Assessment (LCA) methodology, which includes:

    - the incorporation of the IISI Recycling methodology which considers the environmental credits and burdens associated with the end of life of steel products and the utilisation of steel scrap in the steel making process

    - developing a methodology to determine environmental credits and burdens associated with the production and use of valuable materials in the steel making process, namely the co-products (e.g. blast furnace slag), which are subsequently used in other industries. Further discussions of this methodology are required prior to its implementation.

  In addition, a review of life cycle costing (LCC) methodologies was undertaken to determine their potential use within the steel industry.

- The development of a material flow analysis (MFA) of steel throughout Europe to expand the level of detailed knowledge within the steel industry. The data that has been collected is illustrated below and shows the ‘closed loop’ flow of steel throughout EU15, based on 2004 data. Determination of scientifically accurate recycling rates was not possible due to a lack of data availability from the necessary countries.



LT: Lifetime [years]
Values in Million Metric Tons

Data taken from the International Iron and Steel Institute (IISI), Steel Statistical Yearbook 2006, World Steel in Figures 2006, CAEF 2005, European Blast Furnace Committee 2006, Data updated: October 2007

Figure 2: Illustration of Steel Flows in EU 15 from 2004

The eco-design packages, the developments within the LCA methodology and the MFA data cover a broad range of data throughout the whole of the life cycle, and encompass product specific requirements that fall under the umbrella of IPP, whilst supporting varying geographical requirements. As the backbone to a growing number of legislative requirements, LCA is of course a key aspect to the eco-design packages, enabling the environmental impact of the product life cycles to be quantified.

In terms of product development, eco-design and sustainability issues, there are numerous and varied approaches that are being developed by EUROFER's member companies, at a national or European level. It is therefore important to ensure that as much consistency is achieved as possible when providing data and for communication purposes. A benefit of this IPP project will be to assist in such schemes by providing the necessary steel and/or LCI data and the corresponding methodology relating to the life cycle of steel products. This will ensure both the non-duplication of work and resources as well as producing a more consistent, harmonised approach to IPP and LCA related issues.

Having completed the IPP Project, the following recommendations can be made:

Use of the Eco-design packages

The Eco-design packages have been developed for use by EUROFER members. It is intended that the format and design of these packages can be utilised for company specific and product specific applications, as desired by each company. The packages can then be used by all interested parties throughout the product lifecycle (be they steel manufacturers, product designers and manufacturers, the consumer or the end-of-life recycler) for the harmonisation and communication of steel industry data and information.

Co-product methodology

As a follow-up to this project, a number of areas for investigation are recommended:

- A critical review of the methodology and incorporation of any appropriate recommendations.
- Discussions with the users of the steel industry co-products, such as cement manufacturers.
- Possible implementation of the co-product methodology within the new IISI data collection.
- Following the critical review of the methodology applied to the integrated steelmaking route and discussions with the co-product users (e.g. the cement manufacturers), potential development of a methodology to incorporate the Electric Arc Furnace route co-products from carbon and stainless steel manufacture.
- Future discussions with IISI and other steel industry organisations for the inclusion of the EUROFER co-product methodology within other datasets.
- Potential inclusion of European steel industry LCI data incorporating the co-product methodology, with LCI data providers, software developers and the European Commissions ELCD.

MFA – Material Flow Analysis

Having collected the relevant data to produce an illustration of steel flows within EU15 in 2004, it is now recommended that this illustration is used within the industry, to determine its applicability (e.g. for communication purposes) and to receive any feedback about the model. The model and the data should be re-visited within the next 5 years to determine any potential further work required. Further development might include, for example, a more accurate and detailed level of data collection.

LCC - Life Cycle Costing

EUROFER should focus on Life Cycle Costing internally to gain more understanding of what this approach will mean for the steel industry and their products. Particular attention should be given to developments where regulations are taken into account, to define additional product related costs, e.g. CO_2 emissions. In addition to this, EUROFER should continue the identification/ analysis of social parameters used within sustainability reporting systems, which might be of importance in the future for the evaluation of steel products.

CONCLUSION

The European steel industry has been proactive in meeting the requirements of an Integrated Product Policy. EUROFER has disseminated eco-design information to help quantify and reduce the environmental impacts of products throughout their life cycle. The positive environmental life cycle aspects of steel products have also been highlighted in the construction, automotive and consumer markets.

The interviews performed during the preparation phase of the Eco-Design packages provided clear feedback from the interviewed industries that such direct business to business communication and discussions regarding product related aspects and challenges are a beneficial development within product development.

The Eco-Design packages help to harmonise the communication from EUROFER and it's member companies. The packages provide a comprehensive overview of information and data that is available to perform environmental analysis of steel-containing products.

Having successfully completed this project, EUROFER is now in a good position to demonstrate its positive contribution to the future requirements of the European Commission's Integrated Product Policy, which falls under the remit of Sustainable Consumption and Production, SCP. The European Commission participated in the projects' final workshop in March 2007, and acknowledged the pro-active efforts undertaken by the steel industry as an important contribution to the overall developments within IPP and also to the future of SCP.

5. INTRODUCTION

5.1. An Introduction to Steel

Steel is produced via two routes: the integrated route from virgin raw materials (iron ore, coke, limestone) and steel scrap in the blast furnace and basic oxygen furnace, and the electric arc furnace route (EAF) where scrap is predominantly used as the raw material, see Figure 3. Despite the high steel recycling rates and the fact that all available steel scrap is recycled, there is not sufficient scrap available to meet the global demand for steel by the EAF route and therefore the blast furnace route is required. There is a long established market for recycling scrap steel at the end-of-life as well as for recycling scrap from the steel production process. Steel is easy to separate from other materials by well established technologies for various applications, e.g. magnetic separators for extracting steel from municipal waste or construction waste. To further enhance re-usability and recyclability, technologies for adaptability and disassembling have been developed, e.g. for automotive, construction and furniture products. Especially at the end of the useful life of buildings and vehicles, steel components can be dismantled easily. Reclaimed steel products can be recycled several times or reused without losing their inherent properties.

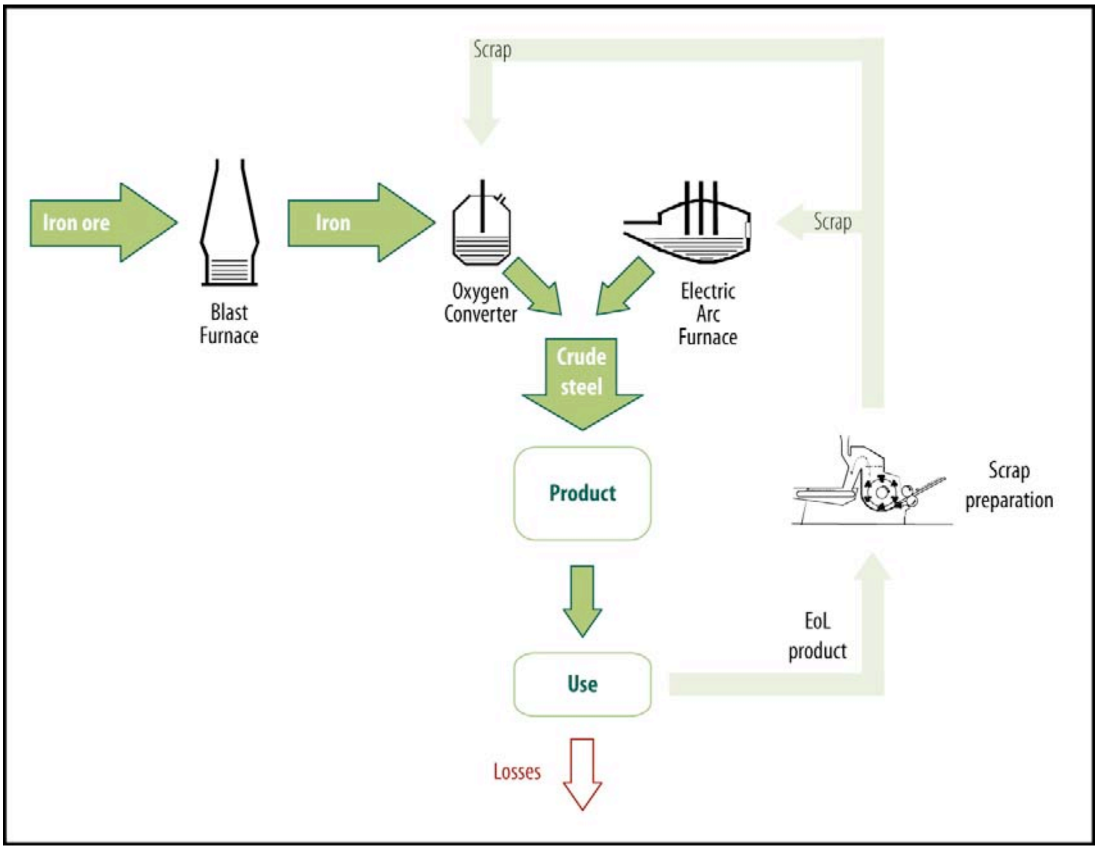


Figure 3: Steel Production Routes

5.2. An Introduction to IPP and the EUROFER Project

It is an increasingly acknowledged fact that all products and services cause some form of impact on the environment (both positive and negative), whether it be in the manufacturing phase, use phase or at the end of its life. Everything has an environmental impact – it is the phase of the life cycle where the greatest impact occurs that will vary.

In June 2003, the European Commission released a communication on Integrated Product Policy (IPP). The Commission is implementing IPP with an aim to develop practical tools to assess and encourage the improvement of the environmental performance of products and services in all aspects of the life cycle including extraction of natural resources, the design of a new product, the manufacture, assembly, marketing, distribution, sale, use and maintenance of the product and the end of life – ensuring that options are considered where possible for the reuse and recycling of materials. This will be achieved by engaging with each of the involved parties using various initiatives to investigate possible consistent approaches to IPP rather than developing new legislation. Throughout Europe there are various initiatives and tools in place, be they voluntary or mandatory, which aim to achieve environmental improvement (e.g. economic instruments, substance bans, voluntary agreements, environmental labelling and product design guidelines). IPP should aim at providing a more consistent approach to such an improvement and consider the developments of associated initiatives such as Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE), Directive 2000/53/EC on End of Life Vehicles (ELV), Directive 2004/12/EC on Packaging and Packaging Waste (amending 1994/62/EC), Directive 1992/75/EC on Energy Labelling, COM(2003) 572 on Natural Resource Strategy, COM(2003) 453 on Eco-design Requirements for Energy-Using Products (EuP), Ecolabels (European environmental certificate) etc.

The European Confederation of Iron and Steel Industries, EUROFER, has a keen interest in the work of the Commission and is playing an active role in the development of the Commission’s European Platform on Life Cycle Assessment (LCA) with respect to steel industry Life Cycle Inventory (LCI) data. EUROFER is also paying particular attention to the pilot projects on the mobile telephone and teak garden chair.

In addition, EUROFER is taking a pro-active approach and is working in parallel with the Commission in order to develop knowledge and procedures on IPP within the European steel industry. EUROFER commissioned a shadow IPP project to run in parallel with the Commission’s pilot projects to contribute to the IPP discussion and to develop a steel industry approach to IPP. The introductory phase of this project was a general study to evaluate the material steel and its products in the context of the IPP communication. The study identified several contributions that the steel industry has made in relation to improving the product’s environmental impacts over its life cycle, as well as determining where further development would be beneficial.

The primary aim of IPP is to reduce the environmental impact of products, and LCA has been identified as one of the key tools in achieving this objective. While the steel industry believes that LCA can be a useful business to business tool, the current LCA methodologies and databases are still under development and therefore unsuitable for inter-material comparisons. LCA must be kept in perspective, as there are many tools that can be used for the environmental appraisal of materials. With this in mind, the EUROFER IPP project is aimed at developing a broad range of eco-design information for steel industry products, including LCA. EUROFER have conducted a number of interviews with key actors in the supply chain to ensure that their specific requirements and expectations are identified and addressed. These interviews covered the full life cycle of a range of steel applications in Europe.

The completed eco-design packages focus on product and technical information as well as environmental data, and are based on the findings of the interviews. The manufacturers of steel-containing products are thereby equipped with a practical information package containing the relevant eco-design information which satisfies existing and future requirements. A thorough approach to the environmental considerations of product development is a determining factor in achieving sustainable development through eco-design. The methodology takes account of steels' high recyclability and the beneficial use of by-products from the steel making process.

The EUROFER IPP project has provided the basis for constructive communication with the European Commission in the policy development process and as such, EUROFER sought an open dialogue with the Commission about the requirements of IPP as has been developed with its members’ customers. Progress on the project has been communicated to the Commission and published at relevant stages throughout its course.

6. MOTIVATION

6.1. European Commission IPP Communication and initiatives

6.1.1. Pilot projects

The European Commission is working towards achieving a more harmonised approach to environmental issues in terms of IPP, and as part of their work, has undertaken two pilot projects on a Nokia mobile phone and a teak garden chair provided by Carrefour. Commitments have been made by the companies involved within these projects to make environmental improvements, and this has been seen as an important boost for IPP. These commitments were strongly welcomed by EU Environment Commissioner, Stavros Dimas, who has urged other industries to follow their lead.

The mobile phone producers have committed to:

- go beyond current regulatory standards on hazardous substances in mobile phones by eliminating certain flame retardants and phthalates
- reduce energy consumption in handsets by fitting reminders to unplug chargers once batteries are recharged
- engage with consumers to increase participation in take-back and recycling
- look at existing recycling schemes over two years to identify what works best and why

The teak garden chair producers have committed to:

- improve product design
- make its material use more environmentally friendly
- make it easier to transport
- improve consumer information on environmental factors

The Commission has said that it would assess progress on both these sets of commitments in a year's time.

6.1.2. The EIPRO Study

Furthermore, as part of IPP, the Commission commissioned the EIPRO study to evaluate the environmental impacts of products and to analyse (the six most relevant) existing studies and methodologies. It took a top-down oriented approach based on environmental input/output analysis to identify those product sectors with the most potential for environmental improvement (food and drink, transport and housing). The subsequent work, the IMPRO study, is to identify improvement options to reduce the life cycle environmental impacts. However, from an industry point of view, this study is too ambitious and too complex and it is not realistic to have one methodological approach which is applicable for all products; indeed there are many disadvantages seen in the chosen methodological approach, which is difficult to compare to existing studies. In addition, the available data is not sufficient and there is also a lack of data for the new member states. The steel industry therefore needs to continue to follow the developments of IPP to ensure appropriate methodologies are developed.

6.1.3. European Platform on LCA

The Commission is developing a European Platform on Life Cycle Assessment to support life cycle thinking in the development of goods and services and in a broad range of policies. Part of this initiative includes a European Reference Life Cycle Data System (ELCD) which contains core LCI data obtained from European industry associations and aims also to include energy, transport and waste management. The steel industry is playing an active role in the production of this database and is part of the Business Advisory Group for the ELCD, together with representatives from the aluminium, copper, plastics and corrugated board industries. LCI data is provided for four steel products, including carbon and stainless steel, together with information on the data and how it should be used. It is not intended to provide a comprehensive list of all steel grades and products but to provide data on a number of steel products and the methodology used – through links on the website, more information and further data sets can be obtained by contacting:

- The European Confederation of Iron and Steel Industries, EUROFER for European data.
- The International Iron and Steel Institute, IISI, for Global data.
- The International Stainless Steel Forum, ISSF, for stainless steel data.
- The European Association of Producers of Packaging for Steel, APEAL for packaging data.

6.1.4. Sustainable Consumption and Production

IPP now falls within the scope of the European Commission's 'Sustainable Consumption and Production' (SCP) programme, which addresses social and economic development within the carrying capacity of ecosystems and aims to decouple economic growth from environmental degradation. It is intended to 'achieve more with less', to reinforce existing initiatives and provide better coherence, by taking a scientific approach and focussing on the most damaging areas. Stakeholder involvement and collaboration is a focal part of the work. SCP aims to have a Green Paper consultation in the second half of 2007, with an Action Plan Communication and eco-design legislation in 2008.

6.2. How the Steel Industry Already Contributes to the Concept of IPP

As one of the major material producers, the steel industry is keen to improve the environmental performance of its products and to provide the necessary product information to interested parties. The steel industry has a long history in improving the environmental performance in all phases of the life cycle, and throughout the different sectors such as construction, automotive, packaging, consumer/ white goods, machinery etc. In addition to process related improvements such as reductions in specific energy consumption and emissions (e.g. carbon dioxide and particulates) and the applications of Best Available Technologies (BAT) under Integrated Pollution Prevention and Control (IPPC) requirements, there are a number of initiatives that the steel industry is involved in which are focused on continuous environmental improvement and which are integrated into product development. A number of these initiatives are listed here:

- LCA forms the basis of much of this work and is undertaken by the International Iron and Steel Institute (IISI) and its member companies, and which undergoes continuous improvement. Within the industry, LCA can be used for the environmental evaluation of processes, to compare products carrying out the same function and as a basis for customer information to counteract misconceptions or to provide information for their choice between different products. It is very important to integrate environmental assessments into product design at an early stage in order to improve the environmental and economic performance of the product. This is appreciated by the steel industry which has developed an LCA methodology and uses the results for this purpose.
- IISI also has an on-line initiative, Steel University, which is aimed at providing a comprehensive package of informative, advanced, sophisticated and highly interactive e-

learning resources on steel technologies, covering all aspects of the steelmaking processes through to products, their applications and recycling.

- Investigations have been conducted by the steel industry itself, or with its participation, to determine:
    - which stages of the life cycle are most relevant for a specific product
    - what should the main focus be when considering the environmental improvements of a specific product
    - what benefits are derived from environmental improvement of products
    - whether the functional, safety, aesthetic or other product requirements are still met alongside the environmental improvements.
- In automotive products, light-weighting (using high strength steels), fuel economy and emission improvements are key areas of development. The steel industry has developed new products, for example passenger car bodies using tailor welded blanks in the UltraLight Steel Auto Body Programme (ULSAB) which, as a result of reduced weight and resulting better fuel consumption with lower CO_2 emissions during the utilisation phase, helps to mitigate the environmental impacts in comparison to conventional steel bodies. The attained goal of the ULSAB Programme was to demonstrate steel's capability for reducing substantially the weight of a vehicle's body structure at no additional cost and, at the same time, enhancing safety with improved comfort and driving performance.
- Construction products also focus on light steel framing (which improves construction efficiency and reduces construction waste) as well as the development of steels that are resistant to specific weather conditions. Ultimately, the reduction of energy consumption during steel production, extending lifetimes of steel products and the minimisation of the use of chemicals and production of waste are all key factors for the industry's product development.
- Member companies implement environmental managements systems and apply standards based on the ISO 14000 series such as LCA, Environmental Product Declarations (EPDs) etc. and develop specific product information for their individual customers.
- Recycling of steelmaking by-products, such as the use of blast furnace slag in cement manufacture, is already well established.
- There is a very well established market for the recycling of steel scrap, both within the steel making process and also for recycling the scrap steel at the end of a products life. Well established methods of separation are utilised, e.g. magnetic separators. Design for disassembly further enhances the steel at the end of a product's life.
- Minimisation of the use of chemicals within, for example, steel coatings, or developing steel products which require minimal (re)painting or cladding systems and which thus reduces the overall environmental impacts of these products.
- In March 2004, EUROFER launched its Strategic Research Agenda of the European Steel Technology Platform (Vision 2030) (ESTEP). The Platform offers a global vision on the innovation and Research and Development initiatives which will lead to the achievement of the objectives identified in the framework of a sustainable leadership of the steel sector in the coming decades. Based on a sustainable approach, there are three industrial programmes with large societal impacts which are the focus for ESTEP, namely: Safe, clean, cost-effective and low capital intensive technologies; Rational use of energy resources and residues management; and Appealing steel solutions for end users. Each of these three programmes is assigned prioritised areas for research.

- The European Steel Industry has already signed up to the challenge of lowering CO_2 emissions by creating a consortium of industries and research organisations that has taken up the mission of developing breakthrough processes to reduce these emissions. This is known as the ULCOS Consortium (Ultra Low CO_2 Steelmaking) materials.

The different market sectors supplied by the steel industry have increasing environmental expectations concerning the perceived and actual impact that the materials they use have and how they are produced. Therefore, the activities of the steel industry are increasingly being carried out in close cooperation with the customers in order to identify their expectations, to respond efficiently and to generate a beneficial situation for both the steel manufacturers and their customer industries.

The steel industry is committed to the concept of sustainable development, and LCA fits into this context - LCA is one of the tools increasingly being used to consider the environmental issues associated with the production, use, disposal, and recycling of products, including the materials from which they are made. The steel industry is well advanced in the world of LCA and has been providing LCIs for steel products, from cradle to steel factory gate since 1995. This methodology and data collection has been undertaken by the International Iron and Steel Institute, and is based on the ISO 14040 series. This information is readily available on request from the steel industry, or via the ELCD website (see Section 6.1.3), with which the steel industry has played an active role in its development.

The steel industry is currently updating its LCI data – throughout Europe for stainless steel and globally for carbon steel. Once collected and verified, this data will then become available on the Commission’s ELCD website. While neither the use of this data nor the methodologies within which this data is used can be controlled by industry, it is therefore very important to ensure that the correct data is used to ensure the greatest representivity of the data.

6.3. EUROFER’s approach to IPP

EUROFER is taking a pro-active approach to the work of the Commission and is working in parallel with them in order to develop knowledge and procedures on IPP within the European steel industry. The initiatives of the Commission that are of specific interest to the steel industry include:

- The IPP pilot projects
- The EU directory of LCI/LCA databases
- Cross-sector consensus on LCI/LCA methodology
- Sustainable use of natural resources

Initially, it was thought that the steel industry, through EUROFER, could provide a pilot project for the Commission’s IPP study, but it was subsequently felt that the industry should carry out its own study in parallel to that of the Commission, concentrating specifically on the steel aspects of a number of case study products. It is necessary to be proactive in the development of IPP to avoid the ranking of products and materials based on only environmental criteria, and to avoid the risk of restricted access to the market, and so a separate project on IPP would help the industry tackle this issue.

As stated, the primary aim of IPP is to reduce the environmental impact of products, and LCA has been identified as one of the key tools in achieving this objective. While the steel industry believes that LCA can be a useful business to business tool and is in support of the Commission’s work in achieving a common approach to LCA through the use of the ELCD, the current LCA methodologies and databases are still under development and therefore unsuitable for inter-material comparisons. LCA must be kept in perspective, as there are many tools that can be used for the environmental appraisal of materials.

7. EUROFER'S IPP PROJECT

7.1. Background

There are numerous legislative requirements that need to be taken into consideration and these will become stricter and more numerous – for example the European Chemicals Regulation, REACH, the End of Life of Vehicles Directive (ELV), and the RoHS Directive (restriction of the use of certain hazardous substances in electrical and electronic equipment) etc., where among other requirements, recycling targets or the banning of the use of certain substances in products are required. The provision of such information is often mandatory, and will be provided to the customer. However, there is also much more information that is desired by the customers from the steel industry and the optimum way of providing the most useful data is to work together with the customer to determine their product related environmental requirements. Based on customer requirements, recommendations can be developed for how the steel industry can anticipate customer expectations and pro-actively fulfil them.

- EUROFER therefore commissioned a shadow IPP project to run in parallel with the Commission's pilot projects, in order to:
- provide the basis for constructive communication with the European Commission in the policy development process and as such develop an open dialogue with the Commission about the requirements of IPP
- support the work of the Commission
- be proactive in the development of IPP
- develop a steel industry approach to IPP
- enable the industry to provide better data and information for its customers
- avoid the development of new legislation

This project aimed to develop a broad range of eco-design information for steel industry products, including LCA. It also aimed to develop the use of LCI data that is currently available by putting it into a framework rather than using it as a sole indicator of environmental performance. The development of the steel LCI data aims to achieve a cross-sector consensus on LCI/LCA methodology throughout Europe.

7.2. Project consortium

The project was funded by and carried out under the leadership of EUROFER, working closely together with an expert steering group with representatives from the member companies Arcelor Mittal, Corus, Outokumpu, Thyssen Krupp Stahl and Ruukki. The project went out to tender in June 2005, to engage consultants to work together on the project. The tender was won successfully by PE International and LBP, University of Stuttgart.

During the course of the two year project, EUROFER, the member companies and the consultants worked closely together to ensure a harmonised approach to the project, aiming to meet the requirements of each of EUROFER members and their customers, as well as complying with any existing or future legislative approaches. As a European funded project, it was necessary to ensure that national as well as European factors were considered where at all possible, as well as all types of steel from the blast furnace and electric arc furnace route, as well as carbon and stainless steel products.

7.3. The Project Parts

The project is split into three separate yet inter-connected sections and are explained in further detail in the following sections:

Project Part A – the development of product specific eco-design packages

Project Part B – the development of the use of LCA data to incorporate the valuable materials within the methodology, namely co-products and steel scrap

Project Part C – the development of a material flow analysis of steel throughout Europe

7.4. Communication

One of the aims of the project was to communicate the outcomes of the work of the European steel industry in the context of IPP, both to the Commission as well as to other industries, consultants, academia and interested parties. This has been addressed within the project, in the form of a press release, direct communication to the European Commission, communication within member companies and other steel organisations, e.g. IISI, articles in newsletters or magazines e.g. PERSPECTIVE (PE International) and Corus Automotive Emotion Magazine, and at the following conferences:

- LCE 2006, University of Leuven, May/June 2006
- SAM1, Seville, February 2007
- SETAC Europe 17th Annual Meeting, Porto, May 2007

8. PROJECT PART A: ECO-DESIGN PACKAGES

8.1. Introduction

The aim of this part of the project was to produce product specific eco-design packages that incorporated many aspects, including product information, technical, environmental, LCA, social and economic information. The actual content of these packages was determined in conjunction with the steel industry and the customers that were interviewed for the project. They are not meant to replace existing documentation, nor to be an Environmental Product Declaration, but more to consolidate existing information in an easily accessible and useful format for all interested parties throughout the life cycle of the product. The expectation was not to develop stand-alone eco-design information that has a single purpose, but to develop a package of information that can be used throughout the supply chain – from the steel producers to the product manufacturers, users and finally those who will dispose of or recycle the product. The manufacturers of steel-containing products will then be equipped with a practical information package containing the relevant eco-design information which will satisfy existing and future legislative or voluntary requirements. A thorough approach to the environmental considerations of product development is a determining factor in achieving sustainable development through eco-design.

8.2. Determination of case study products

The project was funded by EUROFER. It was therefore necessary to determine case study products representative of both stainless and carbon steel as well as the different steel product groups such as sections, long products, flat products etc, so as to include a variety of different steel products, and to cover different market sectors.

The case study products ultimately chosen are detailed below, including their relevant steel parts:

- Automotive – a tailor welded blank (TWB), comprising electro-galvanised carbon steel
- Construction – carbon steel: a composite flooring system, comprising steel sections (beams), hot dip galvanised steel (decking), rebar and electro-galvanised steel (studs)
- Construction – stainless steel: a roofing system, comprising 304 2B hot rolled coil
- White goods – a dishwasher casing, incorporating both carbon and stainless steel, comprising organic coated carbon steel and 304 2B hot rolled stainless steel coil.

Based on customer interviews (see Section 8.4) and the member companies' expertise, the functional unit for each of the case study products was determined. During the interview process, the interviewees were asked to specify their preferred requirements for the functional unit for the case study products. It was found that within the construction sector, requirements varied across Europe, depending on a typical construction layout and the dimensions of a standard building. Subsequently, each of the case study products was assigned what was felt to be representative of a generic product and are outlined below:

8.2.1. Tailor welded blank

- ♦ A generic steel part, weight 12.3 kg, containing four high strength sheet parts of different thicknesses, ranging between 0.67 and 1.47 mm. A TWB is a combination of steel sheets of different thicknesses and grades which are laser welded together. High strength steels are often used for such applications. Such a design results in optimal material arrangement, provide weight reduction for vehicles, part-count reduction, an improved stiffness/weight ratio, enhanced crash energy management and improvements in process efficiency, machine flexibility and reduction of manufacturing costs.

8.2.2. Composite flooring system

- The functional unit, representative of a system within Europe, has an area of 7.5 by 7.5 m and consists of the following (excluding the columns):
- 1229 kg steel beams (with an intumescent coating on three sides)
- 708 kg profiled sheet decking (galvanised 20 µm)
- 228 kg steel reinforcement bars and mesh
- 24 kg steel shear studs
- 9720 kg light weight concrete
- 97 kg coating

8.2.3. Stainless Roofing System

- A 1 m^2 stainless steel cover, 304 2B, 0.4 mm thick, weighing 3.45 kg. 0.1 kg of stainless steel clips and nails are also required for fittings. Normally the stainless steel roof is laid on a supporting structure, which is commonly constructed from wood, concrete or carbon steel. An insulation layer between the support and the stainless roof is also provided for purposes such as energy preservation or noise insulation. For the purpose of this study, both the supporting structure and the insulation have not been included in the calculations as roofing systems vary greatly in nature and design.

8.2.4. Dishwasher Casing

- Within this product, both carbon and stainless steel is required. For the outer casing, organic coated carbon steel, 1 m^2, 0.7 mm thick and weighing 5.5 kg was used. For the inside lining, stainless steel 304 2B was used, 1 m^2, 0.7 mm thick and weighing 5.6 kg. The size of the steel sheet of 1 m^2 is an estimation, since the dishwasher itself is not the main focus of the package, but more to represent a product within the white goods sector. The carbon steel is ideal as an outer casing due to its durability, appearance and high quality surface finishing properties. Stainless steel is ideal for the interior due to its corrosion resistant properties, its attractive appearance and the fact that this material requires very little maintenance.

8.3. Interviewees

In order to develop product specific eco-design packages that could be utilised throughout the supply chain, it was necessary to include key customers of the European steel industry as well as the steel manufacturers themselves. This ensures that the information that is provided is useful and required by the different stakeholders, rather than what the steel industry thinks is required.

In identifying these key customers in each of the different sectors, it was necessary to try to ensure that a geographical cross section of companies was chosen so as to accommodate the variations in eco-design requirements throughout the different countries of Europe. To determine the companies and organisations that could be interviewed, the member companies provided contact details of a number of their customers, with contacts often being made through the marketing or sales departments. Some other interviewees were identified through PE INTERNATIONAL. The aim was to interview approximately five companies per case study product; some of the construction sectors were interviewed for both the roofing and the flooring systems.

8.4. Interviews

Having been provided with the necessary information relating to the project, and following their agreement, the interviewees were sent the questionnaire in advance of the interview so that they could prepare themselves fully for the interview. The questionnaires were developed by the project steering group and the consultants, and included the following aspects:

- Environmental management within the company
- Their current/future situation relating to eco-design within their organisation
- Eco-design tools which the organisations have / currently / will / won’t utilise
- Their expectations and opinions about utilising steel and information requirements
- Their customer requirements in terms of eco-design

The full questionnaire is included in Appendix 17.1.

Face-to-face interviews were preferable in order to maximise the information obtained from the interviewees. In the few cases where this was not possible, telephone interviews were carried out. Each interview lasted between 2 and 3 hours and, in addition to representatives from the company, was attended by the EUROFER IPP Project Manager, a representative from the consultants and sometimes a member of the project steering group if desired. The interviews were treated confidentially, with all outcomes being kept anonymous prior to discussion and circulation of results and outcomes.

8.5. Interview outcome

The customers that were interviewed were all very appreciative of the efforts to promote an open dialogue between them and the steel industry. Nevertheless, some were concerned that this approach could lead to additional burdens being placed upon them. The interviews highlighted the differences in the governing legislative approaches between each market sector, particularly with respect to the construction industry, the range of activities between companies interviewed, and the differing requirements throughout Europe.

It appears that the level of eco-design activity varies between the sectors interviewed. Within the automotive industry, eco-design is fully integrated into the work ethics and procedures, not simply for compliance purposes, but also to identify environmental and economic risk and thus encourage improvements. The white goods industry focuses on legislative compliance, with increasing focus now on the end-of-life phase. Within the construction sector, it is mainly the larger companies that are active in the field of eco-design, with other companies focusing on complying with the minimum requirements. This varying level of involvement with eco-design results in the sectors’ differing requirements for information from the steel industry, from technical LCI data to more promotional literature focusing on the advantages of using steel.

It is all very well to impose rules and regulations on material producers and product manufacturers, but do they always work? From the interviews conducted, it is clear to see that in some cases more effort needs to be applied at the implementation stage of the legislation to ensure that the maximum benefit can be achieved, by all relevant parties (directives are implemented in different ways in each member state and so will determine how effective they will be). For example, the WEEE Directive now requires that the electronic and electrical equipment producers are responsible for a products' End of Life (EoL). One stage at which to address the recyclability of a product is in the design phase. Support from the steel industry in relation to the end-of-life phase would be appreciated by the interviewees, particularly now as the WEEE Directive imposes stricter requirements on the industry.

In the automotive industry the end of life of the products is governed by the End of Life Vehicles Directive where specific targets are set for the recycling of end of life vehicles. The high recyclability of steel will help achieve these targets; further developments in the disassembly of electronics within a car will help separate materials prior to shredding and thus increase opportunities for recycling.

More collaboration between material producers and their customers at an early stage in the product design phase is desired – this could be in terms of offering lightweight solutions, providing technical support for alternative designs of products in construction etc. In addition, customers would appreciate more marketing information about steel so that they themselves can promote its use.

Also highlighted were the differences in opinion relating to environmental criteria relating to sustainability issues,, both between the different sectors that were interviewed, but also with the steel industry. For example, using recycled content as a criterion of environmental performance, as well as the actual definition of recycling.

A detailed analysis of the results from the interviews is included in Appendix 17.2.

8.6. LCA Case Studies

One aspect of this part of the project was to develop product LCAs, and as determined during the course of the interviews, it was requested that this information be included in the eco-design packages. It was felt by the interviewees that information relating to the use phase of the products should not be incorporated as they themselves have more information available about their products. Therefore, the system boundaries for each of the case study product LCAs included steel production and processing, product manufacture and transportation and end of life (scrap processing and recycling). Where appropriate, calculations were undertaken to determine the benefits during the use phase by using the steel products in question.

The functional unit for each of the products is detailed in section 8.2 and further information on the case studies is detailed in Appendix 17.3.

8.7. Eco-Design Packages

The four Eco-design packages can be downloaded or ordered from the EUROFER website, www.EUROFER.be for the following case study products:

- Tailor Welded Blank
- Composite Flooring System
- Stainless Steel Roofing System
- Dishwasher Casing

9. CONTENT OR STRUCTURE OF THE ECO-DESIGN PACKAGES

The main goal of the Eco-Design packages is to increase the communication with the customers of EUROFER. As described earlier in this report, an interview survey was performed to better understand the requirements of EUROFER's customers with regard to Eco-Design. The outcome from these interviews indicated that there is:

- a need to provide an overview of existing information and data needed for the process of Eco-Design, and
- the challenge and opportunity to increase the exchange with the existing clients who appreciated the effort from EUROFER to proceed with an active discussion.

Based on this feedback, the expert group of the project decided that the Eco-Design packages should address the following aspects:

- The importance of life cycle considerations during product development
- The closed loop, material to material recycling of steel
- The availability of steel life cycle inventory data and information on the steel industry's sustainability development

In the following section, the principle structure and content of the Eco-Design package is described.

The layout of the Eco-Design package was defined as a 4-page brochure. The following content for each page was decided upon:

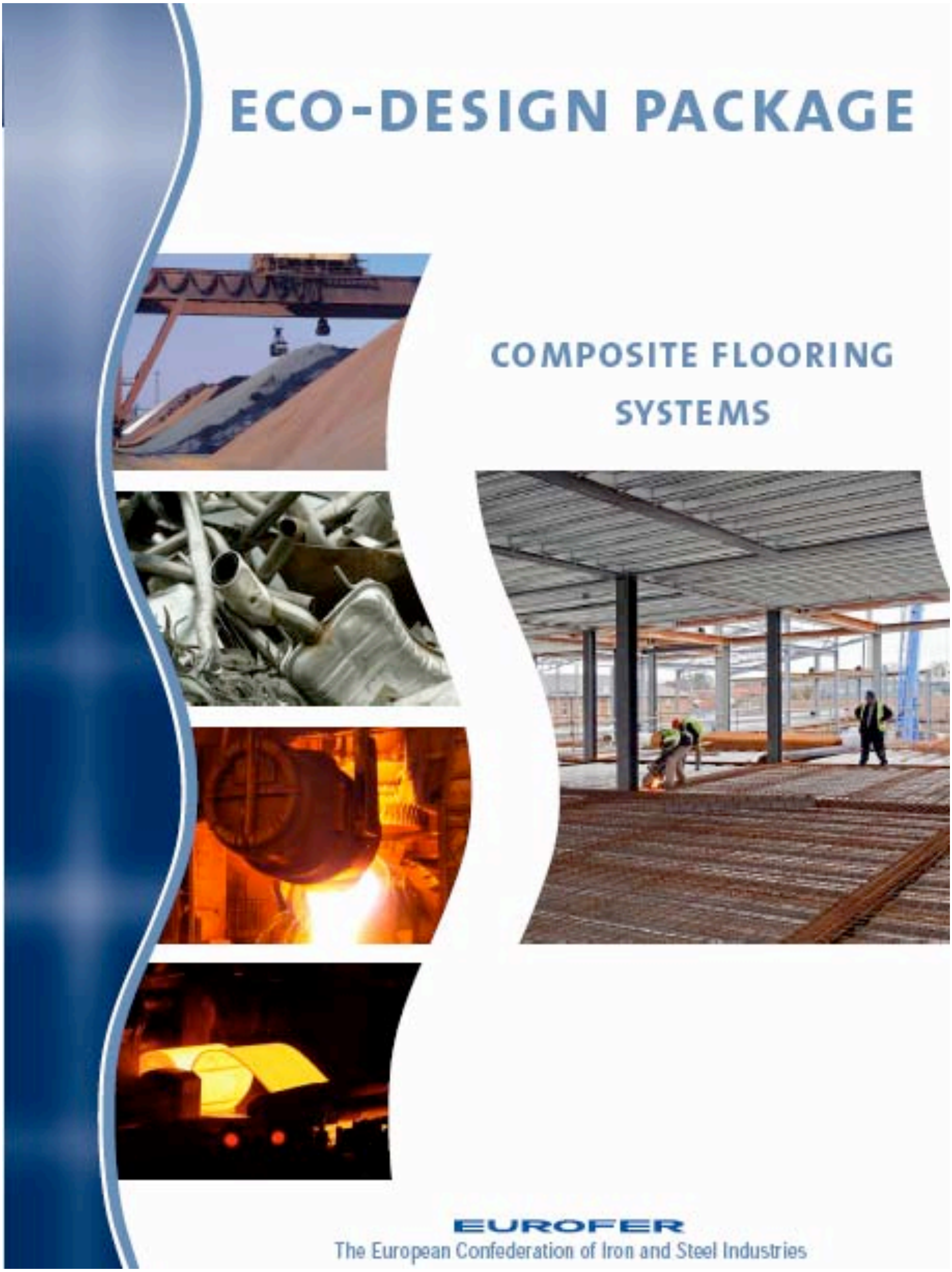
First page: The cover page of the Eco-Design package indicates the case study product and therefore which industrial sector is being addressed.

Second page: This page provides an introduction to EUROFER and explains the idea of Eco-Design. A technical description of the case study product is given, outlining its major characteristics.

Third page: This page focuses on the life cycle aspects of the case study product. This includes the principle approach of Life Cycle considerations and Life Cycle Assessment. In addition, selected LCI and LCIA parameters are presented and discussed. These give an example of how typical information generated within the procedure of Eco-Design can be presented.

Fourth page: The final page describes aspects on material flow within the steel industry and provides specific information on steel products with regard to their technical performance and typical dimensions. In addition, information on who to contact to get more details and LCI relevant data and also important sources of data are listed.

On the following pages one of the Eco-Design packages is shown in detail. This and the other Eco-design packages can be downloaded or ordered from www.eurofer.be.



ECO-DESIGN PACKAGE

COMPOSITE FLOORING SYSTEMS

EUROFER
The European Confederation of Iron and Steel Industries

PRODUCT INFORMATION

General information on material flows in steel making

Material flow analyses for steel products demonstrate that material-to-material recycling of post and pre-consumer scrap is already common practice. The fact that steel is 100% recyclable back into new steel products without loss of quality ensures that the material loop is closed.

Figure 4: Flow of material through society /6/

Modern steel making is dominated by two principle process routes:

- **Iron ore-based production** where hot metal (pig iron) is produced by the reduction of iron oxide in the blast furnace, followed by refining in the basic oxygen furnace to produce steel. In the refining process, excess heat is produced, allowing steel scrap to be added to the melt.
- **Scrap-based production** where steel is produced by melting steel scrap in the electric arc furnace, sometimes followed by refining. Highly alloyed steel grades, like stainless steel and tool steels, are generally made from scrap. Alloying elements utilised, such as chromium and nickel, depend on the type of scrap used as well as from extra additions to the melt.

Energy efficiency has always been a priority within the steel industry and thus both process routes operate in a very energy efficient way. Continuous improvements to further develop this are ongoing /7/.

The recycling of scrap closes the loop of the material (steel) flow in the steel production process. Input of steel scrap to the production process can be up to 100 %, depending on the steel production process route. Europe recycles 101 million tonnes of steel scrap per year, which represents 54% of total steel production /8/. This saves 190 million tonnes of CO_2 emissions which is equivalent to saving CO_2 emissions generated by 34 million households /9/.

Steel product information

Hot dip galvanised coil (HDG) is made by passing cold rolled coil, in a continuous process, through a molten zinc bath to achieve a protective coating with a typical thickness of 0.02mm on both sides. The zinc layer provides corrosion protection to the steel substrate. HDG coil is used to make the profiled steel decking sheets as well as many other construction products. Typical thickness ranges for steel decking are between 0.8 and 1.2mm.

Steel sections include hot rolled I-beams, H-beams, wide-flange beams, and sheet piling. These products can be found on the market for direct use and can be used in construction, multi-story buildings, bridge trusses, vertical highway supports, and in riverbank reinforcements etc.

Rebar (Reinforcing Bar) is hot rolled steel. It can be found on the market for direct use or is further processed into finished products by the product manufacturers.

Rebar and reinforcing mesh is used to strengthen concrete in highway and building construction and is also used in floors to prevent the concrete from cracking and increase fire performance.

Further information

Steel products used within the construction industry support existing legislation. It is also necessary that relevant country-specific guidelines are followed. Further information may be gained from other environmental publications such as Environmental Product Declarations or environmental assessment schemes. The use of steel in such construction products will assist in achieving the requirements specified by these various guidelines.

Eurofer has LCI data available for HDG coil, steel sections, rebar steel and other steel products, together with the methodology report and advice on use of the data and product applications. Contact lca@eurofer.be or visit www.eurofer.org.

Further information relating to steel in the construction industry can be obtained from the following locations:

- The European Convention for Constructional Steelwork - www.steelconstruct.com
- Living Steel - online resource for information on residential steel matters - www.livingsteel.org
- Steel University - www.steeluniversity.org
- International Iron and Steel Institute, IISI - www.worldsteel.org.
- EUROFER - www.eurofer.org

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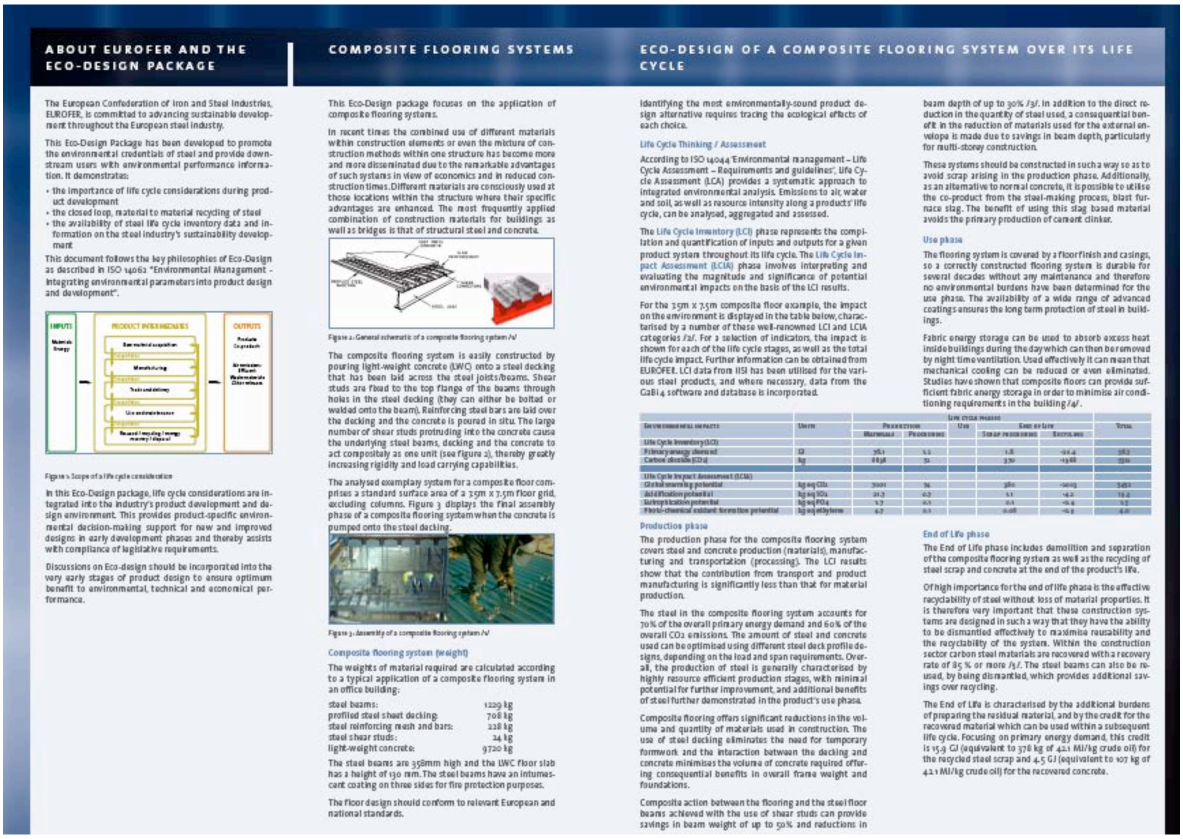
ECO-DESIGN PACKAGE

COMPOSITE FLOORING SYSTEMS

EUROFER
The European Confederation of Iron and Steel Industries

Figure 4: First and fourth page of the Eco-Design package for a composite flooring system



ABOUT EUROFER AND THE ECO-DESIGN PACKAGE

The European Confederation of Iron and Steel Industries, EUROFER, is committed to advancing sustainable development throughout the European steel industry.

This Eco-Design Package has been developed to promote the environmental credentials of steel and provide downstream users with environmental performance information. It demonstrates:

- the importance of life cycle considerations during product development
- the closed loop, material to material recycling of steel
- the availability of steel life cycle inventory data and information on the steel industry's sustainability development

This document follows the key philosophies of Eco-Design as described in ISO 14062 "Environmental Management - Integrating environmental parameters into product design and development".

Figure 1: Scope of a life cycle consideration

In this Eco-Design package, life cycle considerations are integrated into the industry's product development and design environment. This provides product-specific environmental decision-making support for new and improved designs in early development phases and thereby assists with compliance of legislative requirements.

Discussions on Eco-design should be incorporated into the very early stages of product design to ensure optimum benefit to environmental, technical and economical performance.

COMPOSITE FLOORING SYSTEMS

This Eco-Design package focuses on the application of composite flooring systems.

In recent times the combined use of different materials within construction elements or even the mixture of construction methods within one structure has become more and more disseminated due to the remarkable advantages of such systems in view of economics and in reduced construction times. Different materials are consciously used at those locations within the structure where their specific advantages are enhanced. The most frequently applied combination of construction materials for buildings as well as bridges is that of structural steel and concrete.

Figure 2: General schematic of a composite flooring system /1/

The composite flooring system is easily constructed by pouring light-weight concrete (LWC) onto a steel decking that has been laid across the steel joists/beams. Shear studs are fixed to the top flange of the beams through holes in the steel decking (they can either be bolted or welded onto the beam). Reinforcing steel bars are laid over the decking and the concrete is poured in situ. The large number of shear studs protruding into the concrete cause the underlying steel beams, decking and the concrete to act compositely as one unit (see figure 2), thereby greatly increasing rigidity and load carrying capabilities.

The analysed exemplary system for a composite floor comprises a standard surface area of a 15m x 7.5m floor grid, excluding columns. Figure 3 displays the final assembly phase of a composite flooring system when the concrete is pumped onto the steel decking.

Figure 3: Assembly of a composite flooring system /1/

Composite flooring system (weight)

The weights of material required are calculated according to a typical application of a composite flooring system in an office building:

steel beams:	1229 kg
profiled steel sheet decking:	708 kg
steel reinforcing mesh and bars:	228 kg
steel shear studs:	24 kg
light-weight concrete:	9720 kg

The steel beams are 358mm high and the LWC floor slab has a height of 130 mm. The steel beams have an intumescent coating on three sides for fire protection purposes.

The floor design should conform to relevant European and national standards.

ECO-DESIGN OF A COMPOSITE FLOORING SYSTEM OVER ITS LIFE CYCLE

Identifying the most environmentally-sound product design alternative requires tracing the ecological effects of each choice.

Life Cycle Thinking / Assessment

According to ISO 14044 'Environmental management – Life Cycle Assessment – Requirements and guidelines', Life Cycle Assessment (LCA) provides a systematic approach to integrated environmental analysis. Emissions to air, water and soil, as well as resource intensity along a products' life cycle, can be analysed, aggregated and assessed.

The **Life Cycle Inventory (LCI)** phase represents the compilation and quantification of inputs and outputs for a given product system throughout its life cycle. The **Life Cycle Impact Assessment (LCIA)** phase involves interpreting and evaluating the magnitude and significance of potential environmental impacts on the basis of the LCI results.

For the 15m x 7.5m composite floor example, the impact on the environment is displayed in the table below, characterised by a number of these well-renowned LCI and LCIA categories /2/. For a selection of indicators, the impact is shown for each of the life cycle stages, as well as the total life cycle impact. Further information can be obtained from EUROFER. LCI data from IISI has been utilised for the various steel products, and where necessary, data from the GaBi 4 software and database is incorporated.

Environmental impacts	Units	Life cycle phases					Total
		Production		Use	End of Life		
		Materials	Processing		Scrap processing	Recycling	
Life Cycle Inventory (LCI)							
Primary energy demand	GJ	76.1	5.5		1.8	-24.4	[illegible]
Carbon dioxide (CO_2)	kg	[illegible]	31		370	[illegible]	[illegible]
Life Cycle Impact Assessment (LCIA)							
Global warming potential	kg eq CO_2	7001	[illegible]		380	[illegible]	[illegible]
Acidification potential	kg eq SO_2	21.3	0.7		1.1	-4.2	19.2
Eutrophication potential	kg eq PO_4	1.7	0.1		0.1	-0.4	1.5
Photo-chemical oxidant formation potential	kg eq ethylene	4.7	0.1		0.08	[illegible]	[illegible]

Production phase

The production phase for the composite flooring system covers steel and concrete production (materials), manufacturing and transportation (processing). The LCI results show that the contribution from transport and product manufacturing is significantly less than that for material production.

The steel in the composite flooring system accounts for 70% of the overall primary energy demand and 60% of the overall CO_2 emissions. The amount of steel and concrete used can be optimised using different steel deck profile designs, depending on the load and span requirements. Overall, the production of steel is generally characterised by highly resource efficient production stages, with minimal potential for further improvement, and additional benefits of steel further demonstrated in the product's use phase.

Composite flooring offers significant reductions in the volume and quantity of materials used in construction. The use of steel decking eliminates the need for temporary formwork and the interaction between the decking and concrete minimises the volume of concrete required offering consequential benefits in overall frame weight and foundations.

Composite action between the flooring and the steel floor beams achieved with the use of shear studs can provide savings in beam weight of up to 50% and reductions in beam depth of up to 30% /3/. In addition to the direct reduction in the quantity of steel used, a consequential benefit in the reduction of materials used for the external envelope is made due to savings in beam depth, particularly for multi-storey construction.

These systems should be constructed in such a way so as to avoid scrap arising in the production phase. Additionally, as an alternative to normal concrete, it is possible to utilise the co-product from the steel-making process, blast furnace slag. The benefit of using this slag based material avoids the primary production of cement clinker.

Use phase

The flooring system is covered by a floor finish and casings, so a correctly constructed flooring system is durable for several decades without any maintenance and therefore no environmental burdens have been determined for the use phase. The availability of a wide range of advanced coatings ensures the long term protection of steel in buildings.

Fabric energy storage can be used to absorb excess heat inside buildings during the day which can then be removed by night time ventilation. Used effectively it can mean that mechanical cooling can be reduced or even eliminated. Studies have shown that composite floors can provide sufficient fabric energy storage in order to minimise air conditioning requirements in the building /4/.

End of Life phase

The End of Life phase includes demolition and separation of the composite flooring system as well as the recycling of steel scrap and concrete at the end of the product's life.

Of high importance for the end of life phase is the effective recyclability of steel without loss of material properties. It is therefore very important that these construction systems are designed in such a way that they have the ability to be dismantled effectively to maximise reusability and the recyclability of the system. Within the construction sector carbon steel materials are recovered with a recovery rate of 85 % or more /5/. The steel beams can also be reused, by being dismantled, which provides additional savings over recycling.

The End of Life is characterised by the additional burdens of preparing the residual material, and by the credit for the recovered material which can be used within a subsequent life cycle. Focusing on primary energy demand, this credit is 15.9 GJ (equivalent to 378 kg of 42.1 MJ/kg crude oil) for the recycled steel scrap and 4.5 GJ (equivalent to 107 kg of 42.1 MJ/kg crude oil) for the recovered concrete.

Figure 5: Second and third page of the Eco-Design package for a composite flooring system

9.1. Technical

The Eco-Design packages include a description of the technical parameters of the selected case study products to ensure a common understanding of the analysed products. This contains information on the functional unit as well as a listing of the technical specifications.

In addition to this, information on the provided LCI profiles on steel products are described by the type of manufacturing process applied, typical standard dimensions produced as well as giving an overview on the most common application.

Furthermore, the material flows within the steel industry are characterised and industry specific recycling rates are provided. In addition the compliance of the steel products with existing regulations is provided, addressing end of life issues such as recovery and recyclability rates in the automotive sector and hazardous substance in the electronic sector.

9.2. Environmental

The Eco Design package provides information on the environmental performance of steel products as well as on more downstream applications where steel products are a major component. For this, the project's expert group has decided that the whole life cycle of the selected products should be analysed following the methodological approach of Life Cycle Assessment (LCA) as defined in the ISO 14040 series.

To describe and demonstrate results of such a system analysis, the following environmental parameters will be included in the Eco-Design packages:

- Primary energy demand in MJ
- Carbon dioxide emissions to air in kg
- Global warming potential (GWP) in kg CO_2 equivalents
- Acidification potential (AP) in kg SO_2 equivalents
- Eutrophication Potential in kg phosphate-equivalents (PO_4-eq.)
- Photochemical Ozone Creation Potential (POCP) potential in kg ethylene-equivalents (C_2H_4-eq.)
- Ozone depletion potential (ODP) in kg CFC 11 equivalents

Alongside the results of the LCA case studies information, steel inventories provided by the steel industry (IISI, EUROFER and ISSF) are included.

9.3. Economic

One major aspect identified at the beginning of the project was a focus on Life Cycle Costing (LCC). For this, a survey of existing LCC methods was performed. The detailed results of this part of the project can be found in Section 14. One of the findings was that a large variety of LCC methods exists and therefore no clearly defined approach which is applied commonly within industry can be seen at this time.

During the interviews the importance of LCC was also discussed with EURFOER'S customers. The general feedback on this point was that LCC is not addressed at this time, or is at an early development stage, and that there is no clearly defined request for information. Nevertheless it was the common understanding of all industrial sectors interviewed that LCC will play a more important role in the future.

Therefore, the project expert group decided not to include any information on LCC in the Eco-Design packages at this stage. Furthermore, it was decided that EUROFER should focus on Life Cycle Costing internally to gain more understanding of what this approach will mean for the steel industry and their products.

9.4. Social

The project's expert group also discussed the social aspects to be included within the Eco-Design packages. During this discussion, it was identified that the structured analysis of social aspects over a products life cycle faces some challenges:

- Definition and selection of parameters characterising the "social performance" and social aspects of products is not yet decided upon
- The methodological implementation of social aspects or parameters into standardised methods such as Life Cycle Assessment (LCA) is currently at a starting point
- Sources providing consistent information and / or data on social aspects and parameters are not available

The interviews identified that all industries agree that social aspects or sustainability in general will play a more important role within the next couple of years. Currently they do not provide their customers with any information related to social aspects.

Based on these findings and on the feedback gained from the interviews, the expert group has decided that at this time there will be no information provided within the Eco-Design packages describing the social performance of steel products. In addition to this, EUROFER should continue the identification/analysis of social parameters which might be of importance for the evaluation of steel products.

10. PROJECT PART B: LCA

One intention of the project is to develop the use of LCI data. It is also a requirement of steel industry customers to have such data for the materials that they use. In line with the Commission's thinking, LCA plays a key role in this project, but it is not the sole focus for data provision. LCA alone cannot determine the main environmental improvements achievable in the product life cycle but should be put into a framework where it can be used with meaning.

Currently, there is cradle to gate LCI data available for steel industry products. The methodology used takes into consideration the credits and burdens that should be applied due to the high levels of recycling of steel scrap at the end of a products' life. Within the work at EUROFER, it is intended to build on the IISI methodology in the following way.

There are a number of valuable materials that arise throughout the life cycle of steel products. At a site level, co-products are produced, and at the wider product level, scrap is recovered at the end of life of products and along the production route, and is made available for recycling back into the steel making process.

It is necessary to incorporate the LCI associated with these valuable materials into the steel product LCI, and therefore two different methodologies have been developed to do this.

- The co-product methodology looks at those materials produced in the steel making process, other than steel, but that have a value, for example slag produced in the blast furnace and basic oxygen furnace, and aims to assign them an LCI.
- The recycling methodology assigns a burden to the scrap that is entering the process, and gives a credit to the scrap that is produced at the product's end of life and is available for recycling.

Having developed these methodologies and incorporated them both within the GaBi 4 modelling software, LCIs for each of the case study products were developed, from cradle to grave, including recycling, but excluding the use phase as generally preferred by the steel industry customers. As detailed in section 8.2, the functional unit is representative of the customer's requirements, and a generic LCI for the European market was produced:

- Office building floor - the area between 4 columns; 7.5 m by 7.5 m, including all parts of the floor but not the columns.
- Stainless steel roof - 1m^2; uncoated 304 2B; two joints; including the steel manufacture, slitting process and on-site work only.
- Tailor welded blanks – data on a flat blank is provided, including scrap produced in the process but not during forming as this is carried out by the car manufacturers.
- Casing of a dishwasher, including both the outer carbon steel layer and the stainless steel inner lining.

The results of each of these LCAs are presented as a part of the eco-design information for the specific product. The way in which this is presented has been determined in conjunction with the steel manufacturing companies, by the requirements of the customers and the needs or requirements of their customers.

The two new aspects of the steel LCI methodology, namely the co-product and the recycling methodologies, are detailed in the following sections.

11. CO-PRODUCT METHODOLOGY

In the process of steel making a number of co-products (e.g. slag, tar and benzene) are also produced that are then sold on to other industries. These co-products are beneficial to society and often have significant environmental benefits as the use of them results in less virgin materials being used. For example, slag from the blast furnace is used by the cement industry – it can substitute the use of clinker used in the process and thereby reduces the cement industry's need to produce clinker from limestone and subsequently also reduces their CO_2 emissions. Ground and granulated blast furnace slag is also used as a direct replacement of Portland cement in concrete. An LCI is therefore required for this slag and other such co-products. The methodology to determine this LCI has been developed and incorporated into the steelmaking LCI model.

11.1. Motivation

Within the steel making process there are a number of other materials of value that are produced in addition to the steel. Within ISO 14040, these materials are known as co-products, which are defined as "any of two or more products coming from the same unit process or product system". In other legislative and subject fields, such as the Waste Framework Directive, co-products are alternatively referred to as by-products.

There are a number of co-products produced from integrated and electric arc steelmaking processes that are valuable and have a positive use and are not discarded as wastes. This paper states the rules by which environmental burdens and credits of steel making are allocated between products and co-products, in order to be able to calculate the environmental impacts of using co-products in other industries.

The IISI LCA methodology currently uses system expansion to account for the fact that co-products are produced as well as the steel in the process. The steel making 'system' is expanded to incorporate those processes which use the co-products from the steel making process and which therefore avoid the alternative production using primary materials. This 'maximum'/whole credit that is associated with the avoidance of primary production of materials is then incorporated within the steel LCI.

However, in using this system expansion methodology, no burden is specifically allocated to those industries using the steel industry co-products, who therefore effectively take them as being environmentally burden-free. To accurately assess the environmental impact of the use of these materials, and their use in the production of other products, a suitable burden should be allocated to them, in line with the credit that would subsequently be allocated to the steel product.

An example of a valuable co-product that is produced in the steel making process is blast furnace slag, which can be used as a replacement for virgin cement clinker in cement manufacture, or virgin cement directly in concrete manufacture, as well as other uses such as for roadstone, embankment or as a fertiliser. The avoided environmental burden will vary for each application of the slag, depending on the primary production options.

1 tonne of blast furnace slag replaces 0.9 tonnes (AFNOR P 18-305) of primary clinker production, resulting in a subsequent CO_2 saving per tonne of clinker. This 'avoidance' credit is currently allocated to the steel making process through system expansion. This new co-product methodology aims to develop an acceptable LCI to be applied to, for example, both the cement and steel making industries.

There is great value in using steel industry co-products as a replacement to raw materials, and, using the cement industry as an example, selected benefits include:

- In terms of strength, the utilisation of blast furnace slag is as good as or even better than using the traditional primary materials
- No requirements for calcination
- Lower capital costs
- Lower environmental burden
- Lower energy requirements and CO_2 production

Furthermore, within the European Commission's European Life Cycle Reference Data (ELCD) System http://lca.jrc.eu.europa.eu/, there is a requirement to have LCI data available for all materials. Steel LCI data is already provided on the database, but other co-products produced are not yet available.

Co-product specific LCIs are therefore required and this methodology sets out the way in which the European steel industry determines such an LCI for both the steel that is produced as well as the other co-products. A number of different rules have been incorporated within the final methodology. The rules were analysed with respect to their justification and impact on the burdens associated with the co-products to ensure that a realistic and justifiable methodology was developed. The impact of the changes in the results, in comparison to the previous methodology, was determined for verification and plausibility purposes and as a cross-check of the applied rules.

The incorporation of this methodology within the steel making LCI data focuses only on the steel industry's own flows and does not include the non-steel-related flows which are associated with the avoided production of other materials (e.g. clinker) and which are included in the system expansion approach. It will also result in less distortion when comparing materials, as the actual environmental impact will be associated with the materials produced. Due to the system expansion rule, LCI flows appeared within the steelmaking LCI which are never actually part of an original steel Life Cycle or unexpected values for certain materials could also be present which are related to the avoided production of the replaced material. This can cause confusion for those using the datasheets. Utilising this new methodology will avoid such perceived abnormalities within the datasets.

11.2. Development of Methodology

In cases such as the integrated steel making process (namely the blast furnace and the basic oxygen furnace) where a process has more than one product, the allocation procedure must be applied in accordance with ISO 14044:2006, and should follow this three step approach:

Step 1: Wherever possible allocation should be avoided by:

- dividing the unit process to be allocated into two or more sub-processes
- expanding the product system to include the additional functions related to the co-products

Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships (e.g. mass) between them.

Step 3: Where physical relationships alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic values of the products.

In general, allocation approaches are applied in cases where real multi-functional systems have to be modelled into one or several mono-functional systems, where the two sub-points of Step 1 are not applicable, see Figure 6. The aim is to allocate the steel plant inventory between the different main and co-products (e.g. steel, blast furnace slag etc.).

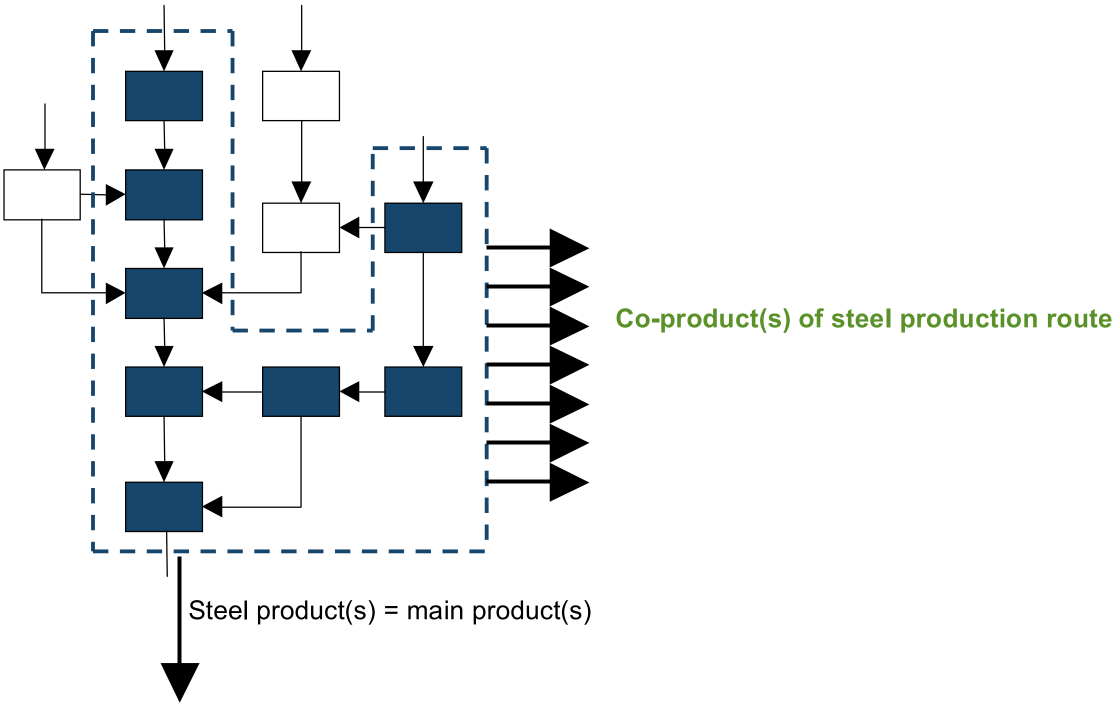


Figure 6: Multi-functional system with different main and co-products

The existing IISI World Steel Life Cycle Inventory Methodology Report 1999 – 2000, details the data collection procedure and LCI methodology used for steel products. It also describes how co-products are handled and how the approach of system expansion is used to avoid allocation. System expansion is an allocation procedure based on the fact that the co-product saves another product with equivalent function (e.g. blast furnace slag saves clinker production). The expanded system will then include the route of the product(s) replaced by the co-product. Figure 7 shows this method in detail below.

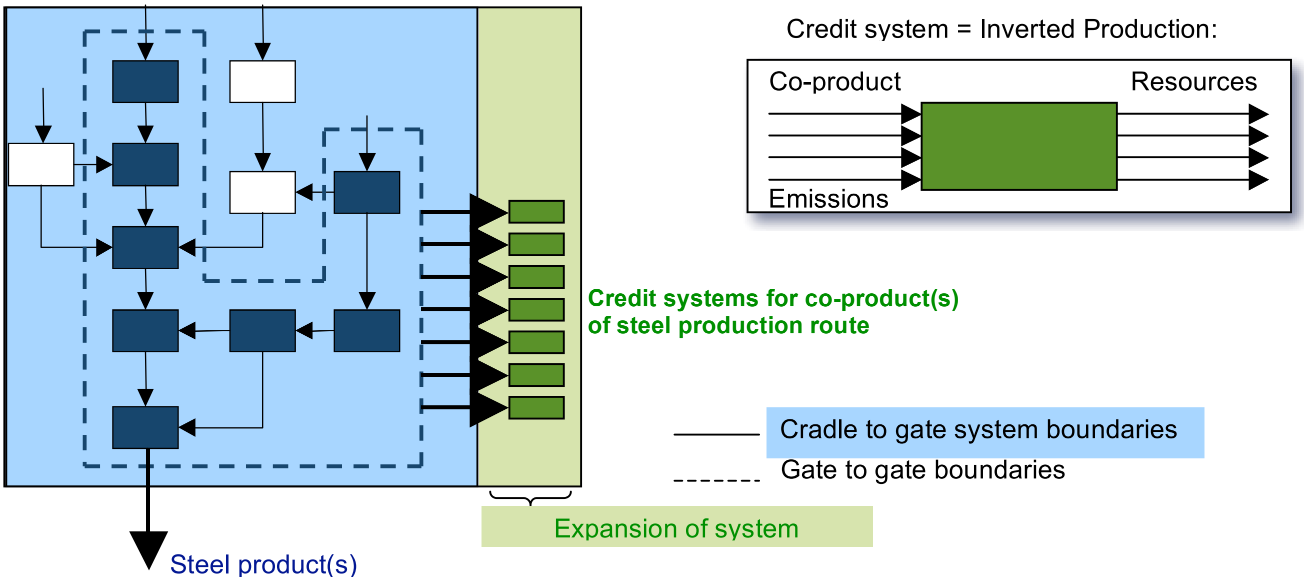
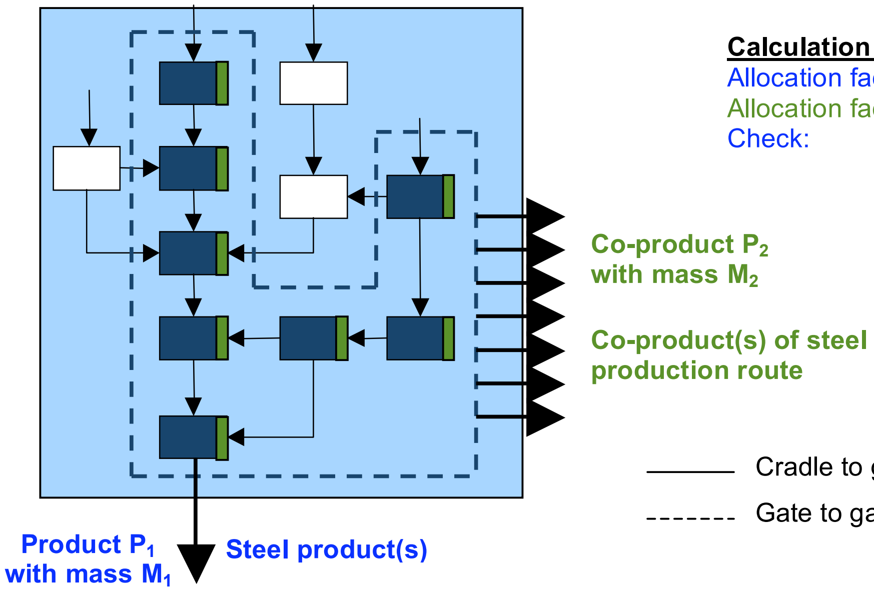


Figure 7: Multi-functional system, system expansion method

The new co-product methodology detailed in this report is an alternative to system expansion, and focuses on allocation methodologies. Typically, one methodology is used, be it system expansion, or allocation etc. Within this methodology, a number of allocation rules have been set up on a manual basis, and are applied on the level of the single flows per process and not one rule that is valid throughout the whole process. These allocation rules are then assigned on the level of each flow (and is done so within the GaBi 4 software by selecting from the list of pre-determined allocation rules), to allocate the burdens between the different co-products depending on the function of the flow. These rules are described in detail in the report. The allocation procedures outlined below are dealt with in accordance with ISO14044:2006 section 4.3.4.2 on Allocation. Allocation is the partitioning of the system inputs and outputs (including the upstream and downstream burdens) between its different products or functions according to certain rules, e.g. according to the underlying physical relationships or according to economic parameters.

Figure 8 below shows, as a matter of principle, how the methodological approach of allocation differs from the one of system expansion. The main difference between these two methodologies is that in system expansion, a credit is given 'on top' of the steel LCI by subtracting the LCI of the replaced co-product. In allocation, the existing steel LCI is divided/allocated between the single main and co-products, with no extension or splitting of the system.



Calculation of allocation factor using mass:

Allocation factor for P1: $AF_{P1}=M1 / (M1 + M2)$

Allocation factor for P2: $AF_{P2}=M2 / (M1 + M2)$

Check: $AF_{P1} + AF_{P2} =1$

———— Cradle to gate system boundaries

------- Gate to gate boundaries

Figure 8: Multi-functional system: allocation method

The partitioning and distribution of the environmental burdens and credits is done initially based on the description above and using the specific allocation methodologies described below, and then followed by system expansion for the production of process gases, steam, hot water and electricity, as they are mainly used internally within the steel making process, though they are also used externally. Allocation methodologies, based on calculations associated with the metallurgical properties within the steel making process, are only applied to the main co-products for each of the processes - see each process below for details of the main co-products. All other materials (the non-main co-products) will be considered via system expansion.

To demonstrate the system for dealing with process gases, and using the principles shown in Figure 8, the following example within the blast furnace can be used:

Total output of process gas = 1 tonne

Allocation rule applied for process gas (as described in Section 11.3.3) is based on a function of the total energy of the overall production of the hot metal and the slag, and this function is referred to as fEHM for the energy function associated with the hot metal, and fES(BF) for the energy function associated with the slag.

Allocation to the hot metal, fEHM = 95%, allocation of process gas output = 950 kg

Allocation to blast furnace slag, fES(BF)= 5%, allocation of process gas output = 50 kg

Assuming that 30% of the process gas is flared and 70% is used to produce electricity, the following result is produced:

> The hot metal has to carry the flaring burden of 0.3 * 950 kg of process gas and gets a credit for 0.7 * 950 kg of process gas used as electricity.
>
> The slag has to carry the flaring burden of 0.3 * 50 kg of process gas and gets a credit for 0.7 * 50 kg of process gas used as electricity(including the burden to generate electricity out of process gas).

In order to verify the new EUROFER methodology, a simplified model, with a reduced list of flows, was initially developed and tested to analyse the effects of the methodological approach on the basis of a simplified model platform with specific focus on CO_2 within the system (from the coke plant to the hot rolling mill). An exemplary steel production site was then used to test and validate the methodology on real site data prior to implementation within the model utilised by selected sites.

11.2.1. Relevant Flows

The flows that are considered throughout this procedure are those which account for 95% by mass of the inputs and outputs to a process and also, any flow which has a significant environmental impact. This incorporates those flows identified as ‘accounted flows’ in the IISI data collection exercise. Accounted flows are those which are of environmental relevance with respect to steel production.

Those minor flows which have a minimal environmental burden or credit are allocated between the co-products based on the energy equations described in more detail below.

The **non-site-made** additions (e.g. upstream additions such as coke from external supplies) are provided with upstream burdens based on the average collected site data for each addition. Where available, this data is also modelled in accordance with the EUROFER co-product methodology.

11.2.2. Default Values

In order to carry out the allocation, some additional process data was required (e.g. hot metal temperature), and default data has been used. In future data sets, this information will be collected from each manufacturing site. If a site is not able to provide the information, the average of the provided data will be used for this site. In certain cases, default values will be used where the value would be unlikely to vary across steelmaking sites. The default values were determined by Arcelor and cross-checked by Corus – the data is based on European steelmaking sites.

11.3. Allocation Procedures by Process Unit

The co-products and plant-specific allocation rules are detailed individually below:

11.3.1. Coke ovens: Co-products are coke, benzene, tar, BTX (Benzene, Toluene, Xylene) and sulphur.

The Coke Oven co-products are mainly energy-based products i.e. with a significant calorific value, and so the inputs and outputs related to the production of the co-products are partitioned based on the ratios of the total energy content (net calorific value, NCV) of each of them. The partitioning of the flows between the co-products is determined in the following way, taking coke as an example:

$$\frac{NCV_{coke} \times Mass_{coke}}{(NCV_{coke} \times Mass_{coke}) + (NCV_{other.coproducts} \times Mass_{other.coproducts})}$$

The exceptions to this methodology is process gas, steam etc. As they are generally used internally within the steel making process, and to avoid further complications in allocation principles in other process units (see blast furnace below), they are dealt with by system expansion.

Surplus of steam, hot water and **electricity** output is dealt with by system expansion.

11.3.2. Sinter and pellet plant: Product is sinter or pellet.

The only product from this process is sinter or pellet and so no allocation is required.

11.3.3. Blast Furnace: Main co-products are pig iron (hot metal) and slag.

Within the blast furnace process, straight partitioning is complex as the process gases are often recovered internally and used within the steel making process and the other two co-products are for external use. In order to simplify matters, process gases are accounted for by system expansion as these are often used internally (but also externally), thus avoiding the production of electricity in the power plant, and therefore it is unlikely that other industries will be interested in blast furnace gas as a co-product LCI. The process gas produced in the blast furnace can have different functions, but all activities associated with the gas (internal use as heating or electricity, flaring, exported surplus) are allocated (burdens and credits) in the same way, according to the allocation in the blast furnace, between the hot metal and the slag.

System expansion is therefore carried out for the process gases, but will be done after the mass bearing co-products (pig iron and slag) have been dealt with by allocation.

The blast furnace is a thermodynamic system requiring energy for production purposes and the energy associated with the actual mass of the co-products should therefore be the basis for the partitioning of the flows between the co-products. The majority of the partitioning of the blast furnace is thus carried out using a function of the total energy of the overall production of the hot metal and the slag, and this function will be referred to as fEHM for the energy function associated with the hot metal, and fES(BF) for the energy function associated with the slag. The partitioning is based on the energy used within the blast furnace to form the iron and the slag from the raw materials. Therefore, fEHM for the hot metal is made up from the energy used to reduce iron oxide to iron and oxygen; the sensible heat of the hot metal (the energy required to take it from 25°C to 1500°C); the energy required to reduce the oxides of Silicon, Manganese and Phosphorus; the energy required for the dissolution of Carbon, Manganese, Silicon and Phosphorus; and finally, the energy that is associated with the carbon present in the hot metal which will later be reduced to form steel in the BOF plant. The fES(BF) associated with the slag is the energy taken to form a molten slag (sensible heat). Based on these energy functions and the mass of both the hot metal and the slag produced in the process, the partitioning ratio between the hot metal and slag can be calculated. This ratio is then used to allocate the associated burdens of the inputs and the outputs between the hot metal and slag:

For the hot metal:

$$\frac{fEHM \times Mass_{hot.metal}}{(fEHM \times Mass_{hot.metal}) + (FES(BF) \times Mass_{slag})}$$

For the slag:

$$\frac{fES(BF) \times Mass_{slag}}{(fES(BF) \times Mass_{slag}) + (fEHM \times Mass_{hot.metal})}$$

For all relevant flows, the partitioning method is described and justified in detail below, with some flows being assigned a more appropriate method than the energy function described above:

CO and CO_2 are produced (and some CH4) during the combustion of coal and coke in the blast furnace which are used for energy purposes (producing hot metal, slag and gases). Allocation of these emissions to air is therefore to both the hot metal and the slag, based on the energy function (fEHM and fES(BF)).

Energy sources e.g. natural gas, coal, coke: these are used in the operation of the process and therefore associated with both the hot metal and the slag and thus allocated in this manner, based on the energy function (fEHM and fES(BF)). The allocation for blast furnace gas by energy later determines the burden of process gas combustion as well as the credit due to the avoided production of electricity, which are allocated between the slag and the hot metal.

Fluorspar – is added to control the slag efficiency and is therefore allocated totally to the slag.

Hydrogen sulphide, H2S, is allocated to both the hot metal and the slag by the energy function (fEHM and fES(BF)) as, although the emissions of the H2S mainly occur during quenching of the slag at the slag pouring tap, this has no more link (metallurgically) to the slag than to the hot metal.

Iron ore, sinter, pellets, sinter fines and direct reduced iron – allocations between the slag and hot metal of these flows are calculated based on the proportion of gangue and iron that is present in the material. Gangue content is defined as the non-iron content of the material and is determined by calculating the iron/ferrous content in the material – the proportion of the material that is iron is therefore allocated to the hot metal. The gangue content in the iron ore is calculated based on the iron content using the formula: [gangue = 1 – (1.43 * iron content)], where the 1.43 relates to the proportion of iron ore (which is a mix of haematite, Fe_2O_3, and gangue) that is iron. Where no site specific data is available, default values are used instead. The gangue forms the slag product and therefore the proportion of gangue content is allocated to the slag.

The benefits of having gangue present in the sinter product is that it produces a material that can be inserted into the blast furnace due to its hardness and using such products produces a good quality slag that can beneficially be used by industries such as the cement industry.

	Default Gangue content %
Sinter (fines)	17.9
Pellets	5.6
Iron ore	11.4
DRI	4.0

Table 1: Default gangue content values

Iron Scrap inputs are added for iron content and are therefore totally allocated to the hot metal.

Limestone ($CaCO_3$) is added to the blast furnace and has many functions within the steel making process. It is used to remove the gangue from the iron ore, in order to clean it, and also to aid with the slag formation. It enables the slag to reach a specific basicity and the liquidus temperature required, with correct calcium levels, and therefore enables it to be decanted, and to create a granulated slag. The limestone is allocated between the hot metal and the slag, on the basis of the energy function (fEHM and fES(BF)), which results in the hot metal taking most of the burden for the limestone.

This is also the reason why the dolomite ($CaCO_3.MgCO_3$), bauxite and olivine are allocated between the metal and the slag by the energy function (fEHM and fES(BF)).

Metallic additions (e.g. Manganese) – these are added in order to achieve the correct steel grade and therefore allocated to the hot metal.

Scales and Steel Scrap are added as recycling iron units and therefore the entire burden is associated with the hot metal.

Sodium carbonate is added at the hot metal desulphurisation stand, and the formed slag is stripped out and not mixed to the BF/BOF slag (steel slag). For this reason it should be completely allocated to the hot metal.

Steam as an energy input is allocated to the steel as it is used for maintenance purposes within the steel production process. Steam used in the wastewater treatment process, or occurring as an output, is allocated to both the hot metal and the slag by the energy function (fEHM and fES(BF)).

Water – is used for the granulation and cooling of slag, process cooling water and for the cleaning of the gases (CO, CO_2, CH_4). Water is therefore allocated to both the hot metal and the slag by the energy function (fEHM and fES(BF)).

Wastewater treatment - as the wastewater comes from the cleaning of the gases, which are allocated by the energy function (fEHM and fES(BF)) to both the hot metal and the slag, it follows that the water treatment process is allocated in the same manner. Thus, the water used, the treatment chemicals, and the discharges produced (wastewater/sludges) are allocated by the energy function (fEHM and fES(BF)) to both the hot metal and the slag.

Miscellaneous: packaging is allocated to the steel; covering powder is added to the ladles to reduce heat loss from the steel and is therefore allocated to the steel.

11.3.4. Basic Oxygen Furnace (BOF): Main co-products are the steel product and the slag.

The main inputs and outputs are allocated using either the energy function calculations (fEST (energy function of steel) and fES(BOF)), gangue calculations, or are directly attributable to one or other of the co-products, as has been described above. In addition, there are a number of additional allocation rules which are applicable to the BOF:

Additions (e.g. calcium carbide) or specific slags / sludges / dusts / scales produced (e.g. desulphurisation slag) which are required or produced in order to achieve the **desired steel grade**, are allocated to the steel.

Additions (e.g. gases used for the removal of inclusions in the steel or for mixing, covering powder in the ladles to reduce heat loss) and outputs produced (e.g. grease used in the casting process, scrap and sludge produced) specifically for the actual **steelmaking process** and with no relevance to the slag, are allocated to the steel.

Manganese - in the BOF process, the manganese dust/sludge comes from Manganese as part of the Hot Metal composition which is oxidised during the blowing phase. It does not come from the addition of manganese as an alloying element which occurs at the metallurgical stand. The slag at the metallurgical stand is not mixed to the "BOF slag" (Steel Slag). Manganese is therefore allocated to both the slag and hot metal by the energy function (fEST and fES(BOF)). Any manganese added such as ferromanganese, is allocated to the steel as it is added for the steel grade.

Manganese as an emission is allocated between the hot metal and the slag.

For **hot metal** inputs, the allocation is split between the hot metal and the slag by determining the proportion of impurities that are present in the hot metal inputs (e.g. Silicon, Manganese and Phosphorus), and allocating this proportion of impurities to the slag.

Synthetic slag is added to the process after the production of the BOF slag and therefore it is allocated to the steel.

11.3.5. Hot Rolling: Product is hot rolled coil.

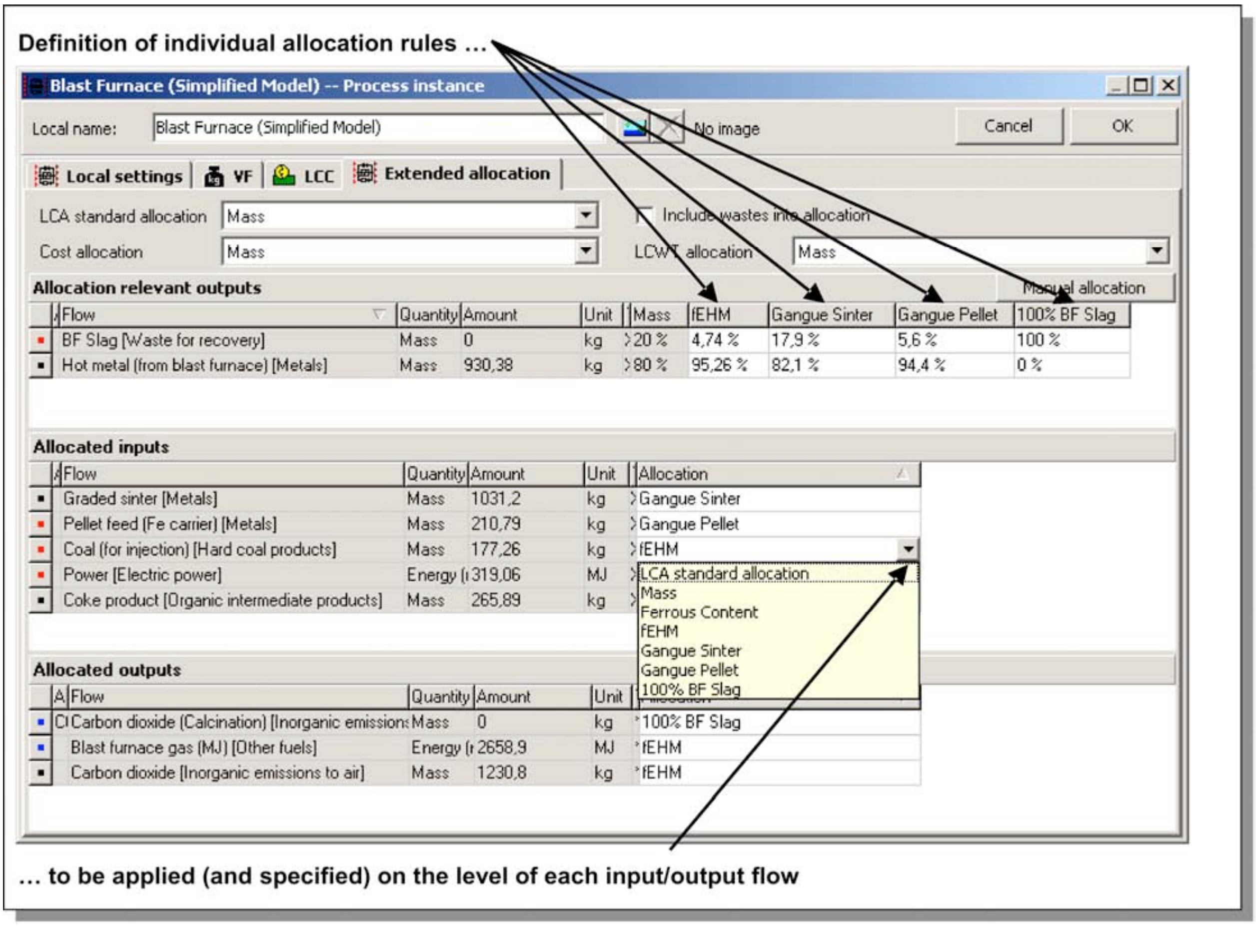
The only product from this process is hot rolled coil and so no allocation is required and all flows are allocated to the coil.

11.3.6. Electric Arc Furnace (EAF) and the Stainless Steel EAF: Co-products are the steel product and slag.

Allocation rules for the EAF processes, for both carbon and stainless steel, will follow similar principles as for the other processes described above, with further rules for additional flows within the process. However, the analysis of such data is not considered in this report here. Following the finalisation of the methodology for the integrated route, a proposal will be put forward for the EAF routes.

11.4. Implementation

The EUROFER co-product approach is implemented within the IISI LCI model as set-up in the LCA software system GaBi 4. To cope with the individual allocation requirements of the EUROFER co-product approach the GaBi 4 feature "Extended Manual Allocation" is used which supports the application of individual allocation rules on the level of single input/output flows per process.



Definition of individual allocation rules ...

Local name: Blast Furnace (Simplified Model)

LCA standard allocation: Mass

Cost allocation: Mass

☐ Include wastes into allocation

LCWT allocation: Mass

Allocation relevant outputs

Flow	Quantity	Amount	Unit	Mass	fEHM	Gangue Sinter	Gangue Pellet	100% BF Slag
BF Slag [Waste for recovery]	Mass	0	kg	20 %	4,74 %	17,9 %	5,6 %	100 %
Hot metal (from blast furnace) [Metals]	Mass	930,38	kg	80 %	95,26 %	82,1 %	94,4 %	0 %

Allocated inputs

Flow	Quantity	Amount	Unit	Allocation
Graded sinter [Metals]	Mass	1031,2	kg	Gangue Sinter
Pellet feed (Fe carrier) [Metals]	Mass	210,79	kg	Gangue Pellet
Coal (for injection) [Hard coal products]	Mass	177,26	kg	fEHM
Power [Electric power]	Energy ((	319,06	MJ	LCA standard allocation Mass Ferrous Content fEHM Gangue Sinter Gangue Pellet 100% BF Slag
Coke product [Organic intermediate products]	Mass	265,89	kg	

Allocated outputs

Flow	Quantity	Amount	Unit	Allocation
Carbon dioxide (Calcination) [Inorganic emissions	Mass	0	kg	100% BF Slag
Blast furnace gas (MJ) [Other fuels]	Energy ((	2658,9	MJ	fEHM
Carbon dioxide [Inorganic emissions to air]	Mass	1230,8	kg	fEHM

... to be applied (and specified) on the level of each input/output flow

Figure 9: Extended manual allocation, Blast Furnace (Simplified Model)

Figure 9 illustrates the application of the EUROFER co-product approach using the example of the blast furnace. The use of this GaBi 4 feature allows the application of input/output specific allocation rules not only per process but also differentiating the single site specific process situation.

11.5. Results of methodology to be incorporated

Using the exemplary sites, an analysis between the existing data developed by the IISI using system expansion and this newly developed co-product methodology based on allocation and flow-specific rules is undertaken in order to determine whether the LCI associated with the steel and the slag is justifiable and within a reasonable order of magnitude. Verification with the industries utilising the steel industry co-products, e.g. the cement industry, will be undertaken to cross-check the co-product LCIs. To reflect the fact that the use of these co-products is beneficial to the environment, the burden of using such co-products as a general rule is lower than that for using virgin raw materials.

The model has been developed within the GaBi 4 LCA software, in conjunction with the IISI methodology and model. Currently, five European Integrated steelworks have been utilised to determine the effect of applying this new co-product methodology, to determine the range of environmental burdens that should be associated with the steel industry co-products. An average of the results of these five sites has been produced to determine a first result for a European LCI for these co-products for analysis purposes as well as to start the discussions with the corresponding industries. When the current IISI data collection exercise has been completed, the methodology will be applied to all European integrated steelworks.

Variations in the results between each site will occur and are mainly due to the different input/output characteristics of the steelmaking processes of relevance (coke plant, blast furnace, BOF) as well as due to the different site specific boundary conditions such as the use of process gas on site, export of process gas for external use, the process-internal production of steam, hot water etc. This will therefore reflect the actual fate of these co-products instead of their potential fate (how much is actually reused, flared etc) and will thus encourage the utilisation of these materials as opposed to their disposal. For example, those sites which flare their gas will have a higher burden to be allocated between the co-products than those where the gas is utilised or exported for use elsewhere.

The resulting Life Cycle Inventories calculated on the basis of a number of selected sites are included below. The calculations are based on the data from the previous LCI study from 2000, including the background data used at that time. Within the data transfer to the GaBi 4 software system some simplification was applied, e.g. no consideration of transportation, no individual modelling of water input composition, no consideration of the coke plant allocation, etc. The reason for this simplification was to focus on and analyse the effect of the main allocation rules as applied on the level of the blast furnace and basic oxygen furnace, in comparison to the methodology of system expansion of the 2000 study.

		Total		Relative contribution		
Flow Categories	**Name of flow**	**(in kg]**		**Extern**	**On-Site**	**Substitution**
Resources	**Crude oil**	0,146119		331,8%	0,0%	-231,8%
Resources	**Hard coal**	0,436440		148,6%	0,0%	-48,6%
Resources	**Natural gas**	0,222706		240,2%	0,0%	-140,2%
Resources	**Dolomite**	0,154764		100,0%	0,0%	0,0%
Resources	**Iron ore**	0,620160		231,0%	0,0%	-131,0%
Resources	**Limestone (calcium carbonate)**	-0,709532		-31,3%	0,0%	131,3%
Resources	**Zinc ore**	-0,168545		0,0%	0,0%	100,0%
Resources	**Water**	0,496935		126,4%	0,0%	-26,4%
Resources	**Water (drinking water)**	0,273761		100,0%	0,0%	0,0%
Resources	**Water (fresh water)**	0,164325		0,0%	100,0%	0,0%
Resources	**Water (ground water)**	0,826223		100,0%	0,0%	0,0%
Resources	**Water (lake water)**	0,756782		100,0%	0,0%	0,0%
Resources	**Water (river water)**	-0,177620		100,0%	0,0%	0,0%
Resources	**Water (sea water)**	-0,297983		100,0%	0,0%	0,0%
Emissions to air	**Cadmium**	-0,943312		0,0%	0,0%	100,0%
Emissions to air	**Chromium (unspecified)**	0,000007		0,3%	99,8%	-0,1%
Emissions to air	**Lead**	0,000004		1,2%	99,5%	-0,8%
Emissions to air	**Mercury**	0,000000		7,7%	98,7%	-6,3%
Emissions to air	**Zinc**	0,000002		2,4%	98,9%	-1,3%
Emissions to air	**Carbon dioxide**	2,033683		16,1%	66,8%	17,1%
Emissions to air	**Carbon monoxide**	1,114890		82,3%	17,7%	0,0%
Emissions to air	**Hydrogen chloride**	0,482475		45,0%	55,0%	0,0%
Emissions to air	**Hydrogen sulphide**	0,395917		0,0%	100,0%	0,0%
Emissions to air	**Nitrogen oxides**	0,882066		85,9%	14,1%	0,0%
Emissions to air	**Nitrous oxide (laughing gas)**	0,975881		71,1%	28,9%	0,0%
Emissions to air	**Sulphur dioxide**	0,222431		0,0%	0,0%	100,0%
Emissions to air	**Dioxins (unspec.)**	0,000000		0,0%	100,0%	0,0%
Emissions to air	**NMVOC (unspecified)**	1,074304		13,3%	86,7%	0,0%
Emissions to air	**Methane**	0,722894		73,8%	26,2%	0,0%
Emissions to air	**Dust (unspecified)**	0,193991		100,0%	0,0%	0,0%
Emissions to fresh water	**Chemical oxygen demand (COD)**	0,470193		60,1%	69,1%	-29,1%
Emissions to fresh water	**Cadmium**	0,000000		3,4%	96,8%	-0,2%
Emissions to fresh water	**Chromium (unspecified)**	-0,871514		0,0%	0,0%	100,0%
Emissions to fresh water	**Iron**	0,788587		100,0%	0,0%	0,0%
Emissions to fresh water	**Lead**	0,000000		38,3%	67,2%	-5,4%
Emissions to fresh water	**Nickel**	0,000000		18,4%	82,7%	-1,1%
Emissions to fresh water	**Zinc**	0,000001		4,9%	95,8%	-0,6%
Emissions to fresh water	**Ammonia (NH4+, NH3, as N)**	0,505907		43,7%	56,3%	0,0%
Emissions to fresh water	**Nitrogen**	0,174477		0,0%	100,0%	0,0%
Emissions to fresh water	**Phosphorus**	-0,242622		0,0%	0,0%	100,0%
Emissions to fresh water	**Solids (suspended)**	0,828069		92,2%	24,0%	-16,2%

Table 2: LCI for 1kg Hot Rolled Coil (Average)

Table 2 shows the exemplary LCI result for 1kg of Hot Rolled Coil, calculated on the basis of this new co-product approach applied to a number of selected sites from the previous LCI study. In addition, the table gives information on the contribution of the steelmaking processes taking place on site, the impact of the upstream processes representing external activities as well as the effect of the system expansion approach as applied for all (co-)products other than the steel products, the BF slag and the BOF slag.

Table 3 shows the results generated for the BF slag. The BF slag LCI result is also based on a number of selected sites from the 2000 IISI study. The table gives information on the absolute LCI data in comparison (absolute and relative) to the credit systems of the previous study: LCI of 1kg cement production and LCI of 1kg Embankment production.

		Absolute in [kg]				Relative in [%]	
Flow Categories	**Name of Flow**	**BF Slag Route - Average**	**142 Cement: Production**	**142 Embankment (Massive Rock): Production**		**BF Slag / Cement**	**BF Slag / Embankment**
Resources	**Crude oil**	0,847313373	0,298	0,31111		284,3%	272,4%
Resources	**Hard coal**	0,172284361	0,183	1,99E-01		94,1%	86,6%
Resources	**Natural gas**	-0,197495222	0,82753	1,17E-01		-23,9%	-169,3%
Resources	**Dolomite**	0,559716889				Not existing	Not existing
Resources	**Iron ore**	0,958996952	0,194			494,3%	Not existing
Resources	**Limestone (calcium carbonate)**	0,117826683	1,54			7,7%	Not existing
Resources	**Zinc ore**	1,72E-11				Not existing	Not existing
Resources	**Water**	0,134869448	5,12	5,83E-01		2,6%	23,1%
Resources	**Water (drinking water)**	0,267778754				Not existing	Not existing
Resources	**Water (fresh water)**	0,269695775				Not existing	Not existing
Resources	**Water (ground water)**	0,265158843				Not existing	Not existing
Resources	**Water (lake water)**	0,113499865				Not existing	Not existing
Resources	**Water (river water)**	-0,12626457				Not existing	Not existing
Resources	**Water (sea water)**	-0,164578515				Not existing	Not existing
Emissions to air	**Cadmium**	3,38E-08				Not existing	Not existing
Emissions to air	**Chromium (unspecified)**	6,23E-06				Not existing	Not existing
Emissions to air	**Lead**	3,19E-06				Not existing	Not existing
Emissions to air	**Mercury**	2,64E-08				Not existing	Not existing
Emissions to air	**Zinc**	2,95E-07				Not existing	Not existing
Emissions to air	**Carbon dioxide**	0,533158984	0,9364	0,134165		56,9%	397,4%
Emissions to air	**Carbon monoxide**	0,146112679	0,2344	5,63E-01		62,3%	26,0%
Emissions to air	**Hydrogen chloride**	2,42E-01	1,53E-01			157,6%	Not existing
Emissions to air	**Hydrogen sulphide**	9,78E-06				Not existing	Not existing
Emissions to air	**Nitrogen oxides**	0,734649468	0,2537	1,44E-01		289,6%	509,6%
Emissions to air	**Nitrous oxide (laughing gas)**	2,22E-01	4,57E-01	4,86E-01		48,7%	45,8%
Emissions to air	**Sulphur dioxide**	0,129683533				Not existing	Not existing
Emissions to air	**Dioxins (unspec.)**	4,00E-11				Not existing	Not existing
Emissions to air	**NMVOC (unspecified)**	0,368429966	0,2684	4,47E-01		137,3%	82,4%
Emissions to air	**Methane**	0,132536712	0,11937	1,89E-01		111,0%	70,1%
Emissions to air	**Dust (unspecified)**	0,324743649	0,2	1,17E-01		162,4%	277,1%
Emissions to fresh water	**Chemical oxygen demand (COD)**	2,84E-01	2,79E-01	5,00E-01		101,9%	56,8%
Emissions to fresh water	**Cadmium**	1,45E-09				Not existing	Not existing
Emissions to fresh water	**Chromium (unspecified)**	2,19E-08				Not existing	Not existing
Emissions to fresh water	**Iron**	1,87E-01	0,12			155,6%	Not existing
Emissions to fresh water	**Lead**	9,16E-08				Not existing	Not existing
Emissions to fresh water	**Nickel**	3,79E-08				Not existing	Not existing
Emissions to fresh water	**Zinc**	8,48E-08				Not existing	Not existing
Emissions to fresh water	**Ammonia (NH4+, NH3, as N)**	1,25E-01	2,37E-01			52,9%	Not existing
Emissions to fresh water	**Nitrogen**	3,65E-06				Not existing	Not existing
Emissions to fresh water	**Phosphorus**	5,49E-07				Not existing	Not existing
Emissions to fresh water	**Solids (suspended)**	4,36E-01	1,10E-01	1,67E-01		396,7%	261,8%

Table 3: LCI of 1kg BF Slag (Average)

11.6. Sensitivity Analysis

During the development of this new methodology, a number of different rules have been applied to allocate the various input/output flows as well as their related upstream and downstream burden/credit between the co-products. A simplified model developed by Arcelor was initially used, followed by incorporation of the methodology within one exemplary site, to test the impacts associated with using a number of different flow- and process-specific rules. And finally, after verification of these rules, the methodology was applied to a number of selected steel making sites. Throughout this process, the rules were trialled to see if the associated impact on the resulting burdens applied to the co-products were appropriate. An example to show the iterative process undertaken is detailed below:

> Within the steel making process, depending on the production site in question, the destination of the slag that is produced in the BOF or blast furnace varies. While some/all of the slag can be used as a co-product, there could be a proportion of the slag that is not suitable to be used as a co-product, but is actually a waste and is sent to landfill. It could be seen that this waste material is a '*potential*' co-product, as effectively it is the slag that comes from either of these two processes, and by dealing with the data in this way, it could provide an incentive to have less slag material going to landfill and more to be used as a co-product.
>
> If indeed this material was treated as a potential co-product, the burden associated with the fraction of material that is actually utilised as a co-product out of the overall amount of potential co-product material would differ in comparison to the burden that is associated with the actual co-product that is used, while the slag that went to landfill would simply be treated as waste.
>
> In order to verify that the methodology currently implemented is the most appropriate to use, an analysis of both approaches was carried out to determine the sensitivity of this rule, to ensure that the slag does not get over-burdened.
>
> Example:
>
> - BOF process, producing 1 tonne of slab
> - A total of 0.1 tonnes of slag
> - A resulting 0.2 tonnes of CO_2
>
> Exemplary calculations are carried out for different scenarios, regarding the proportion of the slag that is used as a co-product and that which is disposed of as a waste in a landfill site. These are detailed in Table 4.
>
> Taking as an example here, 75 kg as a co-product and 25 kg as a waste:
>
> Original approach:
>
> - 178.4kg of the CO_2 burden is allocated to the slab and 21.6kg of the CO_2 burden to the slag (75kg slag as co-product)
>
> Potential co-product approach, where the slab receives the proportion of CO_2 allocated to the slab, and to the slag that is sent as waste to landfill:
>
> - 179.2kg of the CO_2 burden is allocated to the slab and 20.85kg of the CO_2 burden to the slag (75kg slag as co-product)
>
> The sensitivity of these two methods can be seen in the Table 4 below, showing the variation in results for each of the scenarios. It shows the sensitivity of the methodologies to the steel slab does not vary greatly (less than 0.6% variation). However, the CO_2 associated with the slag as a co-product is more sensitive, particularly the greater the proportion of the slag that goes to landfill.

LCI (Basic Data)						
		BOF 1	BOF 2	BOF 3	BOF 4	BOF 5
Slab	[t]	1	1	1	1	1
BOF slag [Waste]	[t]	0,1	0,075	0,05	0,025	0,01
BOF slag [Co-Product]	[t]	0	0,025	0,05	0,075	0,09
CO2	[t]	0,2	0,2	0,2	0,2	0,2
fEST (Calculation according to YdL)						
fEST (Approach A)						
		BOF 1	BOF 2	BOF 3	BOF 4	BOF 5
Slab	[%]	86,1	89,2	92,5	96,1	98,4
BOF slag [Waste]	[%]	13,9	10,8	7,5	3,9	1,6
fEST (Approach B)						
		BOF 1	BOF 2	BOF 3	BOF 4	BOF 5
Slab	[%]	86,1	86,1	86,1	86,1	86,1
BOF slag [total]	[%]	13,9	13,9	13,9	13,9	13,9
Results						
CO2 allocated (Approach A)						
[absolute]		BOF 1	BOF 2	BOF 3	BOF 4	BOF 5
Slab	**[kg CO2]**	**172,2**	**178,4**	**185**	**192,2**	**196,8**
BOF slag [Co-Product]	**[kg CO2]**	**27,8**	**21,6**	**15**	**7,8**	**3,2**
[relative]		BOF 1	BOF 2	BOF 3	BOF 4	BOF 5
Slab	**[kg CO2 / t]**	**172,2**	**178,4**	**185**	**192,2**	**196,8**
BOF slag [Co-Product]	**[kg CO2 / t]**	**278**	**288**	**300**	**312**	**320**
CO2 allocated (Approach B)						
[absolute]		BOF 1	BOF 2	BOF 3	BOF 4	BOF 5
Slab	[kg CO2]	172,2	172,2	172,2	172,2	172,2
BOF slag [Waste]	[kg CO2]	0	6,95	13,9	20,85	25,02
Slab + BOF slag [Waste]	**[kg CO2]**	**172,2**	**179,15**	**186,1**	**193,05**	**197,22**
BOF slag [Co-Product]	**[kg CO2]**	**27,8**	**20,85**	**13,9**	**6,95**	**2,78**
[relative]		BOF 1	BOF 2	BOF 3	BOF 4	BOF 5
Slab	**[kg CO2 / t]**	**172,2**	**179,15**	**186,1**	**193,05**	**197,22**
BOF slag [Co-Product]	**[kg CO2 / t]**	**278**	**278**	**278**	**278**	**278**

Difference between both approaches						
CO2 allocation to the Slab	[%]	0	-0,419	-0,591	-0,44	-0,213
CO2 allocation to the BOF Slag Co-Product	[%]	0	-3,472	-7,333	-10,9	-13,12

Table 4: Sensitivity of data to variations in allocation rules

However, having carried out this analysis, and also due to that fact that this material would be used as a co-product if the quality was good enough for use, it has been decided to remain with the original calculation.

11.7. Critical Review

A critical review of this co-product methodology is required. No review of the data or the data collection methodology is required as this was carried out in the IISI data collection exercise, and it is this data that is being used within this methodology, from the 2000 data collection, which includes upstream DEAM data.

11.8. Further work / Outlook

As a follow-up to this project, it is recommended that the following areas are investigated:

- A critical review of the methodology as detailed in Section 11.7 and incorporation of any appropriate recommendations.
- Discussions with the users of the steel industry co-products, such as cement manufacturers.
- Implementation of the co-product methodology within the new IISI data which is currently being collected.
- Potential development of a methodology to incorporate the secondary steelmaking process route, namely the Electric Arc Furnace.
- Potential development of a methodology to incorporate the stainless steel making process which is performed in the Electric Arc Furnace route.
- Future discussions with IISI and other steel industry organisations for the inclusion of the EUROFER co-product methodology within other datasets.
- Potential inclusion of the European steel industry LCI data incorporating the co-product methodology, with LCI data providers, software developers and the European Commissions ELCD.

12. RECYCLING METHODOLOGY

12.1. Motivation

The system boundaries for the LCI data that has traditionally been provided by the steel industry was cradle (raw material extraction and production) to steel factory gate. It did not include the end of life aspects associated with the recycling of end of life products, and the scrap allocation issues, nor did it include a burden for the utilisation of scrap steel as a raw material input. In the past, scrap was considered as a raw material with neither a burden (on the input side) nor a credit (on the output side) and it was up to the LCA practitioners using he steel LCI data to apply (or not) a methodology to allocate for scrap.

The use of steel scrap, in particular from end of life of final products, reduces the primary production of steel and thus saves resources, energy etc. Nevertheless, both routes of steel production (the integrated route and the electric arc furnace route) are needed as there is simply not enough scrap to satisfy the demand for steel. Both routes are inter-related, as they are both steel producers and steel recyclers.

A methodology is therefore required to account for the credits and burdens associated with steel scrap inputs and outputs from life cycle systems involving steel products, and such a methodology has been developed by the steel industry. The methodology reflects a closed material loop system, where there is no deterioration in material properties when the steel is recycled, which reflects the real-life steel production process. In this way the methodology also reflects the benefits of multi step recycling, where steel is recycled over and over again without loss of material properties. One important parameter in the model is the end-of-life recovery rate for the product. The message from this analysis is that in order to design more sustainable products, there is a need to design products that can be recycled or reused.

By taking account of end-of-life recycling issues, there will be a more consistent approach to the use of steel LCI data and it will also reduce the inaccuracies when using steel LCI data.

12.2. Methodology

The methodology that is used by the steel industry has been developed by IISI and is based on the ISO 14040 series of standards on LCA. The methodology, “Application of the IISI LCI Data to Recycling Scenarios, 2005”, can be found in Appendix 17.4. This methodology has been incorporated within the GaBi 4 software for determining the LCI for the four steel case study products within the project. The methodology takes into consideration the ‘value of scrap’, i.e. the savings associated with recycling scrap at the end of a products life as well as the burden associated with the use of scrap within the steel production process.

12.3. Implementation

The IISI approach to account for the ‘value of scrap’ is implemented within the IISI LCI model as set-up in the LCA software system GaBi 4.

Figure 10 illustrates the implementation of the IISI methodology within GaBi 4:

All scrap use within the steel production process, for the integrated steel route as well as the electric arc furnace route, is considered via an upstream ecoprofile representing the ‘value of scrap’.

All scrap arising at the end of life is considered via a downstream credit in the amount of the 'value of scrap'. To assign an end of life credit, a material recovery rate is to be specified which represents in the best case the exact individual final product characteristic, but in most cases is considered as an average or sector-specific recovery rate.

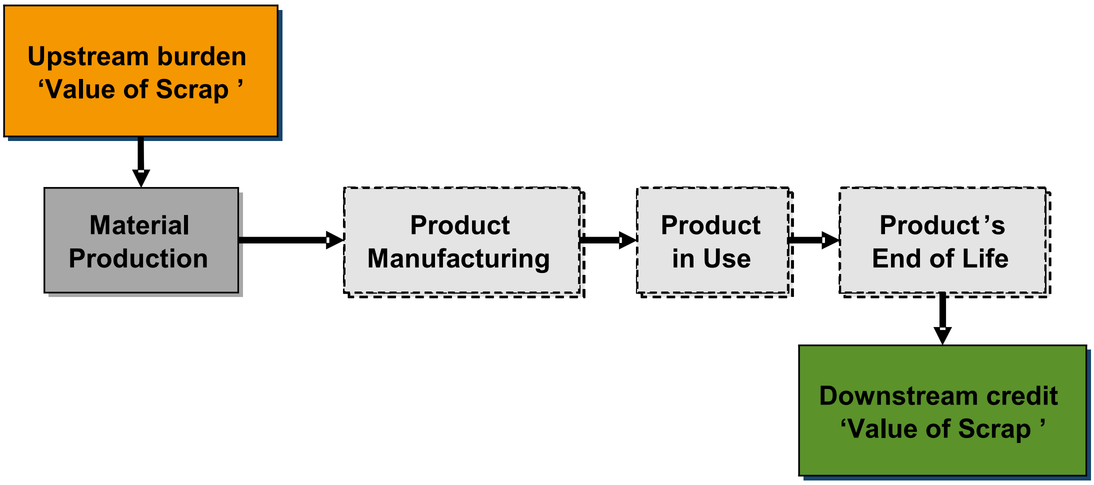


Figure 10: Schematic implementation of the IISI Recycling Approach

Even though Figure 10 includes the life cycle phases of product manufacturing, product in use and the product's end of life, the LCI data generated and provided by EUROFER and IISI does not include these life cycle steps. What is included is the material/steel production including the upstream burdens as well as the end of life scrap credit, which is considered in the 'value of scrap'.

The 'value of scrap' ecoprofile is calculated on the basis of the LCI data from the IISI LCI study in 2000 provided by IISI and following the IISI recycling methodology.

12.4. Outlook

The recycling methodology is incorporated within the IISI LCI data for the 14 steel products for which they provide data, and therefore the data that is provided on the European Commission's ELCD will also contain the credits and burdens associated with the scrap in the steel production process. The methodology has also been incorporated within the GaBi 4 modelling software for use within the individual case study products for this project. This model is available for use by IISI and other approved organisations and member companies.

13. PROJECT PART C: MATERIAL FLOW ANALYSIS

13.1. *Introduction and motivation for the MFA project*

The three project parts address different areas of work. With their complementary characteristic, they provide an important contribution to the achievement of the goals set. In view of the project package, the following logical relationship is given:

The very practical, first part addresses the **tool and communication** level of IPP: What kind of support is expected and needed by customers of the steel industry to cope with the requirements in the context of IPP and how should this information be presented? The result of the project is the concept of an Eco-Design package focussing on the actual industry needs.

The second part delivers the necessary **data and models** for the first part; LCA and LCI models according to the methodological settings of EUROFER: Which Life Cycle Inventories are to be applied how? The results are (generic) LCA models of steel applications (products) in the three main sectors considered within this project.

The third part delivers the necessary **material flow figures** to ensure high-quality results in the second part of the project: Which data is needed to determine the actual steel recycling rate of a generic product and which method to chose for this macro-economic material flow analysis?

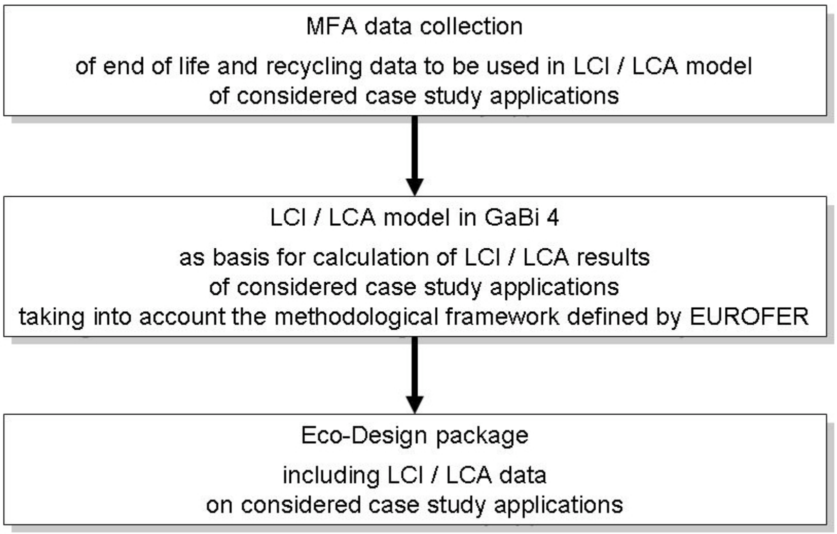


Figure 11: Correlation of Project A, B and C

Figure 11 highlights the correlation between project part A, the Eco-Design package, project part B, the LCI/LCA model(ling), as well as project part C, the MFA data collection. The figure gives a clear indication on the interrelated and systematic structure of the overall EUROFER IPP project.

13.2. *Goal of the MFA*

Whereas conventional MFA studies describe the material and energy flows into, throughout, and out of an economic system for a defined period of time, the specific goal of the work on MFA undertaken within the context of the EUROFER IPP project was to set up a high-quality data basis for calculating the (sector-specific) recycling rate(s) – to be applied in the LCI calculations of project part B.

Due to the functional unit approach of the product-related environmental assessment carried out within project part B, the recycling rate in this project is defined as the amount of material recycled compared to the material introduced into the product-system initially.

To address the differences of the product-systems under analysis within the overall EUROFER IPP project, the goal (and challenge) was to specify at least one average recycling rate per sector rather than to go for only one average recycling rate for steel.

The challenge of this task is due to the fact that ‘traditional’ MFA studies are based on assumptions specifying the sector-specific collection rates for steel scrap and that data on sector-specific scrap arising is, as a general rule, not available. In addition the ‘European steel Flow’ system is not closed and therefore the consideration of steel flows passing the European borders is required.

The sectors differentiated in the EUROFER IPP project are the following: Automotive, Construction, Machinery, Packaging, Consumer goods and Others.

13.3. General approach

The project approach was two-fold:

The first step was to identify an applicable Material Flow Analysis (MFA) method as a basis to provide data on sector-specific recycling rates for Project Part B. A key issue and important goal of Project Part C was therefore to carry out a ‘Critical Review of existing MFA methods. The second step covered the data collection and compilation on European steel flows on the basis of the selected MFA approach.

13.3.1. Critical Review of Material Flow Analysis (MFA) methods

The first step was to outline the different available MFA methods, their definition as well as the interaction with other MFA methods as shown in Figure 12.

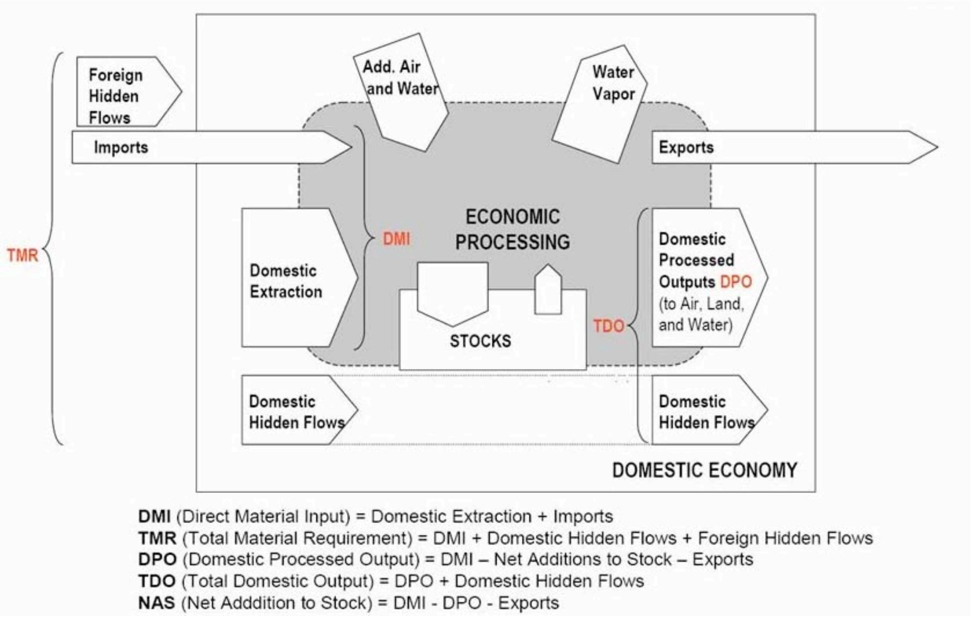


Figure 12: Interrelation of MFA methods [WRI, Matthews et al., 2000

13.3.1.1. Material Flow Analysis (MFA) Methods

Material Flow Analysis (MFA) Methods

The different MFA methods are described in detail below:

Direct Material Input (DMI):

The Direct Material Input (DMI) measures the direct input of materials for use into the economy. It also equals domestic (used) extraction plus imports and is not additive across countries [ETC-WMF 2003].

Total Material Input (TMI):

The Total Material Input (TMI) includes, in addition to DMI, also unused domestic extraction [ETC-WMF 2003].

Total Material Requirement (TMR):

The Total Material Requirement (TMR) includes, in addition to DMI, the upstream hidden material flows[1]. It must be stated that this term builds the best overall estimate for the potential environmental impact associated with natural resource extraction and use. Also, it measures the total ‘material base’ of an economy and is not additive across countries [ETC-WMF 2003].

Domestic Total Material Requirement (domestic TMR):

The Domestic Total Material Requirement (domestic TMR) includes domestic used and unused extraction and is additive across countries [ETC-WMF 2003].

Domestic Processed Output (DPO):

The Domestic Processed Output (DPO) measures the total output of materials, which have been used in the domestic economy and been transformed to emissions or wastes. Not included in the economy are recycled material flows, whereas the exported materials are excluded [ETC-WMF 2003].

Direct Material Output (DMO):

The Direct Material Output (DMO) represents the total quantity of material leaving the economy after use and is not additive across countries [ETC-WMF 2003].

Total Domestic Output (TDO):

The Total Domestic Output (TDO) includes, in addition to DPO, the disposal of unused extraction and represents the total quantity of material outputs to the environment caused by economic activity [ETC-WMF 2003].

Total Material Output (TMO):

---

[1] *Definition “hidden or indirect material flows (HF or IF)”: Indirect material flows that are associated with imports but take place (and predominantly burden the environment) in other countries*

The Total Material Output (TMO) measures the total amount of material that leaves the economy, but it is not additive across countries [ETC-WMF 2003].

Domestic Material Consumption (DMC):

The Domestic Material Consumption (DMC) measures the total amount of material directly used in an economy, i.e. excluding indirect/hidden flows. In addition, the DMC is defined in the same way as other key physical indicators such as gross inland energy consumption [ETC-WMF 2003].

Total Material Consumption (TMC):

The Total Material Consumption (TMC) measures the total material use associated with domestic production and consumption activities. It includes direct material consumption and the indirect/ hidden material flows and excludes exports and their associated indirect/ hidden flows [ETC-WMF 2003].

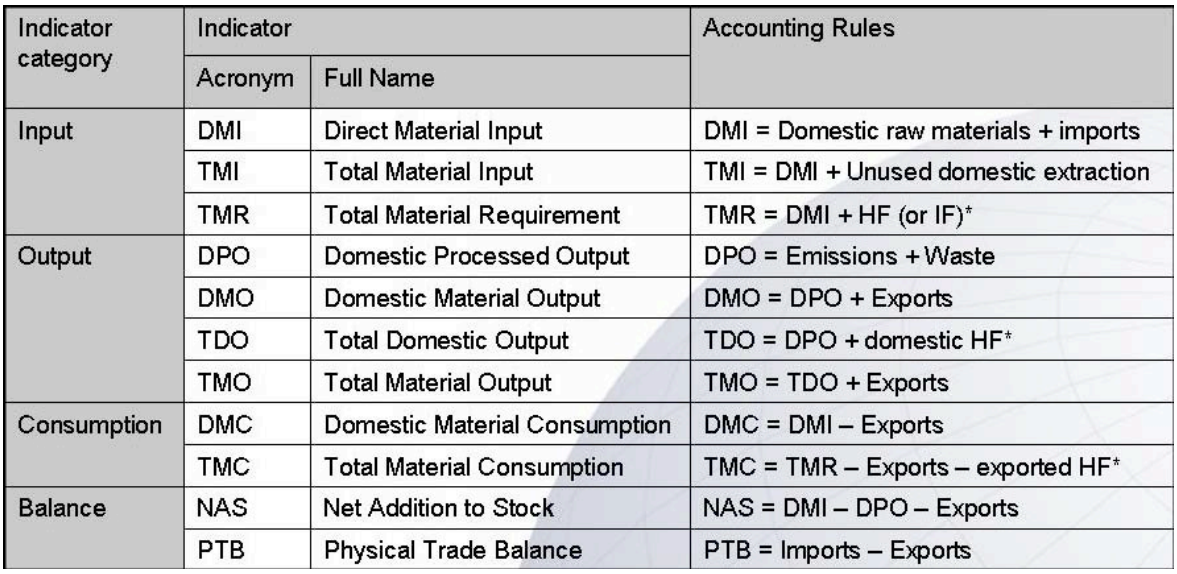
Net Addition to Stock (NAS):

The Net Addition to Stock (NAS) measures the 'physical growth of the economy' and the quantity of incorporated material, e.g. construction materials in infrastructure [ETC-WMF 2003].

Physical Trade Balance (PTB):

The Physical Trade Balance (PTB) measures the physical trade surplus or deficit of an economy. It may also be defined for indirect flows associated to imports and exports and indicates whether a region is a net-importer or net-exporter of materials [ETC-WMF 2003].

Table 5 gives an overview of available MFA methods as well as their specific accounting rules [ETC-WMF 2003], [OECD 2006] and interrelation.



Indicator category	Indicator		Accounting Rules
	Acronym	Full Name	
Input	DMI	Direct Material Input	DMI = Domestic raw materials + imports
	TMI	Total Material Input	TMI = DMI + Unused domestic extraction
	TMR	Total Material Requirement	TMR = DMI + HF (or IF)*
Output	DPO	Domestic Processed Output	DPO = Emissions + Waste
	DMO	Domestic Material Output	DMO = DPO + Exports
	TDO	Total Domestic Output	TDO = DPO + domestic HF*
	TMO	Total Material Output	TMO = TDO + Exports
Consumption	DMC	Domestic Material Consumption	DMC = DMI – Exports
	TMC	Total Material Consumption	TMC = TMR – Exports – exported HF*
Balance	NAS	Net Addition to Stock	NAS = DMI – DPO – Exports
	PTB	Physical Trade Balance	PTB = Imports – Exports

Table 5: Accounting rules of MFA methods

13.3.1.2. Discussion of MFA methods in the context of the EUROFER IPP Project

The 'recycling methodology' of the International Iron and Steel Institute (IISI), which is to be applied within the EUROFER IPP project, takes account of steel recycling at products' End-of-Life within LCI data by calculating the value of scrap.

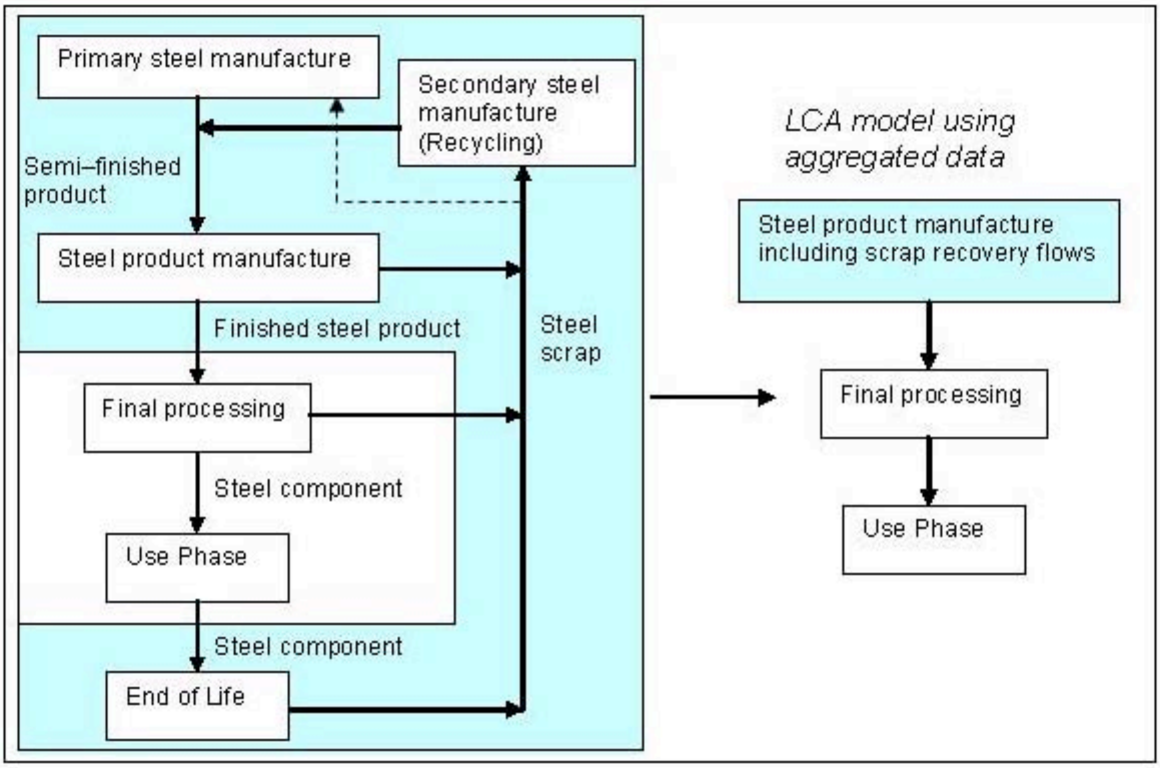


Figure 13: Recycling methodology by IISI [IISI RECYCLING]

The resulting LCI calculation formula for steel including the recovery of steel (scrap) at products' End-of-Life is as follows:

$$LCI_{Steel} = X' - [(RR - S) * Y (X_{pr}-X_{re})]$$

X': Finished steel product LCI

RR: Recovery rate as a function of the product characteristic

Y: Metallic yield of the recycling process

X_{pr}: LCI for the primary route

X_{re}: LCI for the recycling route

S: Scrap input, refers to the amount of scrap used to make the finished steel product

An essential parameter of the above described LCI calculation is the steel recovery rate as a function of the End-of-Life characteristic of the product. Within the EUROFER IPP project, the goal was to calculate sector-specific recycling rates as the product or product group specific data is even more difficult to obtain.

In principle there are two approaches to calculate sector-specific recycling rates:

A) "Retrospective analysis" of sector-specific recycling rates

Using available data for EU25 completed by necessary assumptions or expert judgements

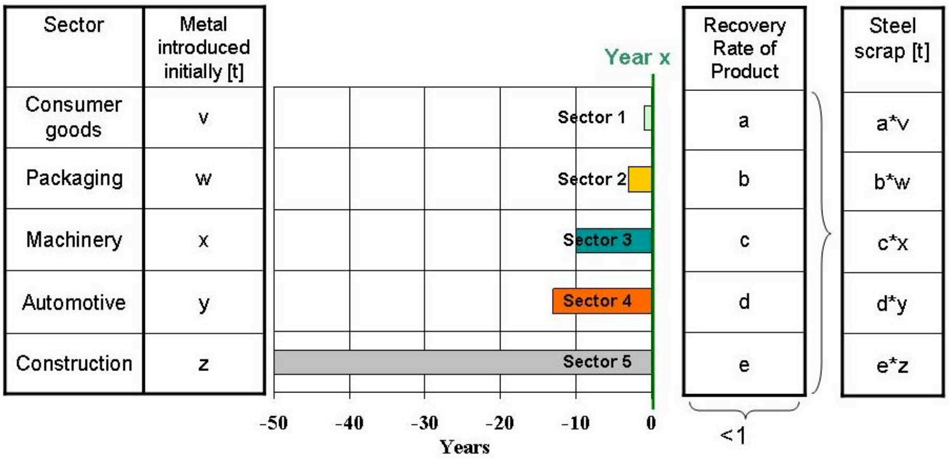


Figure 14: Retrospective analysis

B) “Forward looking analysis” of sector-specific recycling rates

Using available data on regulations, voluntary agreements using expert information, e.g. from recycling associations

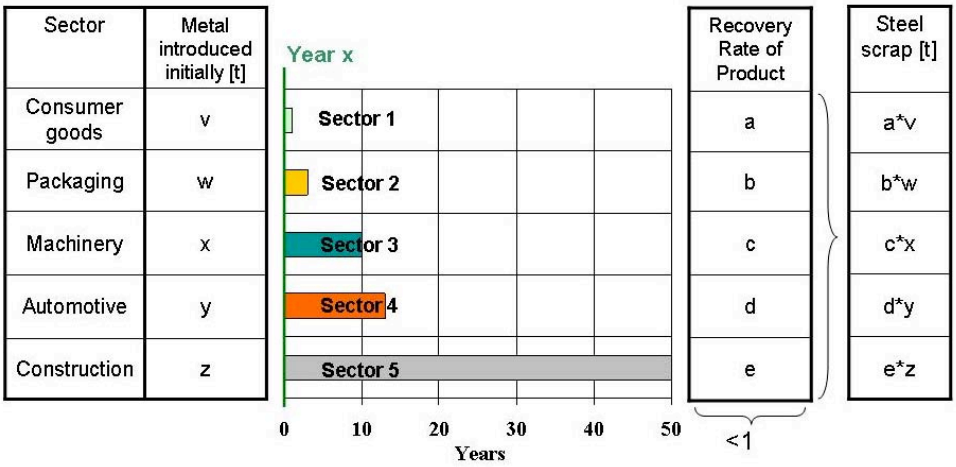


Figure 15: Forward looking analysis

Within the EUROFER IPP project approach A was applied.

13.3.2. MFA data collection

To work out precise data on the sector-specific steel cycle in Europe as a basis for the calculation of the recycling rates per sector, a generic MFA model was developed. The parameterised model is set-up in the standard LCA software system GaBi 4 and fulfils the following requirements:

- Management and administration of the MFA data
- Visualisation of the European steel cycle
- Consideration of the given interrelations between the different steel life cycle stages
- Calculation of main parameters, in particular the sector-specific recycling rate

Figure 16 shows the main stages of the steel life cycle which are taken into account within the parameterised MFA model.

The graph furthermore highlights the very specific aspect of this MFA model – defined by the goal of project part C: the model differentiates the main industrial sectors, e.g. automotive industry, building industry, etc., as well as the different European countries.

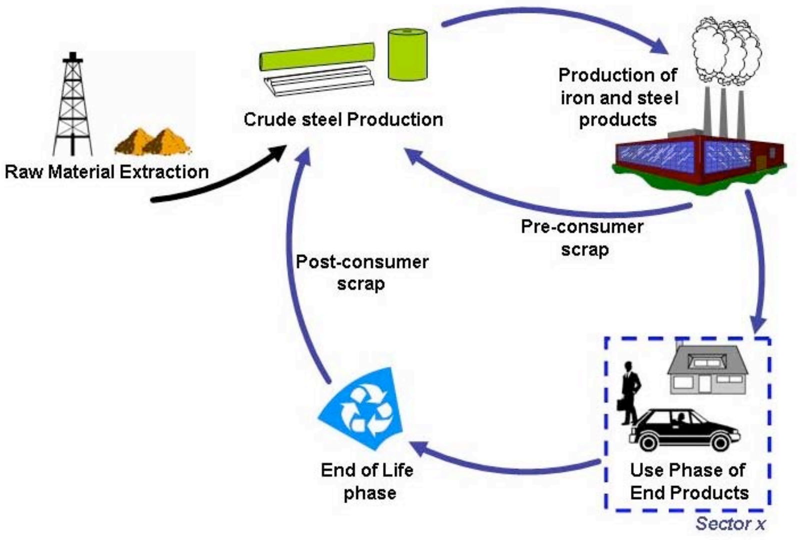


Figure 16: Sector-specific steel cycle

13.3.2.1. General model description

The main goal of the parameterised MFA model is the determination of the sector-specific recycling rates in Europe.

The recycling rate as considered within the EUROFER IPP project is defined as follows:

Amount of steel recycled compared to the steel introduced to the system initially [EUROMETAUX].

Whereby the system is specified by one of the six main sectors (automotive, construction, consumer goods, machinery, packaging and others) within the region Europe – or even more detailed, within one of the European countries.

For this reason a generic model was developed covering the main stages of the European steel life cycle, as shown in Figure 17, and describes the interrelation between those stages for each addressed sector.

The main stages of the steel life cycle considered in the model are:

- the domestic crude steel production
- the arising of home scrap[2], within the domestic crude steel production
- the domestic production of iron and steel intermediate products
- the import and export of iron and steel intermediate products
- the domestic consumption of iron and steel products as a result of the domestic production as well as their import and export

---

[2] Home scrap: Produced at the iron and steel works, this scrap is recycled internally.

- the arising of pre-consumer scrap[3] related to the domestic consumption of iron and steel intermediate products
- the amount of steel introduced to the different sectors via iron and steel intermediate products
- the amount of steel introduced to the different sectors via import and export of manufactured goods
- the theoretical sector-specific Post-consumer scrap[4] arisings
- the apparent domestic scrap supply

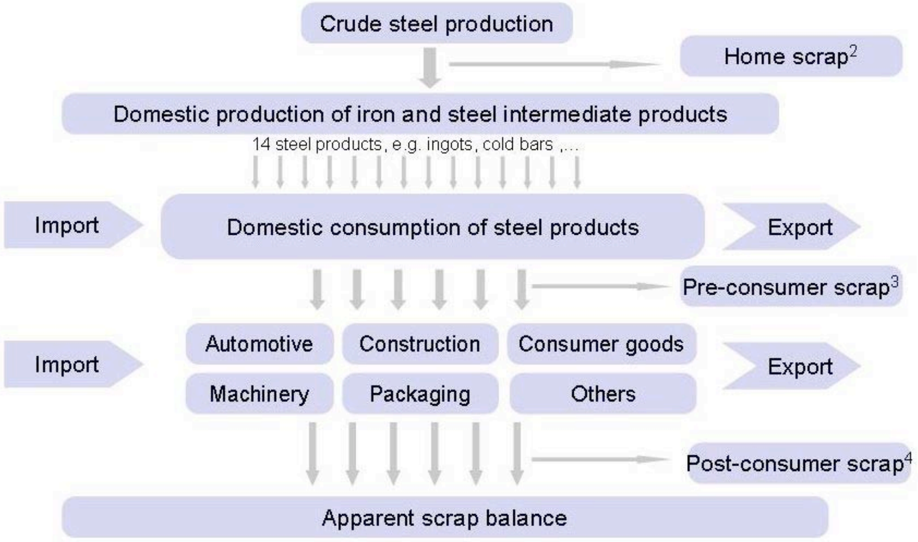


Figure 17: Generic MFA model in GaBi 4

13.3.2.2. Data availability

The following subchapter deals with the data status and availability of the sector-specific steel flows in Europe. A principle decision on the list of European countries to be considered (in detail) has to be made.

Domestic crude steel production

Explanation:

- Domestic crude steel production in a specific country/ region per year.

Data availability:

- The domestic crude steel production for the different European countries is available.

---

[3] Pre-consumer scrap: Pre-consumer material as defined in the ISO 14021 is “a material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.”

[4] Post-consumer scrap: Also known as End-of-Life scrap is defined in the ISO 14021 as “Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain

Data sources:

- [IISI], [EUROFER CRUDE]

Home scrap arising

Explanation:

- Home scrap arising at iron and steel works in a specific country/ region per year.
- The home scrap is recycled internally and therefore not part of the recycling rate calculation.

Data availability:

- The home scrap arising is calculated according to the following formula: Total domestic crude steel production minus crude steel contained in iron and steel intermediate products (via domestic production).

Data sources:

- [EUROFER CRUDE]

Domestic production of iron and steel intermediate products

Explanation:

- Domestic production of iron and steel intermediate products in a specific country/ region per year.

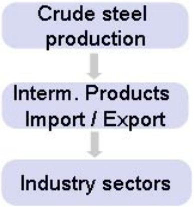
Within the EUROFER IPP project 14 types of iron and steel intermediate products are differentiated:

- Bars forged
- Cold Bars
- Drawn
- Hot rolled coils
- Hot rolled strip
- Ingots
- Medium and heavy

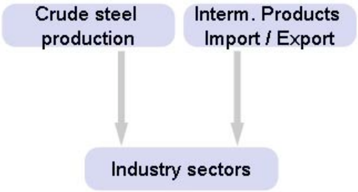
  plates less universals
- Other
- Railway
- Seamless tubes
- Semi finished

There are 2 possibilities:

1. To split up the crude steel production firstly into the 14 different domestic intermediate iron and steel products and then an allocation of the 14 different domestic intermediate iron and steel products into the 6 steel industry sectors as can be seen in Table 6.



2. To split up the crude steel production of a country as well as the imports and exports of the 14 different domestic intermediate iron and steel products into the 6 industry sectors as can be seen in Table 7.



- Semis forged
- Sheets and universals
- Welded tubes

This is necessary for calculating the industry / sector specific consumption of iron and steel intermediate products, because the imports and exports of these products only exists for the 14 iron and steel intermediate products (see section on Import/export of iron and steel intermediate products). So, this split of the crude steel production into the 14 intermediate products is essential to calculate the overall consumption of the intermediate products, containing the production, the imports and the exports of iron and steel intermediate products.

Data availability:

- Data not available!

Proposed Procedure:

- Use of average ratios to allocate available amount of crude steel to the different iron and steel intermediate products.
- Calculation of the total crude steel production through the Crude Steel Equivalent Factors (=CSE) for steel intermediate products from EUROFER data [EUROFER CRUDE]. The CSE Factor is a factor which is multiplied by the amount of the crude steel contained in intermediate steel products to calculate the total required crude steel for the intermediate products.
- Example: CSE Factor for intermediate product hot rolled strip = 1.20. This means that for the production of 1 ton of hot rolled strip 1.2 tons of crude steel is required.

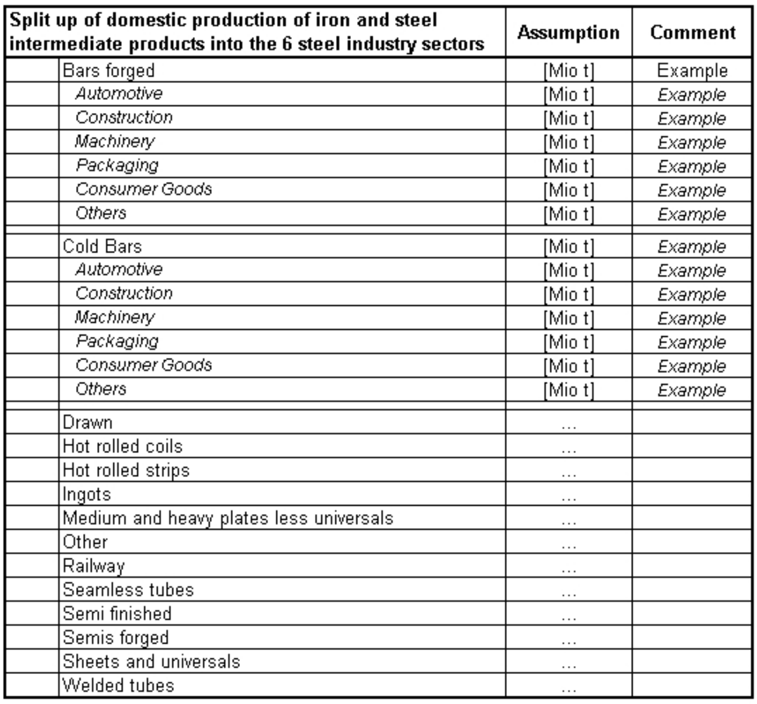
Data sources:

- [EUROFER CRUDE], [ICER REPORT 1998], [ELV]

Future necessary action:

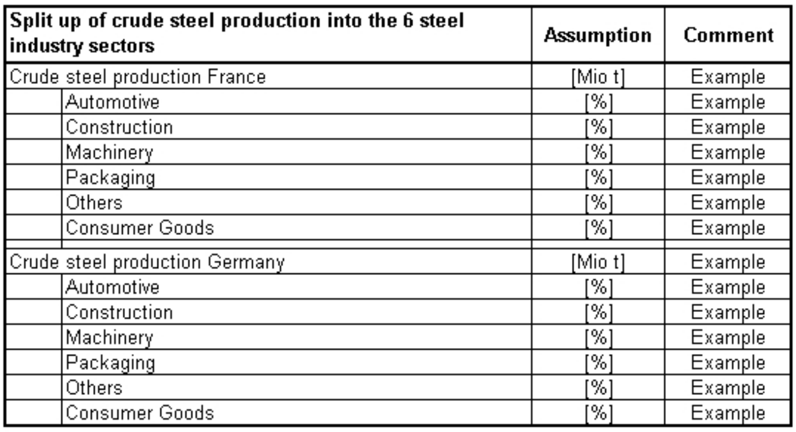
Potential future work that should be undertaken to improve the quality of the data:

- Country-/ region-specific split up of domestic crude steel production and their use respectively further processing into the iron and steel intermediate products
- Use of CSE factors as a basis for the calculation of the amount of iron and steel intermediate products per European country and year
- Specification of CSE factors per single European country and year(EU-25)



Split up of domestic production of iron and steel intermediate products into the 6 steel industry sectors		Assumption	Comment
	Bars forged	[Mio t]	Example
	Automotive	[Mio t]	*Example*
	Construction	[Mio t]	*Example*
	Machinery	[Mio t]	*Example*
	Packaging	[Mio t]	*Example*
	Consumer Goods	[Mio t]	*Example*
	Others	[Mio t]	*Example*
	Cold Bars	[Mio t]	*Example*
	Automotive	[Mio t]	*Example*
	Construction	[Mio t]	*Example*
	Machinery	[Mio t]	*Example*
	Packaging	[Mio t]	*Example*
	Consumer Goods	[Mio t]	*Example*
	Others	[Mio t]	*Example*
	Drawn	...	
	Hot rolled coils	...	
	Hot rolled strips	...	
	Ingots	...	
	Medium and heavy plates less universals	...	
	Other	...	
	Railway	...	
	Seamless tubes	...	
	Semi finished	...	
	Semis forged	...	
	Sheets and universals	...	
	Welded tubes	...	

Table 6: Allocation of iron and steel industry products per sector



Split up of crude steel production into the 6 steel industry sectors		Assumption	Comment
Crude steel production France		[Mio t]	Example
	Automotive	[%]	Example
	Construction	[%]	Example
	Machinery	[%]	Example
	Packaging	[%]	Example
	Others	[%]	Example
	Consumer Goods	[%]	Example
Crude steel production Germany		[Mio t]	Example
	Automotive	[%]	Example
	Construction	[%]	Example
	Machinery	[%]	Example
	Packaging	[%]	Example
	Others	[%]	Example
	Consumer Goods	[%]	Example

Table 7: Allocation of crude steel production per sector

Import/ export of iron and steel intermediate products

Explanation:

- Import and export of iron and steel intermediate products from and to a specific country/ region per year, Table 6.
- The import and export data specifies the 14 different intermediate product categories (see domestic production of iron and steel intermediate steel products and Table 7).

Data availability:

- Data of import and export for the 14 different iron and steel intermediate products is available.

Data sources:

- [EUROFER CRUDE]

Industry-/ sector-specific consumption of steel intermediate products

Explanation:

- The “Industry / sector specific consumption of steel intermediate products” contains the result of the crude steel production, the import and export of the iron and steel intermediate products, as well as the allocation of the 14 iron and steel intermediate products into the 6 industry sectors (automotive, construction, machinery, packaging, consumer goods and others) in a specific country per year.

Data availability:

- Data is available for the consumption of intermediate iron and steel products. This data is calculated.
- Data is not available for the allocation of the 14 iron and steel intermediate products to the 6 industry sectors.
- Different sources on iron and steel intermediate products is available containing 9 steel industry sectors and 12 iron and steel intermediate products (see Table 8)

Data sources:

- [EUROFER CRUDE], [EUROFER PROD]

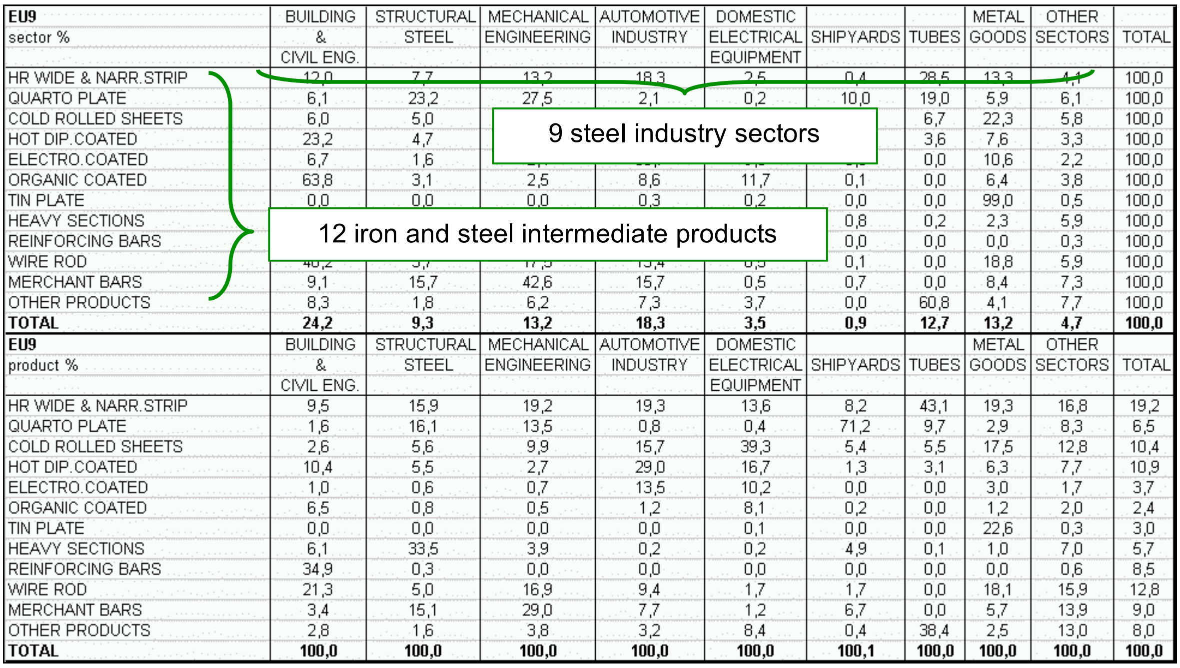
Proposed procedure

- Different sources of data relating to iron and steel intermediate products should be combined to set the basis for consistent data regarding the iron and steel intermediate products

Future necessary action:

Potential future work that should be undertaken to improve the quality of the data:

- Allocation of 14 steel intermediate products introduced to the 6 industry sectors (see Table 7).



EU9 sector %	BUILDING & CIVIL ENG.	STRUCTURAL STEEL	MECHANICAL ENGINEERING	AUTOMOTIVE INDUSTRY	DOMESTIC ELECTRICAL EQUIPMENT	SHIPYARDS	TUBES	METAL GOODS	OTHER SECTORS	TOTAL
HR WIDE & NARR.STRIP	12,0	7,7	13,2	18,3	2,5	0,4	28,5	13,3	4,1	100,0
QUARTO PLATE	6,1	23,2	27,5	2,1	0,2	10,0	19,0	5,9	6,1	100,0
COLD ROLLED SHEETS	6,0	5,0	[illegible]	[illegible]	[illegible]	[illegible]	6,7	22,3	5,8	100,0
HOT DIP.COATED	23,2	4,7	[illegible]	[illegible]	[illegible]	[illegible]	3,6	7,6	3,3	100,0
ELECTRO.COATED	6,7	1,6	[illegible]	[illegible]	[illegible]	[illegible]	0,0	10,6	2,2	100,0
ORGANIC COATED	63,8	3,1	2,5	8,6	11,7	0,1	0,0	6,4	3,8	100,0
TIN PLATE	0,0	0,0	0,0	0,3	0,2	0,0	0,0	99,0	0,5	100,0
HEAVY SECTIONS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0,8	0,2	2,3	5,9	100,0
REINFORCING BARS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0,0	0,0	0,0	0,3	100,0
WIRE ROD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0,1	0,0	18,8	5,9	100,0
MERCHANT BARS	9,1	15,7	42,6	15,7	0,5	0,7	0,0	8,4	7,3	100,0
OTHER PRODUCTS	8,3	1,8	6,2	7,3	3,7	0,0	60,8	4,1	7,7	100,0
TOTAL	**24,2**	**9,3**	**13,2**	**18,3**	**3,5**	**0,9**	**12,7**	**13,2**	**4,7**	**100,0**

EU9 product %	BUILDING & CIVIL ENG.	STRUCTURAL STEEL	MECHANICAL ENGINEERING	AUTOMOTIVE INDUSTRY	DOMESTIC ELECTRICAL EQUIPMENT	SHIPYARDS	TUBES	METAL GOODS	OTHER SECTORS	TOTAL
HR WIDE & NARR.STRIP	9,5	15,9	19,2	19,3	13,6	8,2	43,1	19,3	16,8	19,2
QUARTO PLATE	1,6	16,1	13,5	0,8	0,4	71,2	9,7	2,9	8,3	6,5
COLD ROLLED SHEETS	2,6	5,6	9,9	15,7	39,3	5,4	5,5	17,5	12,8	10,4
HOT DIP.COATED	10,4	5,5	2,7	29,0	16,7	1,3	3,1	6,3	7,7	10,9
ELECTRO.COATED	1,0	0,6	0,7	13,5	10,2	0,0	0,0	3,0	1,7	3,7
ORGANIC COATED	6,5	0,8	0,5	1,2	8,1	0,2	0,0	1,2	2,0	2,4
TIN PLATE	0,0	0,0	0,0	0,0	0,1	0,0	0,0	22,6	0,3	3,0
HEAVY SECTIONS	6,1	33,5	3,9	0,2	0,2	4,9	0,1	1,0	7,0	5,7
REINFORCING BARS	34,9	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,6	8,5
WIRE ROD	21,3	5,0	16,9	9,4	1,7	1,7	0,0	18,1	15,9	12,8
MERCHANT BARS	3,4	15,1	29,0	7,7	1,2	6,7	0,0	5,7	13,9	9,0
OTHER PRODUCTS	2,8	1,6	3,8	3,2	8,4	0,4	38,4	2,5	13,0	8,0
TOTAL	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,1**	**100,0**	**100,0**	**100,0**	**100,0**

Table 8: Country specific intermediate steel products

Pre-consumer scrap arising

Explanation:

- Generated in the manufacturing of various goods in a specific country per year.

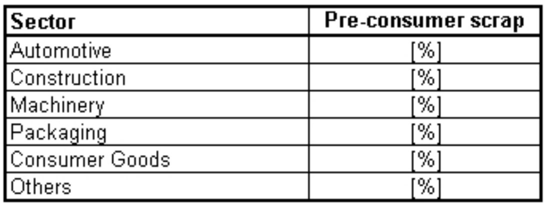
Data availability:

- No data available.
- The pre-consumer scrap arisings are not reported during manufacturing of various goods.

Future necessary action:

Potential future work that should be undertaken to improve the quality of the data:

- Definition of pre-consumer scrap arising within the 6 steel industry sectors (see Table 9).



Sector	Pre-consumer scrap
Automotive	[%]
Construction	[%]
Machinery	[%]
Packaging	[%]
Consumer Goods	[%]
Others	[%]

Table 9: Sector specific pre-consumer scrap

Amount of steel introduced to the different sectors via import/ export of consumer goods

Explanation:

- The imports and exports of consumer goods containing steel within the 6 industry sectors automotive, construction, machinery, packaging, consumer goods and others, in a specific country per year.

Data availability:

- Data not available
- The amount of imports and exports of consumer goods containing steel end products is not easy to determine, because statistics predominantly report monetary flows instead of product flows. No statistics are available for final end flows in each industry sector.

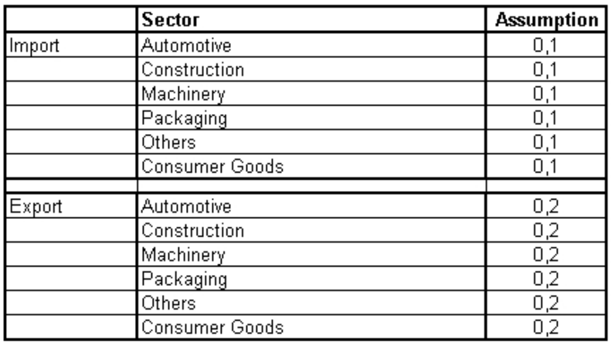
Data sources:

- Sector: Automotive: [ACEA ELC 2005], [ANFAC 2006], [ELV]
- Sector: Consumer goods: [ICER Report 1998], [EU Directive WEEE]
- Sector: Packaging: [EUROFER 2006], [IISI Can 2003], [IISI Packco 2002], [Anfima 2004]

Future necessary action:

Potential future work that should be undertaken to improve the quality of the data:

- Quantification of the share of net imports and exports of final steel end products introduced to the country-specific market (see Table 10)



	Sector	Assumption
Import	Automotive	0,1
	Construction	0,1
	Machinery	0,1
	Packaging	0,1
	Others	0,1
	Consumer Goods	0,1
Export	Automotive	0,2
	Construction	0,2
	Machinery	0,2
	Packaging	0,2
	Others	0,2
	Consumer Goods	0,2

Table 10: Possible split of net import/ export of end products

Data sources:

- [IISI Can 2003], [IISI Packco 2002], [EU Directive WEEE], [ELV]

Sector-specific End-of-Life scrap arising

Explanation:

- Total amount of scrap arising for the 6 industry sectors for a country per year

Data availability:

- Data not available
- Data for scrap arising in a country per year is available. No ratio is available for the split of the scrap arising between the 6 steel industry sectors.

Data sources:

- [IISI]

Future necessary action:

Potential future work that should be undertaken to improve the quality of the data:

- Split up of the End-of-Life scrap arising into the 6 steel industry sectors.

Lifetime of manufactured goods

Explanation:

- The amount of time for which manufactured goods are used.

Data availability:

- Data available.
- Variation throughout different sources

Data sources:

- [IISI Lifetime], [Arcelor], [Biffaward 2004]

The following lifetimes were chosen by EUROFER:

Sector	Lifetime [years]
Automotive	12
Construction	60
Consumer goods	13
Machinery	25
Packaging	1
Others	5

Apparent domestic scrap supply

Explanation:

- Calculated as the scrap consumption in a country in a specific year plus the scrap exports of a country in a specific year minus the scrap imports of a country in a specific year.

Data availability:

- Data is available for the apparent domestic scrap supply from 1975 – 2004 for specific countries (see Figure 18) [IISI].
- Data/ forecasts are not available for the future. An extrapolation has been calculated, delivering forecasts for the apparent domestic scrap supply for the future (in this case until 2010). As an example, Table 11 shows an extrapolation for the apparent domestic scrap supply for Germany.

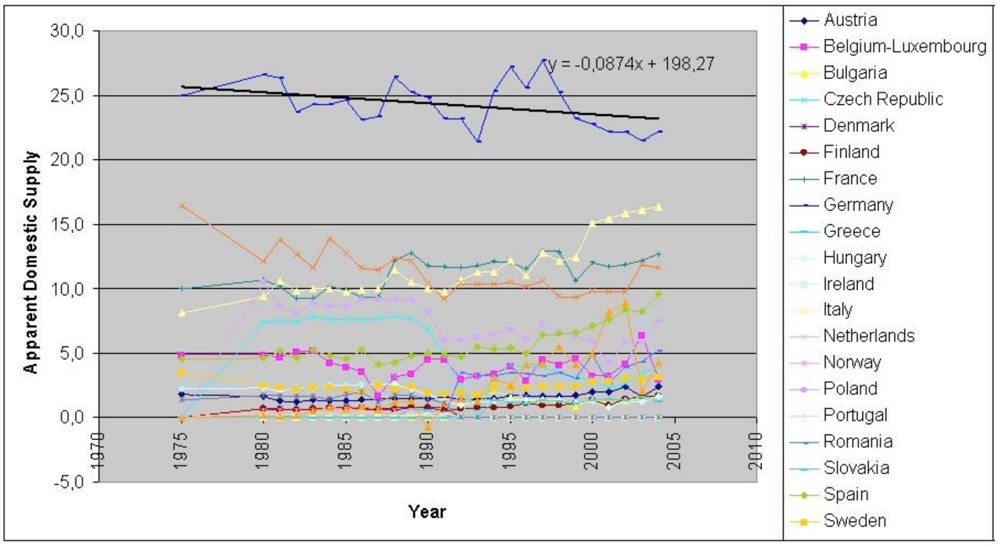


Figure 18: Extrapolation of the apparent domestic scrap supply

Extrapolation for 2005-2010	Consumption	Import	Export	Apparent Domestic Supply
2005	18,0	3,4	8,5	23,0
2006	17,8	3,5	8,7	22,9
2007	17,5	3,5	8,9	22,9
2008	17,3	3,6	9,1	22,8
2009	17,1	3,7	9,3	22,7
2010	16,9	3,8	9,5	22,6

Table 11: Extrapolation of domestic scrap supply for Germany

Data sources:

- [IISI]

Future necessary action:

Potential future work that should be undertaken to improve the quality of the data:

- Agreement on extrapolation of the domestic scrap supply for a specific country

13.4. Comparison to the Japanese MFA study

The pictorial image of the MFA data of the Japanese study (Figure 19) is based on annually collected data of inputs and outputs within Japan as well as assumptions and dynamic models, which has been developed to determine the steel discarded from a society [Government JP], [NIMS 2004],[Shimada 2002],[Jema 2003],[Industry Japan 2003].

The steel consumption data is based on the data obtained from statistics, which is published by the government and the Japanese Iron and Steel Federation (JISF).

- The amount of steel discarded from a society is estimated by a dynamic approach
- The life-time distribution is based on assumptions for each end-use product
- The end-use products are also categorized into different sectors
- The End-of-Life collection rates of each end-use category are based on assumptions

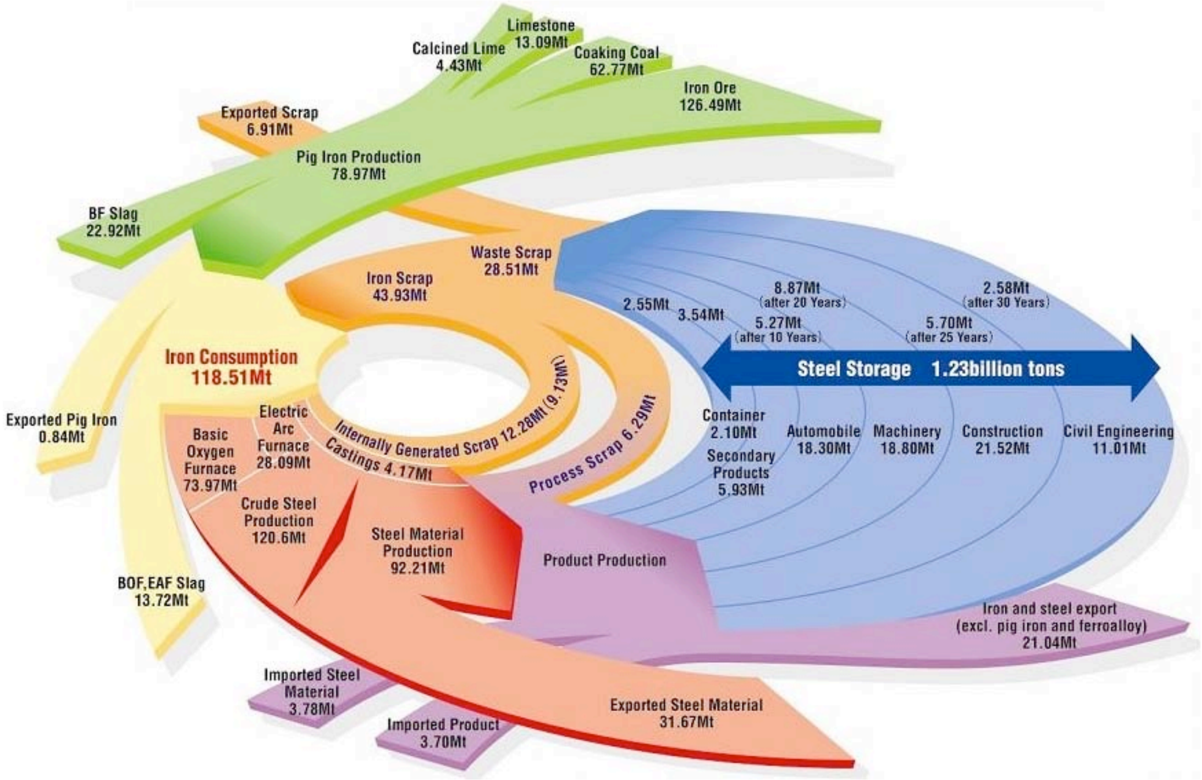


Figure 19: Illustration of steel flows through the Japanese society

Table 12 below gives an overview of and compares the specific MFA approach developed and applied by PE / LBP with the Japanese MFA approach.

Data	PE / LBP MFA model	Japanese MFA model
Crude steel production	The crude steel production for a specific European country is given by different EUROFER statistics.	The Japanese crude steel production is given through statistics.
Home scrap	The home scrap of the crude steel production is calculated by statistics via the CSE Factors given by EUROFER.	The home scrap (Japan: in-house scrap) is not considered in the Japanese MFA model.
Domestic production of iron and steel intermediate products	The domestic production of iron and steel intermediate products for a specific European country is given by different EUROFER statistics. A split of the domestic production of iron and steel intermediate products is given by using a distribution provided by EUROFER.	The Japanese MFA model doesn't use the domestic iron and steel intermediate products and therefore they are not reported. (Split of crude steel production directly into the 5 steel industry sectors)
Net import/ export of iron and steel intermediate products	The net import/ export of iron and steel intermediate products for a specific European country are given by EUROFER statistics.	The Japanese MFA model doesn't use the net import / export of iron and steel intermediate products and therefore they are not reported.
Industry / sector specific consumption of steel intermediate products	The steel consumption for a specific European country is calculated by different EUROFER statistics. End use products are categorised into 6 steel industry sectors by using a distribution given by EUROFER.	The steel consumptions are based on the data obtained from statistics, which is published by the Japanese government and the Japanese Iron and Steel Federation (JISF). The categorisation of the crude steel production into the different sectors (automobiles, machines, construction, containers and other products) is taken from statistics reported throughout the Japanese government.
Net import/export of end products	The net import/export of end products has to be estimated.	The crude iron, steel products, scrap and indirect export of steel by products are reported and given through statistics.
Sector-specific scrap arising	Sector-specific scrap arising in a country per year is available. Ratio of the scrap arising allocated into the 6 steel industry sectors in a country per year have to be estimated.	For the amount of steel discarded from a society the pinch analysis method was used, which means the balance between the supply of scrap (obsolete scrap) and pig iron and the demand for crude steel. The split of the sector specific scrap (Japan: obsolete scrap) is done by using lifetime distributions (Weibull), additional parameters and collection ratios (assumed) of each type of product using steel.
Pre-consumer scrap arising	The pre-consumer scrap of different steel intermediate products is estimated	The pre-consumer scrap (Japan: processing scrap) is reported by statistics (guideline from the Japanese government).
Apparent domestic scrap supply	The apparent domestic scrap supply of a specific country is provided by IISI; forecasts for the scrap arising in the future are extrapolated using IISI statistics.	The Japanese MFA model doesn't use the domestic iron and steel intermediate products and therefore they are not reported.
Lifetime of end products	Lifetime distribution of end	The lifetime distributions are calculated via the

	products for the 6 steel sectors is taken from different statistics (EUROFER and ARCELOR).	Weibull distribution (commonly used distribution to simulate life expectancies of products).

Table 12: Comparison of different MFA models

The following End-of-Life collection rates, which are based on assumptions, were applied within the Japanese MFA model: Automobiles: 90%, Construction: 50%, Machines: 80%, Containers: 93%, Others: 80%

13.5. Conclusions / Interpretation

As a conclusion of the MFA task as outlined above and carried out within the EUROFER IPP project, the data available on European steel flows did not meet the requirements with respect to the specified goal of Project Part C.

Nevertheless a comprehensive and sustainable system was established which comprises the EUROFER MFA approach, the EUROFER MFA model as well as the linkages to available data sources from the steel industry. In addition to the data management system, the data gaps of relevance were identified to support future activities in this field.

One additional important outcome of Project Part C was the gained knowledge on available data and data sources within the steel industry. In particular, the consistency or inconsistency between the single data sources became clear as well as identifying the requirement for further coordination on a national, international and organisational level.

The discussions in the context of Project Part C showed that it is crucial to promote the closed material loop characteristic of steel.

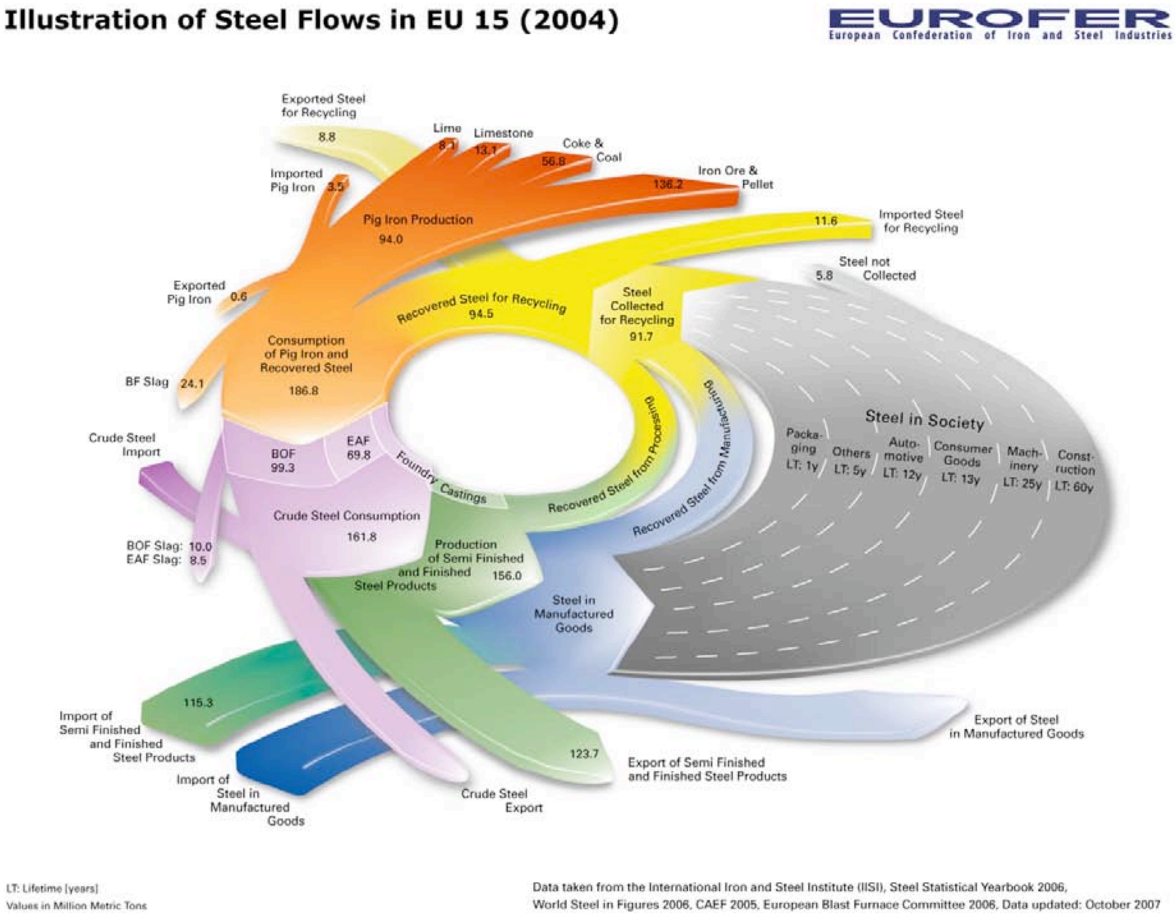
For this reason an additional task was defined in the context of Project Part C, to come up with an illustration of the European steel flows similar to the Japanese MFA graph, which is shown in Figure 20.

The data on lime, limestone, coke and coal, ore and pellet, BF slag as well as EAF/BOF slag results from an expert judgement of the Blast Furnace Committee. For the conversion from pig iron into iron a conversion factor of 0.953 was applied after consultation with the Blast Furnace Committee.

From the IISI Statistical Yearbook 2006 (version December 2006), data were taken for the import, export and production of pig iron, the BOF and EAF production as well as the crude steel consumption and the production, the export and import of semi finished and finished steel products. The crude steel production can be calculated by the crude steel consumption adding the crude steel exports subtracting the crude steel imports. The same rule applies for the calculation of the production of semi finished and finished steel products (consumption of semi finished and finished steel products - import of semi finished and finished steel products + amount of export of semi finished and finished steel products).

Additional data for recycled steel and the imported and exported steel for recycling were taken from the IISI World Steel in Figures 2006 [IISI 2006]. The recovered steel for recycling is calculated by the steel collected for recycling adding the import of steel collected for recycling and subtracting the export of steel collected for recycling.

The data for the EU 15 foundry castings (iron, steel and malleable iron castings) were taken from the European Foundry Association [CAEF].



LT: Lifetime [years]
Values in Million Metric Tons

Data taken from the International Iron and Steel Institute (IISI), Steel Statistical Yearbook 2006, World Steel in Figures 2006, CAEF 2005, European Blast Furnace Committee 2006, Data updated: October 2007

Figure 20: Illustration of Steel Flows within EU 15, Reference Year: 2004

14. LIFE CYCLE COSTING

14.1. Goal

The review on Life Cycle Costing (LCC) approaches is undertaken with specific consideration and focus on the possible application of LCC information at EUROFER

It was clearly stated that a pragmatic review approach should be followed with the main goal to get a first insight into the topic of LCC and to have an information basis to discuss the use of LCC at EUROFER member companies.

This report is only used as an internal knowledge basis for EUROFER.

The critical review of LCC methodologies considers:

- The application and use of LCC as well as requests of LCC information in practice
- The intended application of LCC information at EUROFER
- The use of LCC features provided in GaBi 4

The critical review of LCC methodologies is seen as a basis for a decision on an "LCC strategy" at EUROFER as well as a knowledge basis / reference on LCC in general within the steel industry.

14.2. Characteristic of Life Cycle Costing

In comparison with other life cycle related approaches, e.g. the methodology of Life Cycle Assessment (LCA), significant characteristics are to be highlighted in the context of LCC.

14.2.1. Definition of Life Cycle Costing

Life Cycle Cost:

"All costs associated with the life cycle of a product that are directly covered by any one or more of the actors in the product life cycle (supplier, producer, user/ consumer, EoL-actor) with complementary inclusion of externalities that are anticipated to be internalised in the decision-relevant future."

Source: definition modified by [Rebitzer and Hunkeler 2003] on the basis of the definition of [Blanchard, Fabrycky 1998]

Life Cycle Costing (LCC):

Assessment of life cycle cost, which is considered to be the sum of the acquisition cost and the ownership cost.

14.2.2. System Boundaries

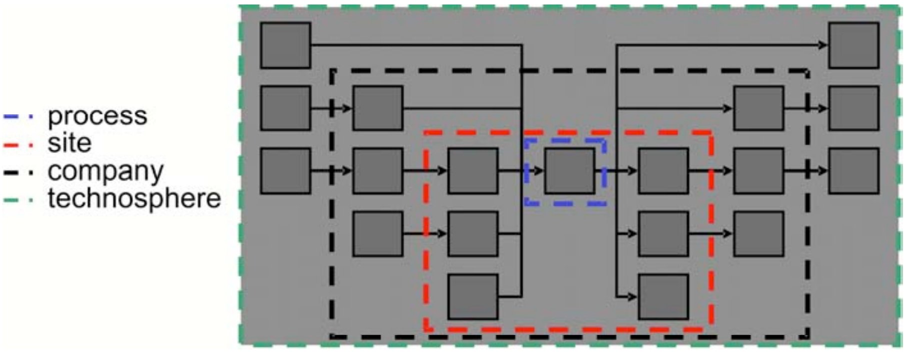


Figure 21: Schematic sketch of system boundaries

Within an environmental life cycle analysis the system boundaries are defined by the product life cycle view with the techno sphere as the system boundary.

Within an economic analysis, by tradition the system boundaries are defined by the company specific boundaries, e.g. the process or site as system boundary with cost centres.

14.2.3. Data

For all types of analyses, the data availability is a key issue. Figure 22 and Figure 23 illustrate the data of relevance for LCA balancing.

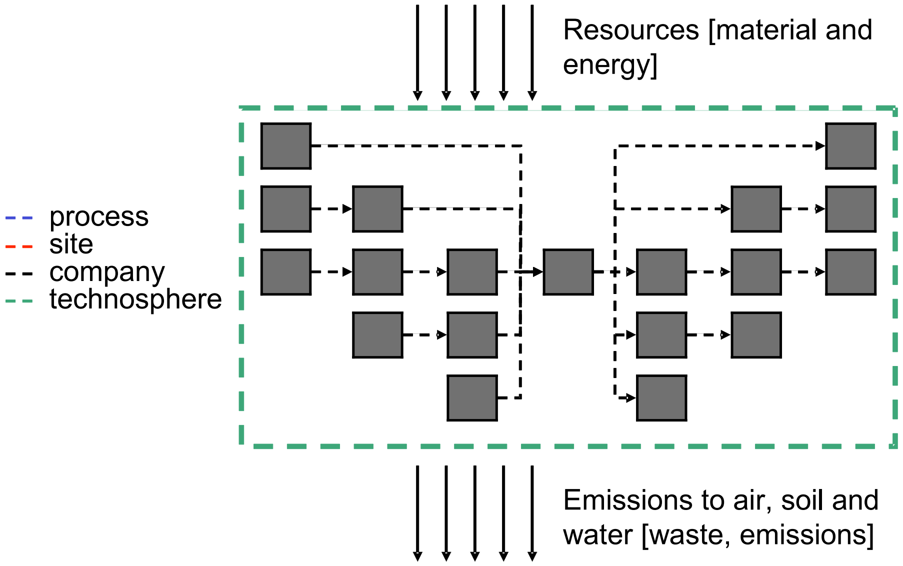


Figure 22: Data categories of relevance for LCA – schematic view

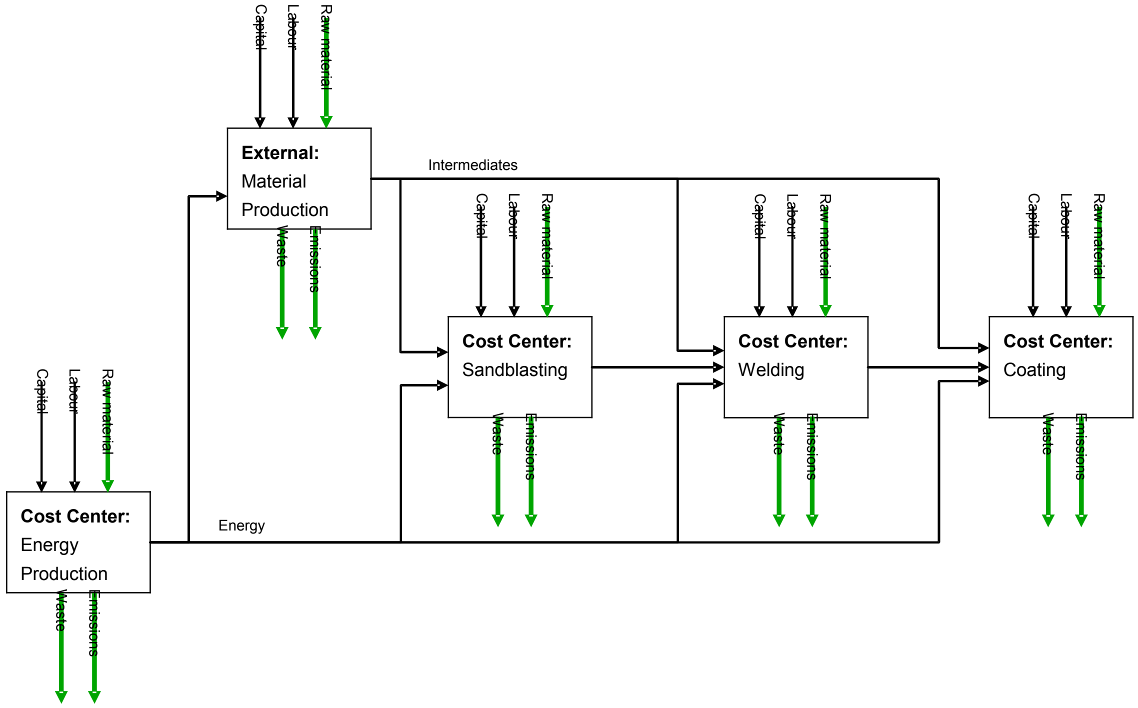


Figure 23: Data categories of relevance for LCA - in detail

Figure 24 and Figure 25 illustrate the data of relevance for a cost accounting activity.

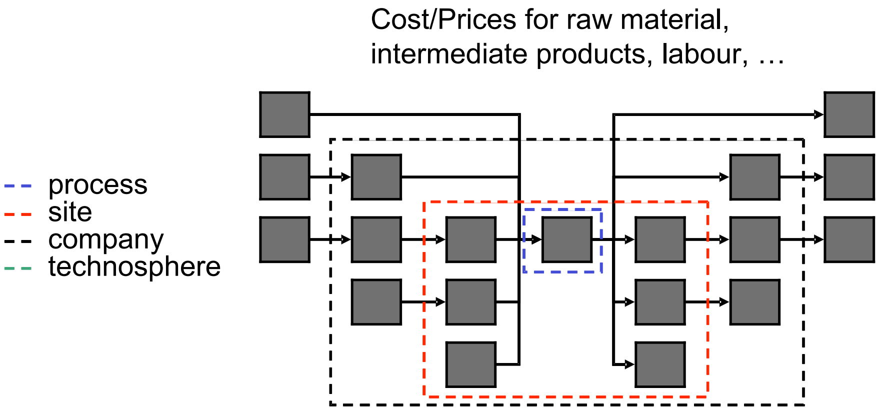


Figure 24: Data categories of relevance for Cost Accounting – schematic view

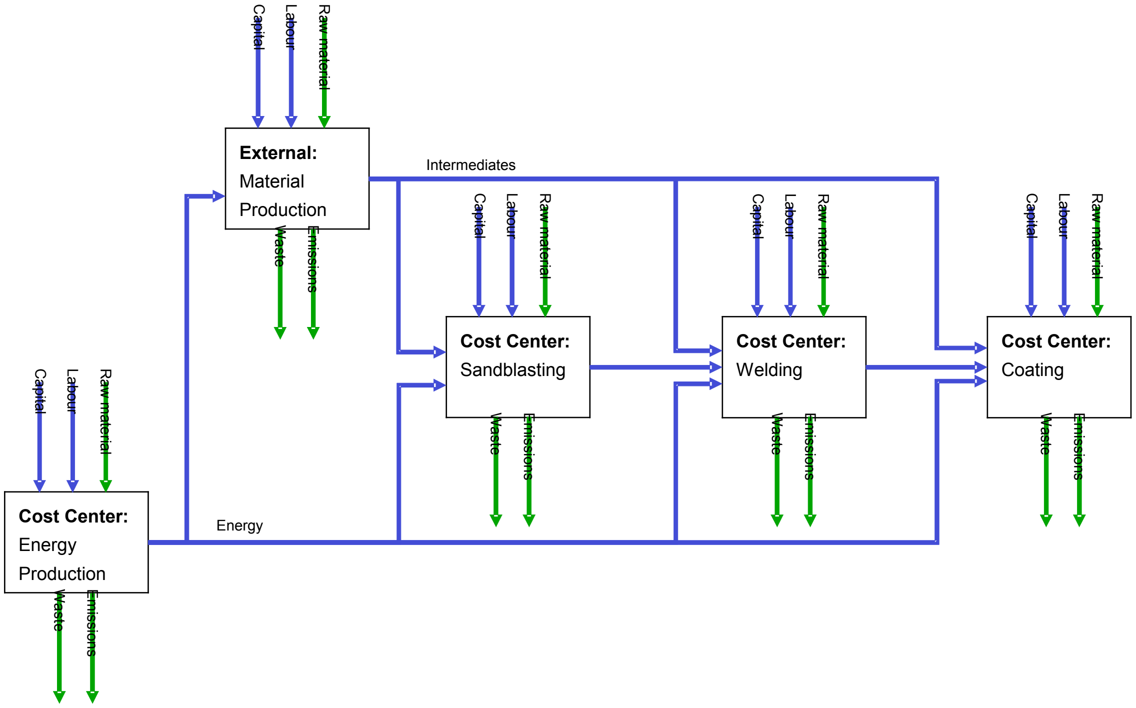


Figure 25: Data categories of relevance for Cost Accounting - in detail

Within a product-related environmental analysis the environmental information is aggregated over the life cycle of a product to get the total environmental burden, the so-called environmental rucksack.

The “rucksack-principle” within an economic analysis has to deal with the fact that price information is not just based on the sum of costs, but the price includes the costs as well as the profit.

14.2.4. Goals of Life Cycle Costing

What is the reason for carrying out a Life Cycle Costing (LCC) analysis? What are the principles followed within an LCC study?

In the following sub-chapters the different possible goals of an LCC analysis are described and discussed. Goals covered by this report are the inclusion of external effects into price considerations (= monetisation of external effects), the inclusion of customer needs into product development (= total cost of ownership) as well as the joint product development in a group of companies along the supply chain (= total production cost).

14.2.4.1. Monetisation of external effects

The transfer of environmental damage into an economic dimension (in €):

- Willingness to pay
- Cost for avoidance of environmental impacts
- Cost for repair of environmental impacts

Example:

NOx emissions in the use phase of a passenger car ⇒ Acidification potential

- Possible damage of cultural heritage by the acid rain
- Possible death of trees

Obviously the tax payer e.g. the consumer has to pay the bill.

The consumer is/should be interested in the external costs of his product choice, i.e. the costs not included within the price of the product.

Monetisation concepts: Willingness to pay

Concept:

The customer is informed about the environmental performance of different product variants, e.g. damage potential of cultural heritage by acid rain, potential of deaths of trees etc.

The customer is asked what additional price he would pay for the more environmental friendly product = “Willingness to pay”

The additional money that the customer is willing to pay can be spent on eco-design or end-of-pipe technologies

Criticism:

The customer is usually not well informed about the environmental performance of product variants

The customer often states his “willingness to pay if only he had the money”

Monetisation concepts: Cost for avoidance of environmental impacts

Concept:

Knowledge about cost for end-of-pipe technologies such as filters, off-gas treatment or incineration.

Criticism:

What is the reference system? Avoidance of environmental impacts to what extent? Is it possible to achieve zero emissions?

Monetisation concepts: Cost for repair of environmental impacts

Concept:

Certain knowledge about the cost for repair of environmental impacts, e.g. renovation of acid rain-damaged cultural buildings

Criticism:

Not all environmental impacts can be repaired: Is it possible to “repair” dying trees?

When is the environmental impact repaired: Is planting a new tree a solution? Will the new tree die from the same cause?

Conclusion:

All monetisation concepts for inclusion of external effects are carried out, but are most likely to end up with more questions and uncertainties than before.

14.2.4.2. Total cost of ownership

Concept:

Looking at the product life cycle from the consumers viewpoint and is of particular interest if:

- the product has a cost intensive use phase
- the product has a cost intensive end-of-life

Examples for products with cost intensive use or end-of-life phase: buildings, copy machines, cars etc.

Criticism:

Good and applicable concept for certain products only (see examples)

Relevant information for customers and can therefore be used for marketing

Does NOT include external effects

14.2.4.3. Total production cost

Situation:

Joint product development of a group of companies along the supply chain, however,

Problem:

Price formation for a product where no market exists so far

Price ≠ sum of the costs

Concept(s):

Willingness to pay, but no reliable concept, see above

Price is calculated from costs and wanted return of investment

Criticism:

Good concept, but only applicable in the case of joint development

Does NOT include external costs

14.2.5. Timing

An analysis of LCC can be carried out in all phases of a product's life cycle, e.g. to support decision making processes. Nevertheless, an early identification of costs and their drivers gives more opportunity of balancing goals against life cycle costs. This is underlined by the fact that 80% of the life cycle costs are determined by decisions that are made within the first 20% of the life cycle of the product / project.

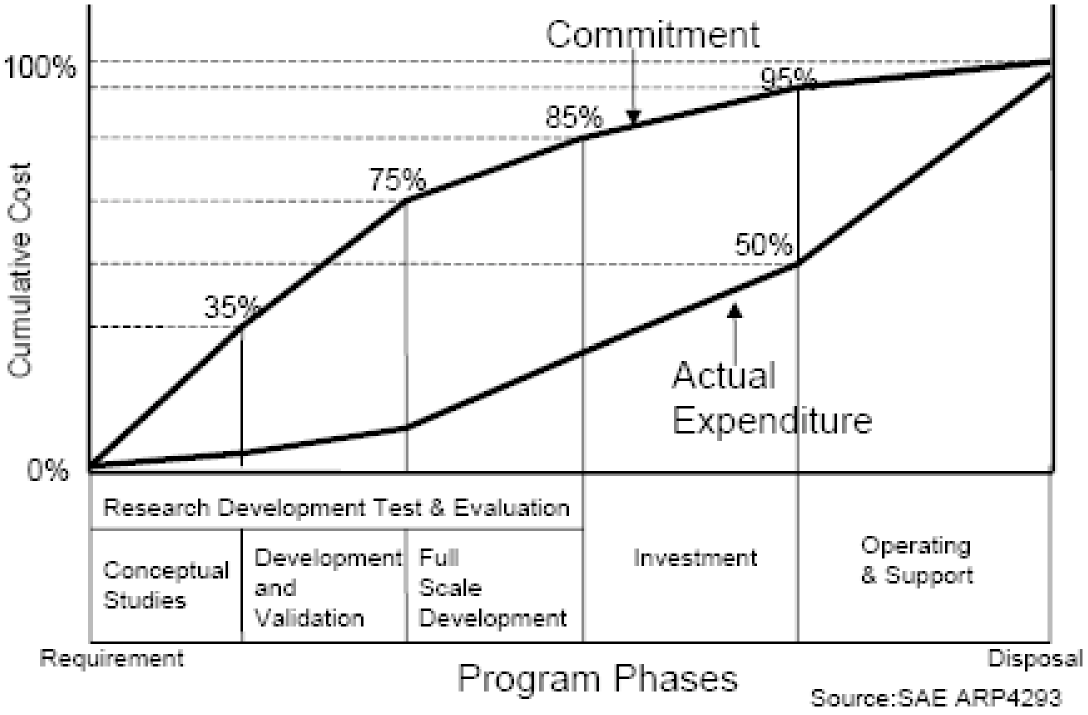
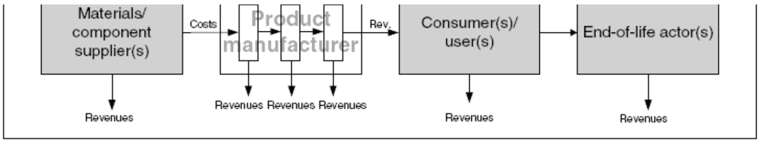


Figure 26: Life Cycle Cost (LCC) analysis in oil and chemical process industries, Kawauchi et al, 1999, http://www.ntnu.no/ross/reports/lcc.pdf

14.2.6. Viewpoint of LCC analysis

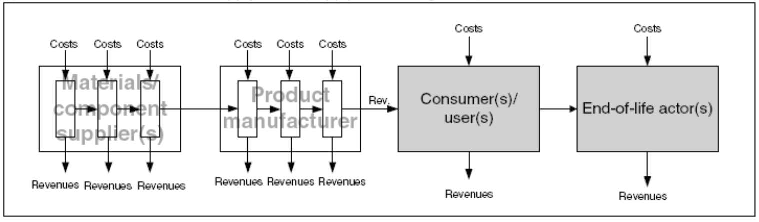
Life Cycle Costing (LCC) includes all costs paid for and revenues received by all the parties which take part in the products life cycle.

However, LCC is usually performed by one of these parties in order to calculate the economic consequences of investment decisions for its own benefit.



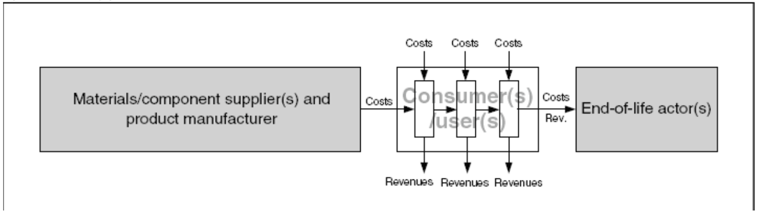
Product manufacturer

b) Product manufacturer and supply chain (supply chain integration)



Product manufacturer and supply chain

c) Consumer(s)/users



Consumer(s) / Users

Figure 27: Viewpoints of Life Cycle Costing Analysis

14.2.7. Internal / External costs

Throughout the life cycle of a product, internal and external costs are to be differentiated between.

Internal Costs throughout the life cycle of a product:

- Someone (a producer, consumer or other directly involved stakeholder) is paying for the production, use or end-of-life expenses
- All the costs and revenues within the economic system
- Differentiation of costs inside or outside of an organisation, depending on the perspective.

External costs throughout the life cycle of a product:

- Inclusion of monetized effects of environmental and social impacts not directly billed to the firm, consumer, or government
- These are the so-called “externalities” which are popular in LCC and LCA debates, and which are outside the economic system, though inside the natural and social system.

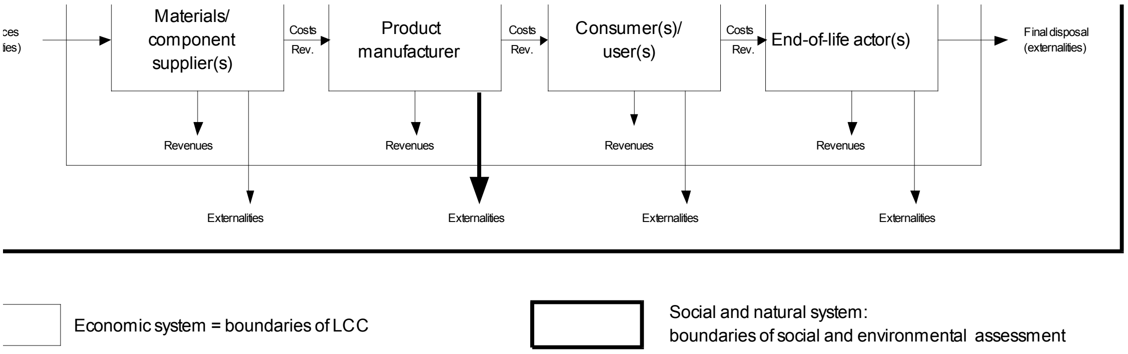


Figure 28: System boundaries for internal/external costs

14.3. *Critical review of LCC methodologies*

14.3.1. Application

Of high importance in terms of the scope of and approach followed within an LCC study is the intended application of the outcome and results.

Selection of application examples:

- Evaluation and comparison of alternative design
- Assessment of economic viability of projects / products
- Identification of cost drivers and cost effective improvements

- Evaluation and comparison of alternative strategies for product use, operation, test, inspection, maintenance, etc.

- Evaluation and comparison of different approaches for replacement, rehabilitation/life extension or disposal of ageing facilities

- Optimal allocation of available funds to activities in a process for product development / improvement

- Long term financial planning

14.3.2. Cost Modelling

There are different LCC cost models available and used in practice to quantify the cost effects.

Investment Appraisal models

- Investment is the conversion from capital to goods. Distinction between static methods and dynamic methods.

- For LCC calculation models, investment appraisal is part of the models but cannot cover the whole Life Cycle. Accounting methods are needed.

Accounting models

- Accounting is the recording and reporting of financial transactions, including the origination of the transaction, its recognition, processing, and summarisation in the financial statements.

Selection of accounting models:

- Activity based costing (ABC)
- Target Costing
- Overhead Value Analysis (OVA)
- Zero-Base Budgeting (ZBB)
- Break-Even Point
- Cost-effectiveness Analysis (CEA)
- Variance Analysis
- Total Cost of Ownership (TCO)
- Input-Output Analysis (IOA)
- Full Cost Accounting (FCA)
- Value Chain Analysis (VCA)
- Supply chain management (SCM)

14.3.3. Cost Bearers

Within an economic analysis it is also of interest whose costs are included, and who the cost bearers are. The following list represents a selection of cost bearers which are usually taken into consideration:

- Supply Chain
- Producer
- Owner(s) / User(s)
- Life Cycle Stakeholders
- Society (local, regional, global)

14.3.4. Cost Categories

All the costs along the life cycle of a product can be classified using a selected list of cost categories or cost category groups.

Examples of different levels of cost categories are:

- Cost categories in economics, e.g. budget costs, market costs, social costs
- Cost categories along the product's life cycle (see Figure 29), e.g. research & development costs, production costs, manufacturing costs, use costs, disposal costs etc.

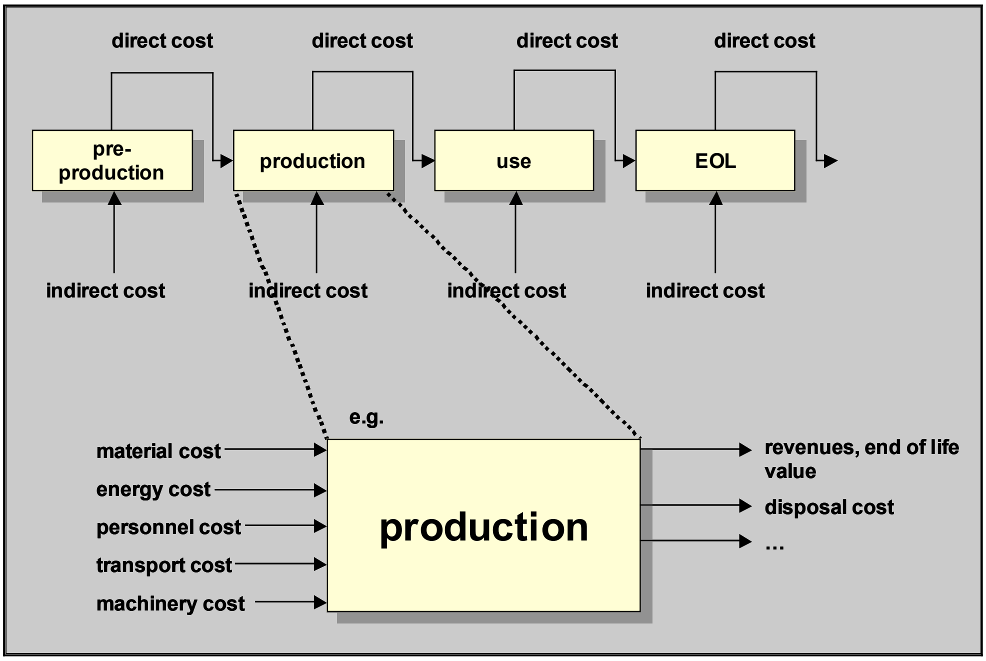


Figure 29: Cost analysis along the product life cycle

- Cost categories according to activity types, e.g. development costs, management costs, extraction costs, manufacturing costs, transport costs, infrastructure costs, research costs etc.

An LCC study can therefore give information on different levels, e.g. focusing on the cost structure per cost element and life cycle phase (see Figure 30).

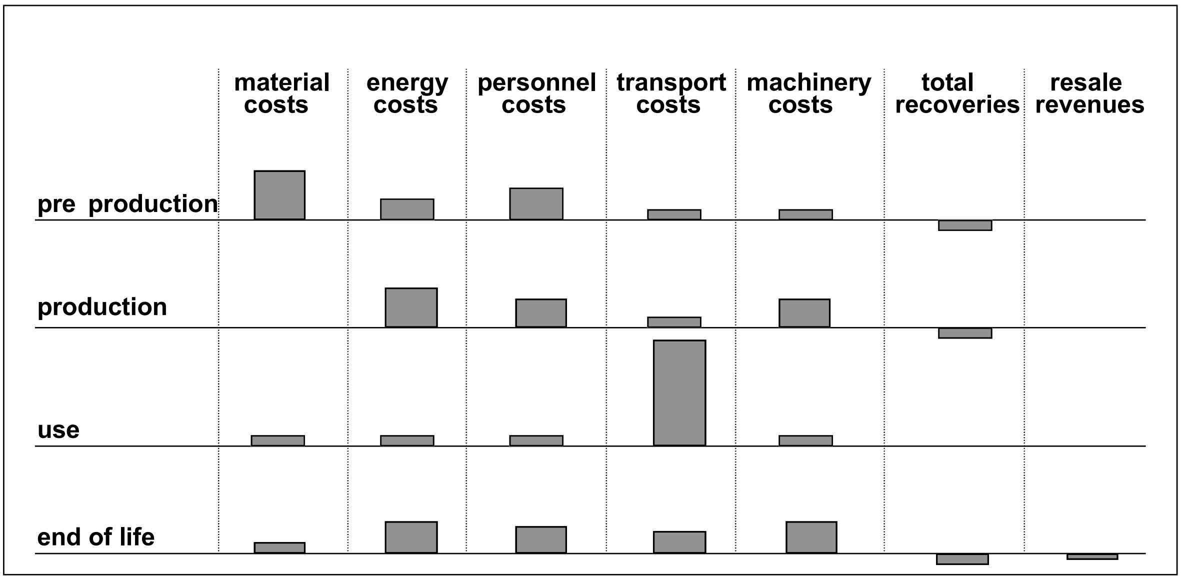


Figure 30: Exemplary LCC profile (per cost element / life cycle phase)

14.3.5. Aggregation of cost

For result analysis the costs are to be aggregated, e.g. over the whole life cycle. For the cost aggregation the following aspects are to be taken into account.

- Average costs in terms of the system, for a unit of function, which may be chosen to reflect the function over one year.
- Discounting should in principle be applied, as the units of function delivered are often spread out over time as well.
- Discounting is a process for taking account of the changing value of money. Since LCC analysis considers costs that will be incurred some time in the future, it is necessary to discount all revenues and expenditures to a specific decision point.

$$NPV = \sum_{n=0}^{T} C_n \cdot (1 + X$$

Formula for discounting, where NPV = net present value of the cost flow, C_n = nominal cost flow in the year n, X = discounting rate and T = time period of consideration

14.4. Conclusion

This critical review of LCC methodologies gives a first insight into the topic of Life Cycle Costing, the special characteristics of this type of life cycle analysis as well as possible application fields within the steel industry.

The main outcome of the discussion and work on LCC is that there are a variety of application fields, and also in the context of the steel industry and its customers.

A selection of the discovered application fields are

- the use of LCC data in the EUROFER Eco-Design Packages

- the improved awareness of the total costs
- the more accurate forecasting of cost profiles
- the analysis of the performance trade-off against cost

In the future, EUROFER will further analyse the need and interest in LCC information with specific focus on customer needs, as well as addressing the steel industry internal uses of such cost information.

In addition, the future focus is on the holistic life cycle analysis – addressing all relevant dimensions, leading to an integrated consideration of economic aspects, social responsibility and environmental effects.

Furthermore the possible application fields and the consideration of externalities will be part of the future work at EUROFER in this context.

15. ECO-DESIGN WORKSHOP

15.1. Motivation

Having completed the Eco-Design packages and the necessary work on the development of the eco-design packages, one of the most important aspects to undertake was to communicate the results and outcomes of the project, including the Eco-Design Packages that have been developed as well as the methodological aspects of LCA.

It was decided to hold an Eco-Design Workshop, aiming to demonstrate the steel industry's approach to Integrated Product Policy and Life Cycle Thinking. The target audience for the workshop included EUROFER member companies and organisations, interviewees, steel industry customers, other industry organisations, research, academia, politicians and those wanting to gain an insight into the European Steel Industry's approach to IPP and Life Cycle Thinking. Furthermore, as outlined in Section 6, one of the aims of the project was to communicate with the European Commission, to provide input where necessary to their work on IPP, but also to inform them of the work of the steel industry. The workshop not only fulfilled this objective, but it also provided the opportunity for the Commission to present an update on their work and the occasion for discussion with them, and the differing approaches to this field of expertise.

15.2. Content

The workshop was organised by EUROFER, and run in conjunction with PE International and LBP University of Stuttgart. The programme of the workshop included the following presentations:

- Implementation of the EUROFER IPP project
- Presentation of the Eco-Design Packages
- European Commission developments of IPP and Life Cycle Thinking
- Methodological aspects of the steel industry LCA
- Material Flow analysis within the steel industry
- Additional Information provision by the steel industry and future activities

The days' presentations fully outlined the work within EUROFER and its' member companies in relation to IPP, the way in which the project was ran and how the eco-design packages were developed. The LCA methodology developed for use within the packages and by the industry was also discussed, to demonstrate the developments that are currently being undertaken to provide a more robust and accurate LCA for steel products and the corresponding co-products that are produced in the steel making process.

The contribution by the European Commission highlighted the progress that has been made in relation to their activities in the field of Life Cycle Thinking and IPP, namely:

- Pilot projects on Nokia mobile phones and CARREFOUR teak garden chairs
- European Platform on LCA, including the European Reference Life Cycle Data System (ELCD) and handbook on LCA methods

- EIPRO and IMPRO studies, looking at the most damaging products and analysing their potential for improvement
- IPP regular meetings
- Sustainable Use of Natural Resources (2005)

IPP now falls within the scope of the European Commission's 'Sustainable Consumption and Production' (SCP) programme, which addresses social and economic development within the carrying capacity of ecosystems and aims to decouple economic growth from environmental degradation. It is intended to 'achieve more with less', to reinforce existing initiatives and provide better coherence, by taking a scientific approach and focussing on the most damaging areas. Stakeholder involvement and collaboration is a focal part of their work. SCP aims to have a Green Paper consultation in the second half of 2007, with an Action Plan Communication and eco-design legislation in 2008.

15.3. Discussion and Summary

The workshop provoked much discussion throughout the course of the day, focussing on the specific work of EUROFER, the development of the eco-design packages and the use of and methodology associated with the life cycle inventory data. Much discussion was also held with the European Commission, to determine the possible way forward regarding their approach to IPP and SCP, and potential future work activities.

The workshop provided a very informative and interesting forum and was very much appreciated by the attendees. The information and brochures provided throughout the day were felt to be a very useful tool, and subsequent requests have been made to utilise this information. There have also been a number of requests for steel life cycle inventory data for use by individual organisations for specific products or projects.

16. OUTLOOK

In terms of product development, eco-design and sustainability issues, there are numerous and varied approaches that are being developed by EUROFER's member companies and at a national or European level. It is therefore important to try to ensure that as much consistency is achieved as possible. A benefit of this IPP project will be to assist in such schemes by providing the necessary steel and/or LCI data and the corresponding methodology relating to the life cycle of steel products. This will ensure both the non-duplication of work and resources as well as producing a more consistent, harmonised approach to IPP and LCA related issues.

16.1. Use of Eco-design packages

The Eco-design packages have been developed for use by the EUROFER members. It is intended that the format and design of these packages can be utilised for company specific and product specific applications, as desired by each company. The packages can then be used by all interested parties throughout the product lifecycle, be they steel manufacturers, product designers and manufacturers, the consumer or the end-of-life recycler.

16.2. Co-product methodology

As a follow-up to this project, it is recommended that the following areas are investigated:

- A critical review of the methodology as detailed in Section 11.7 and incorporation of any appropriate recommendations.
- Discussions with the users of the steel industry co-products, such as cement manufacturers.
- Implementation of the co-product methodology within the new IISI data which is currently being collected.
- Potential development of a methodology to incorporate the secondary steelmaking process route, namely the Electric Arc Furnace.
- Potential development of a methodology to incorporate the stainless steel making process which is performed in the Electric Arc Furnace route.
- Future discussions with IISI and other steel industry organisations for the inclusion of the EUROFER co-product methodology within other datasets.
- Potential inclusion of the European steel industry LCI data incorporating the co-product methodology, with LCI data providers, software developers and the European Commissions ELCD.

16.3. MFA

In order to improve the MFA model that has been developed, it is necessary to continue to collect more data that can be used to provide a more detailed analysis. Incorporating more countries than the 15 that have been used within this study will provide a more accurate overview of the flow of steel throughout society. This data will become more readily available as the reporting requirements on such data become more stringent.

16.4. Life Cycle Costing

EUROFER should focus on Life Cycle Costing internally to gain more understanding of what this approach will mean for the steel industry and their products. In addition to this, EUROFER should continue the identification/analysis of social parameters which might be of importance for the evaluation of steel products.

16.5. Conclusion

Whatever the form that the European Commission implements the requirements of Integrated Product Policy under the remit of Sustainable Consumption and Production, SCP, the European steel industry is well positioned to demonstrate its positive contribution.

17. APPENDICES

14.1 Questionnaire on Eco-Design requirements for Tailor Welded Blanks / Composite Flooring System / Roofing System / White Goods by the European Confederation of Iron and Steel Industries (EUROFER).

14.2 Detailed Interview Outcome

14.3 LCA Case Studies

14.4 Application of the IISI LCI Data to Recycling Scenarios

17.1. Questionnaire on Eco-Design requirements for Tailor Welded Blanks / Composite Flooring System / Roofing System / White Goods by the European Confederation of Iron and Steel Industries (EUROFER).

17.1.1. Introduction and explanation of the questionnaire

EUROFER is the European Confederation of Iron and Steel Industries, founded in 1976, and located in Brussels. EUROFER assists in the co-operation amongst the national federations and companies.

This questionnaire aims to create a better understanding at EUROFER on the requirements of the European Steel Industry customers regarding the delivered iron and steel products in terms of Eco-Design. With this questionnaire EUROFER is addressing general aspects of Eco-Design but also focusing specifically on *tailor welded blanks / composite flooring systems / roofing systems / white goods.*

This questionnaire is divided into 5 sections which are addressing:

- information on the person supporting the answers
- information on current company status referring to overall environmental management
- the current situation in Eco-Design
- expectations of information provided by EUROFER members about their products
- future developments in Eco-Design and subsequent data/information requirements

The questions used in this questionnaire allow either selecting an answer from a predefined list or individual feedback.

The information provided during the interview process will be analysed by EUROFER in order to provide an ideal set of product information needed for Eco-Design. All information provided will be treated anonymously.

17.1.2. Information on person supporting the answers

Company: ____

Name: ____

Position/Function: ____

17.1.3. Information on current company status referring to overall environmental management

a) What is the status of the Environmental Management System (EMS) within your company?

b) Does your company have an environmental policy?

c) What are the main reasons for your company to carry out environmental work?

17.1.4. Current situation in Eco-design

a) Have you introduced design for environment (Eco-Design) into your product design, manufacturing process or management systems?

b) Can you please briefly describe the product development/design processes in your company? (Please specify major steps and feel free to add attachments)

c) Which departments/sections of your company contribute to the Eco-Design activities of your company and which sections will use the outcomes of the eco-design activities/package?

d) Are there specific regulations or directives that are the drivers for your company to undertake these environmental initiatives?

e) What are the environmental aspects that you are taking/would like to take into account during the different phases of product development concerning a product's life cycle?

   i. During product conception and design

   ii. During manufacturing / production

   iii. During product packaging and distribution

   iv. During the use phase (including maintenance)

   v. At the end-of life

   vi. Other aspects concerning the product life cycle

f) Have you set up objectives, targets or programs for improving the environmental performance of your products?

   If yes, can you please specify which aspects are covered by these targets?

g) What are the tools / approaches used for decision making in Eco-Design within your company? Please select from the prepared list; multiple selections per row are possible:

Never used	Used in the past	Used now	Would/would not use again	Plan to use	
					Life Cycle Assessment (ISO 14040)
					Mass and energy balances
					Resource use / use of renewable resources
					Recyclability
					Use of recycled materials
					Energy efficiency
					Benchmarks
					Checklists
					Life Cycle Costing
					Eco-labels
					Environmental Product Declaration
					Guidelines via VDI 2243 1)
					Guidelines via ISO 14062 2)

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1) VDI 2243: Recycling-oriented product development

[2)] ISO 14062: Environmental management-Integrating environmental aspects into product design and development

h) Do you already include additional aspects besides environmental ones in Eco-Design during the product development process?

If yes, can you please give a short description of these aspects and what they are used for?

17.1.5. Information expectations

a) Steel products in general

What is the necessary steel and iron product information that is needed by your company for eco-design purposes on a general basis?

b) Tailor Welded Blanks / Composite Flooring Systems / Roofing Systems / White Goods

i. In your opinion, what information is required to perform Eco-Design effectively for tailor welded blanks / composite flooring systems / roofing systems / white goods products?

ii. When considering the eco-design of a product, what are the perceived strengths and weaknesses of using steel?

iii. What environmental information do you currently provide to your customers?

17.1.6. Future developments in Eco-design

a) Can you please describe how Eco-Design will develop within your company in the future?

b) Generally speaking, how important do you think Eco-Design will be in the future? Why?

c) Do you think that there will be other environmental considerations which might be an issue in the future? If yes, please describe these aspects.

d) What would you like to see from product development within the steel industry in terms of Eco-Design?

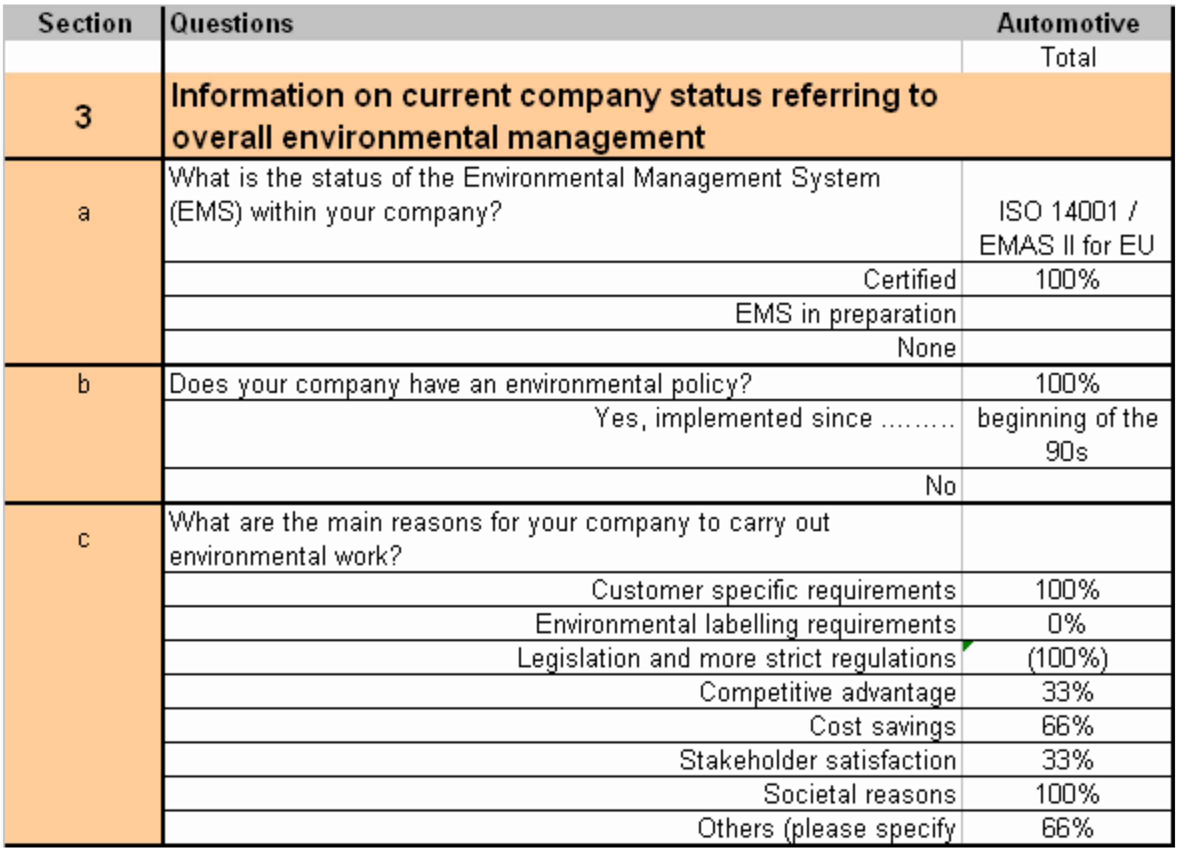
17.2. Detailed interview outcome

Illustrated below are the detailed results from the interviews held with each of the different market sectors, for the four case study products, based on the questions in Appendix 17.1.

17.2.1. Automotive Sector

In the following section, the results from the interviews within the automotive sector are discussed. In total, four companies were interviewed.

All interviewed automotive companies have a fully implemented environmental management system (EMS) in place. In addition to the EMS system all companies also have a defined environmental policy specifying the goals they would like to achieve with their activities. On average, the companies started to implement their EMS systems as well as their environmental policies in the early 1990s.

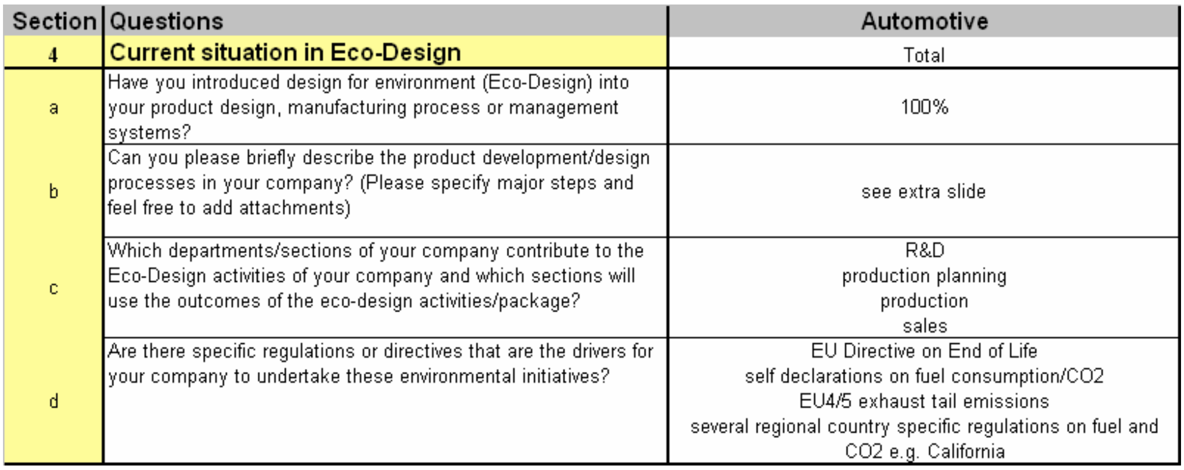


Section	Questions	Automotive
		Total
3	**Information on current company status referring to overall environmental management**	
a	What is the status of the Environmental Management System (EMS) within your company?	ISO 14001 / EMAS II for EU
	Certified	100%
	EMS in preparation	
	None	
b	Does your company have an environmental policy?	100%
	Yes, implemented since ………	beginning of the 90s
	No	
c	What are the main reasons for your company to carry out environmental work?	
	Customer specific requirements	100%
	Environmental labelling requirements	0%
	Legislation and more strict regulations	(100%)
	Competitive advantage	33%
	Cost savings	66%
	Stakeholder satisfaction	33%
	Societal reasons	100%
	Others (please specify	66%

Table 13: Overview on the use of environmental management systems within the automotive industry

The main drivers for the automotive producers to install EMS systems were customer specific requirements, legislation and stricter regulations, and societal reasons. Furthermore, cost saving potentials related to the measurement and analysis of mass and energy flows was indicated to be another important reason.

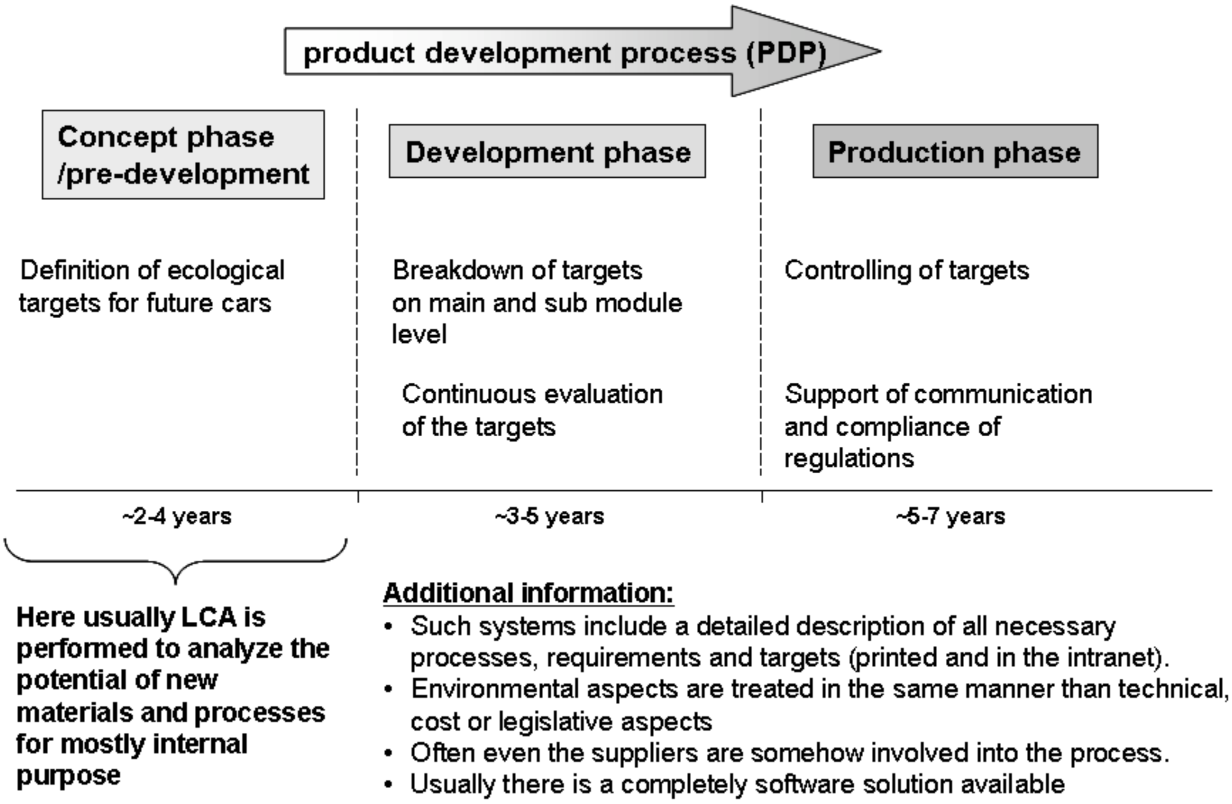
All companies interviewed provided the information that they have implemented Eco-Design guidelines and requirements within their product development process (PDP).



Section	Questions	Automotive
4	**Current situation in Eco-Design**	Total
a	Have you introduced design for environment (Eco-Design) into your product design, manufacturing process or management systems?	100%
b	Can you please briefly describe the product development/design processes in your company? (Please specify major steps and feel free to add attachments)	see extra slide
c	Which departments/sections of your company contribute to the Eco-Design activities of your company and which sections will use the outcomes of the eco-design activities/package?	R&D production planning production sales
d	Are there specific regulations or directives that are the drivers for your company to undertake these environmental initiatives?	EU Directive on End of Life self declarations on fuel consumption/CO2 EU4/5 exhaust tail emissions several regional country specific regulations on fuel and CO2 e.g. California

Table 14: Status on current applied Eco-Design practice within the automotive sector

A schematic overview of this process is shown in Figure 31. The PDP process shows how environmental aspects are defined and monitored during the different phases of development of a new vehicle. The automotive companies interviewed all indicated that they are using full scale LCA software systems to undergo detailed analysis of the environmental performance of the products to ensure a continuous improvement process. Alongside the software systems, they are also using checklists and other approaches depending on the different level of information available.



Here usually LCA is performed to analyze the potential of new materials and processes for mostly internal purpose

Additional information:

- Such systems include a detailed description of all necessary processes, requirements and targets (printed and in the intranet).
- Environmental aspects are treated in the same manner than technical, cost or legislative aspects
- Often even the suppliers are somehow involved into the process.
- Usually there is a completely software solution available

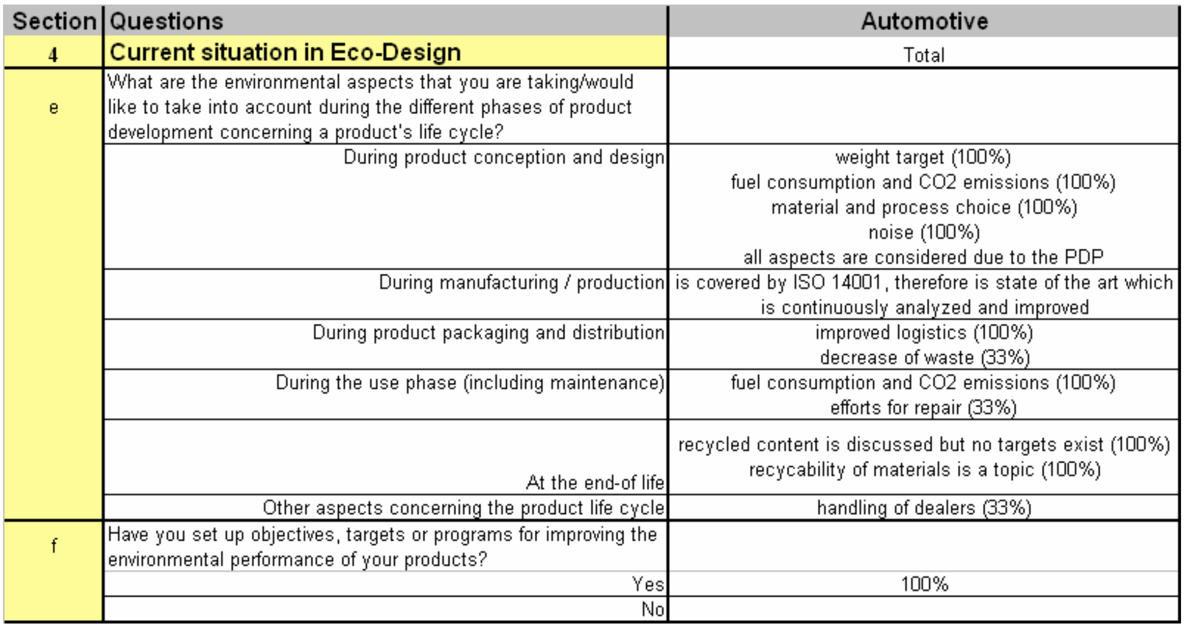
Figure 31: Integration of environmental aspects (Eco-Design) of the product development process within the automotive sector

In general, experts from design, product planning, production and sales are involved within this product development process to ensure that defined goals fulfil all requirements.

A major driver for the automotive producers is the Directive on End of Life Vehicles (2000/53/EC) which includes the calculation of road vehicles recyclability and recoverability according to ISO 22628. Additional drivers for the implementation of such a process were the more strict regulations on exhaust air emissions (EURO 4 to EURO 5 level), the self declaration to reduce the fuel consumption and therefore CO_2 emissions, and the existing regional laws.

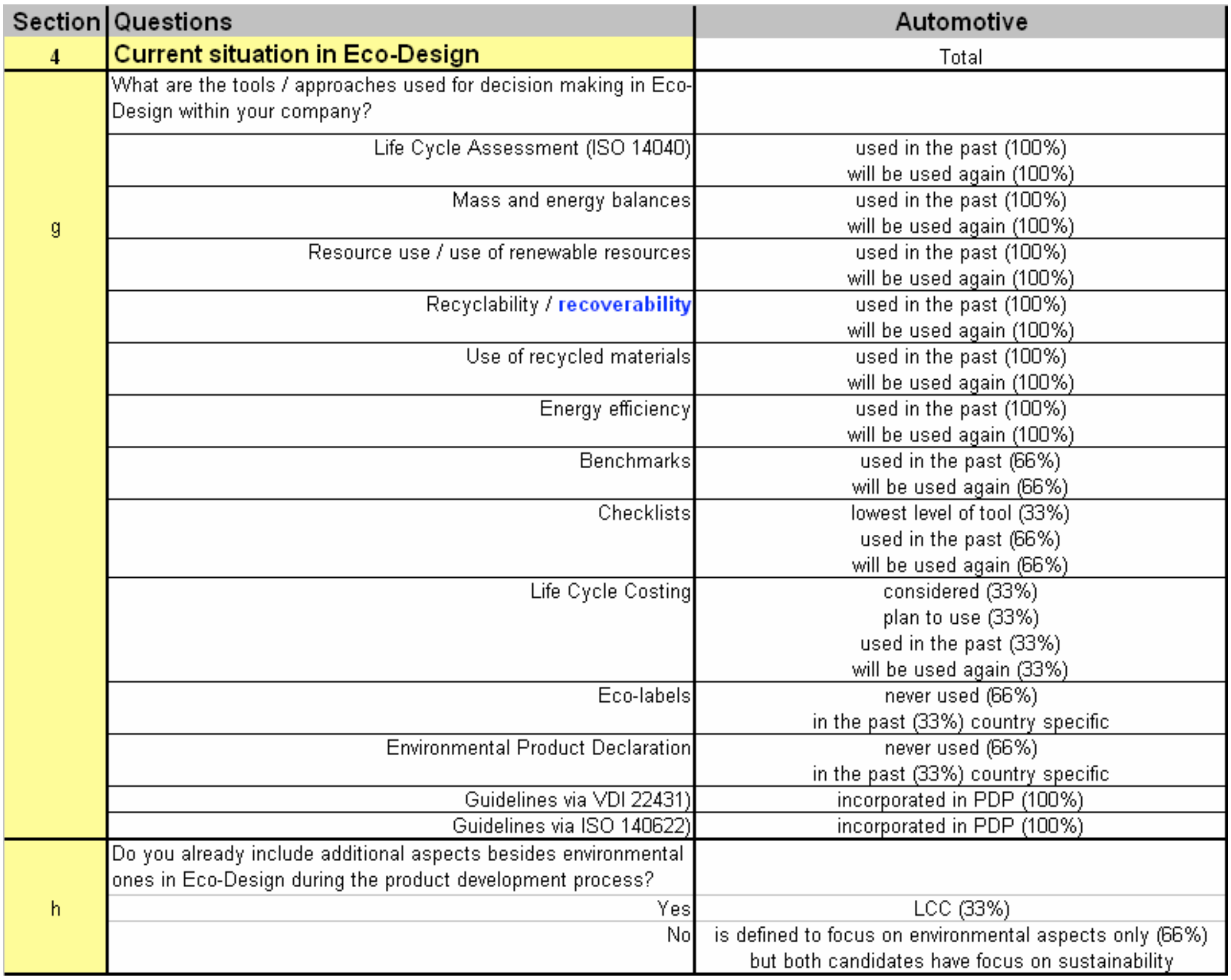
Major parameters that the automotive industry is focusing on within the design and development phase are: the reduction of the vehicle weight (light weighting), the reduction of the fuel consumption by weight and alternative measures (bio fuels, new engine concepts, e.g. hybrid, etc.), the selection of materials and related production processes and the reduction of noise.

Table 15 shows other important targets mentioned by the automotive producers who are addressing additional challenges related to the life cycle phases of the vehicles.



Section	Questions	Automotive
4	**Current situation in Eco-Design**	Total
e	What are the environmental aspects that you are taking/would like to take into account during the different phases of product development concerning a product's life cycle?	
	During product conception and design	weight target (100%) fuel consumption and CO2 emissions (100%) material and process choice (100%) noise (100%) all aspects are considered due to the PDP
	During manufacturing / production	is covered by ISO 14001, therefore is state of the art which is continuously analyzed and improved
	During product packaging and distribution	improved logistics (100%) decrease of waste (33%)
	During the use phase (including maintenance)	fuel consumption and CO2 emissions (100%) efforts for repair (33%)
	At the end-of life	recycled content is discussed but no targets exist (100%) recycability of materials is a topic (100%)
	Other aspects concerning the product life cycle	handling of dealers (33%)
f	Have you set up objectives, targets or programs for improving the environmental performance of your products?	
	Yes	100%
	No	

Table 15: Status on current applied Eco-Design practice within the automotive sector (continued)

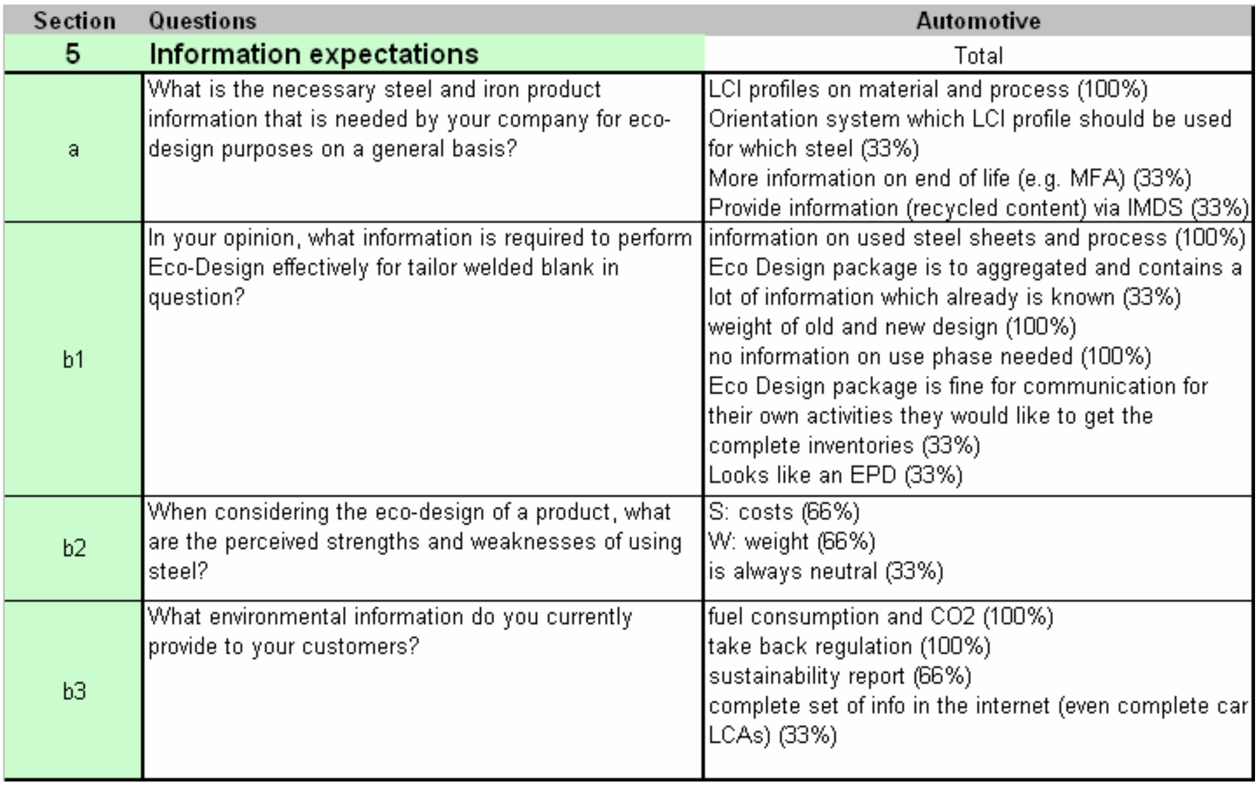


Section	Questions	Automotive
4	**Current situation in Eco-Design**	Total
g	What are the tools / approaches used for decision making in Eco-Design within your company?	
	Life Cycle Assessment (ISO 14040)	used in the past (100%) will be used again (100%)
	Mass and energy balances	used in the past (100%) will be used again (100%)
	Resource use / use of renewable resources	used in the past (100%) will be used again (100%)
	Recyclability / **recoverability**	used in the past (100%) will be used again (100%)
	Use of recycled materials	used in the past (100%) will be used again (100%)
	Energy efficiency	used in the past (100%) will be used again (100%)
	Benchmarks	used in the past (66%) will be used again (66%)
	Checklists	lowest level of tool (33%) used in the past (66%) will be used again (66%)
	Life Cycle Costing	considered (33%) plan to use (33%) used in the past (33%) will be used again (33%)
	Eco-labels	never used (66%) in the past (33%) country specific
	Environmental Product Declaration	never used (66%) in the past (33%) country specific
	Guidelines via VDI 22431)	incorporated in PDP (100%)
	Guidelines via ISO 140622)	incorporated in PDP (100%)
h	Do you already include additional aspects besides environmental ones in Eco-Design during the product development process?	
	Yes	LCC (33%)
	No	is defined to focus on environmental aspects only (66%) but both candidates have focus on sustainability

Table 16: Tools and approaches used within the Eco-Design process

Table 16 provides an overview of tools and approaches which have been used and / or are still used within the automotive industry. The feedback clearly shows that Life Cycle Assessment has commonly been used by all interviewed companies for a long time and that it is an important factor within their internal routines. All interviewed experts have indicated that they have a continuous demand for LCI profiles on new developed steel products (e.g. high strength steel sheets) and also on new processes (e.g. laser welding of tailor welded blanks) as documented in Table 17.

Generally speaking, in the automotive industry there is no indicator system, equivalent to the EPD system in the construction industry that allows any comparison between different vehicles. Other major approaches applied in the automotive industry are focusing on aspects of recyclability and recoverability, and energy efficiency. Currently, within the initial phases are methods such as Life Cycle Costing (LCC) and the integration of social aspects to the general considerations, but there were no clear requirements for such aspects specified this time.



Section	Questions	Automotive
5	Information expectations	Total
a	What is the necessary steel and iron product information that is needed by your company for eco-design purposes on a general basis?	LCI profiles on material and process (100%) Orientation system which LCI profile should be used for which steel (33%) More information on end of life (e.g. MFA) (33%) Provide information (recycled content) via IMDS (33%)
b1	In your opinion, what information is required to perform Eco-Design effectively for tailor welded blank in question?	information on used steel sheets and process (100%) Eco Design package is to aggregated and contains a lot of information which already is known (33%) weight of old and new design (100%) no information on use phase needed (100%) Eco Design package is fine for communication for their own activities they would like to get the complete inventories (33%) Looks like an EPD (33%)
b2	When considering the eco-design of a product, what are the perceived strengths and weaknesses of using steel?	S: costs (66%) W: weight (66%) is always neutral (33%)
b3	What environmental information do you currently provide to your customers?	fuel consumption and CO2 (100%) take back regulation (100%) sustainability report (66%) complete set of info in the internet (even complete car LCAs) (33%)

Table 17: Expectations from the automotive sector regarding the steel industry

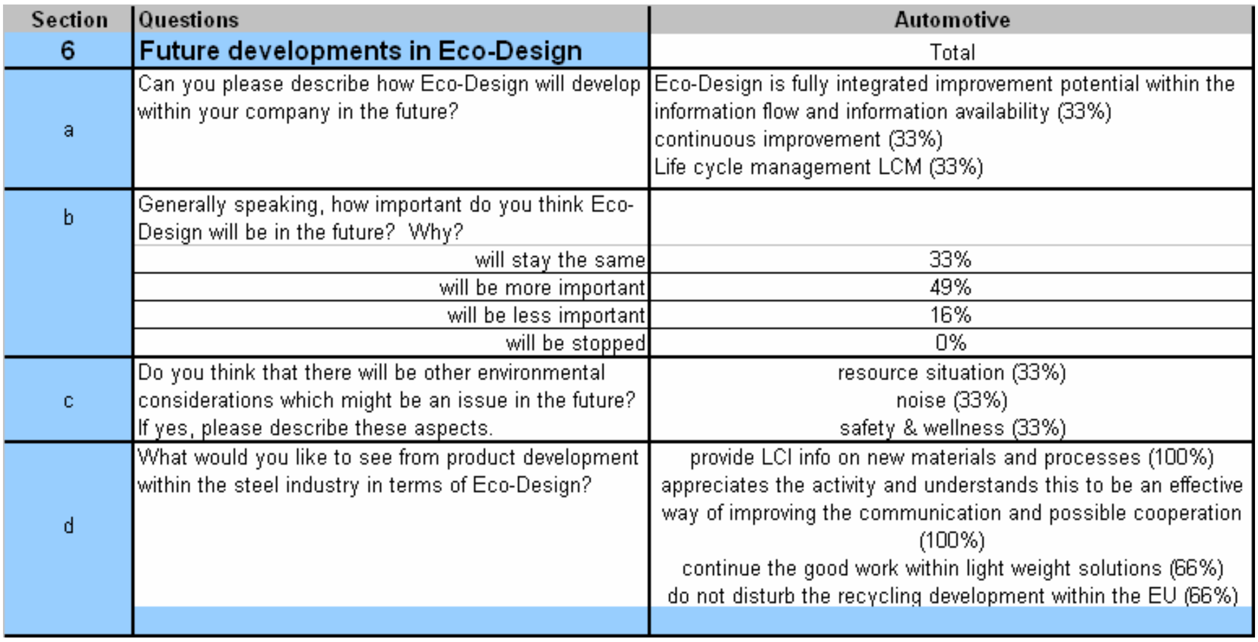
Confronted with a preliminary example of the Eco-Design package, the feedback was that in general the information is helpful and it was also agreed that the steel industry did not need to be concerned with the use phase of vehicles. In addition it was pointed out that the LCI data-related information provided in the Eco-Design package was too aggregated for application within the automotive industry and they would like to receive more detailed information if possible.

In the discussion about the future of Eco-Design, the interviewed experts of the automotive industry indicated that Eco-Design will:

- be more important (50 %)
- stay on the same level (33 %)
- be less important (17 %)

Issues of noise, safety and wellness as well as the situation of material resources were identified as upcoming challenges.

Overall, the automotive industry thinks that the steel industry is already providing very good information. Nevertheless it was mentioned that continuous work in this area would be needed and that communication within and between the two industrial sectors is very important to be aware of upcoming and exciting challenges.



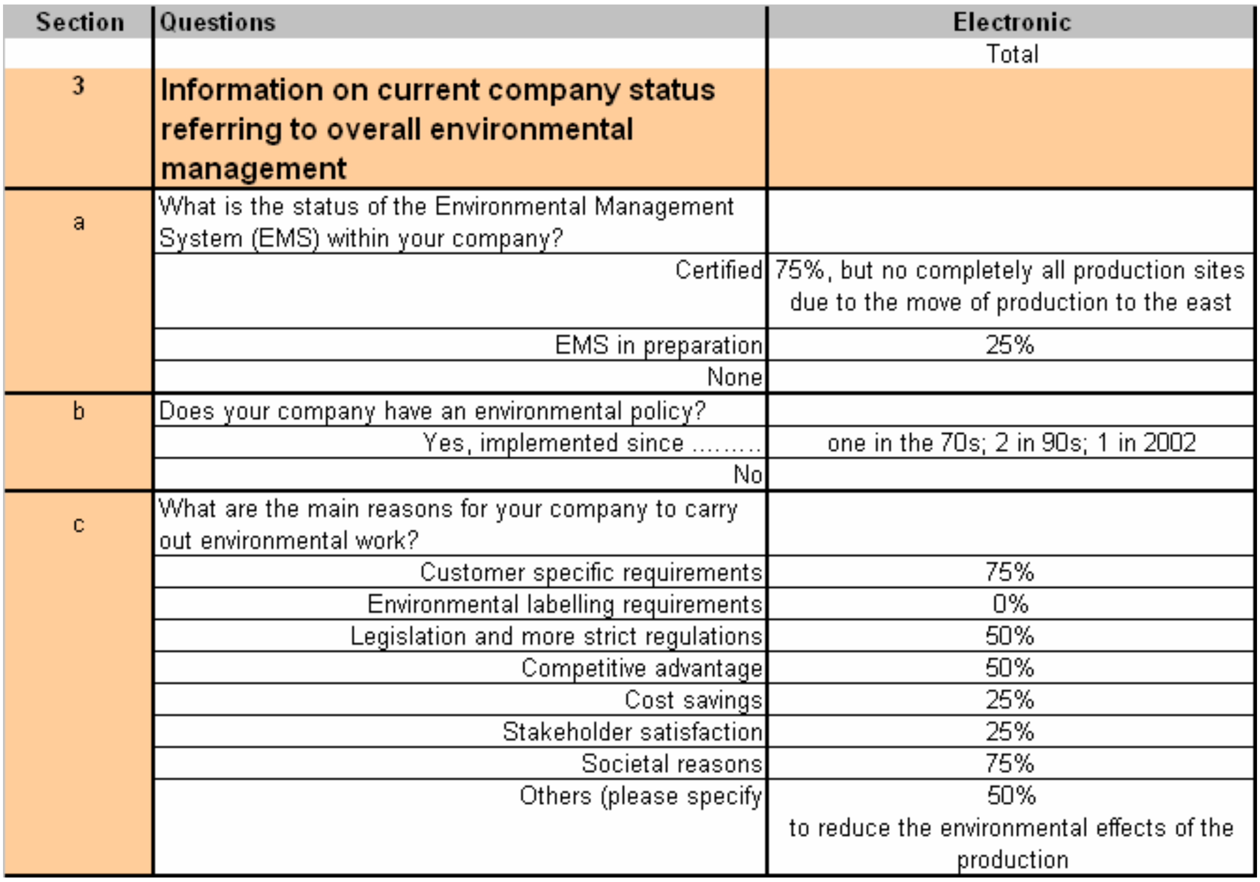
Section	Questions	Automotive
6	**Future developments in Eco-Design**	Total
a	Can you please describe how Eco-Design will develop within your company in the future?	Eco-Design is fully integrated improvement potential within the information flow and information availability (33%) continuous improvement (33%) Life cycle management LCM (33%)
b	Generally speaking, how important do you think Eco-Design will be in the future? Why?	
	will stay the same	33%
	will be more important	49%
	will be less important	16%
	will be stopped	0%
c	Do you think that there will be other environmental considerations which might be an issue in the future? If yes, please describe these aspects.	resource situation (33%) noise (33%) safety & wellness (33%)
d	What would you like to see from product development within the steel industry in terms of Eco-Design?	provide LCI info on new materials and processes (100%) appreciates the activity and understands this to be an effective way of improving the communication and possible cooperation (100%) continue the good work within light weight solutions (66%) do not disturb the recycling development within the EU (66%)

Table 18: Expectations on future developments regarding Eco-Design in the automotive sector

17.2.2. White Goods Sector

In this section the results from the interviews within the white goods sector are discussed. A total of four companies were interviewed.

75 % of the interviewed companies in this sector have an implemented environmental management system (EMS) in place. One company was in the process of implementing the environmental management system at the time of the interview. In addition to the EMS system, all companies also have a defined environmental policy specifying the goals they would like to achieve with their activities. Each of the companies started to implement their EMS systems and environmental policies at different times, i.e., there was no common era of implementation as is the case for the automotive industry. In general, it was seen from the interviews that the white goods sector has not reached the same level of environmental control as was seen in the automotive industry.



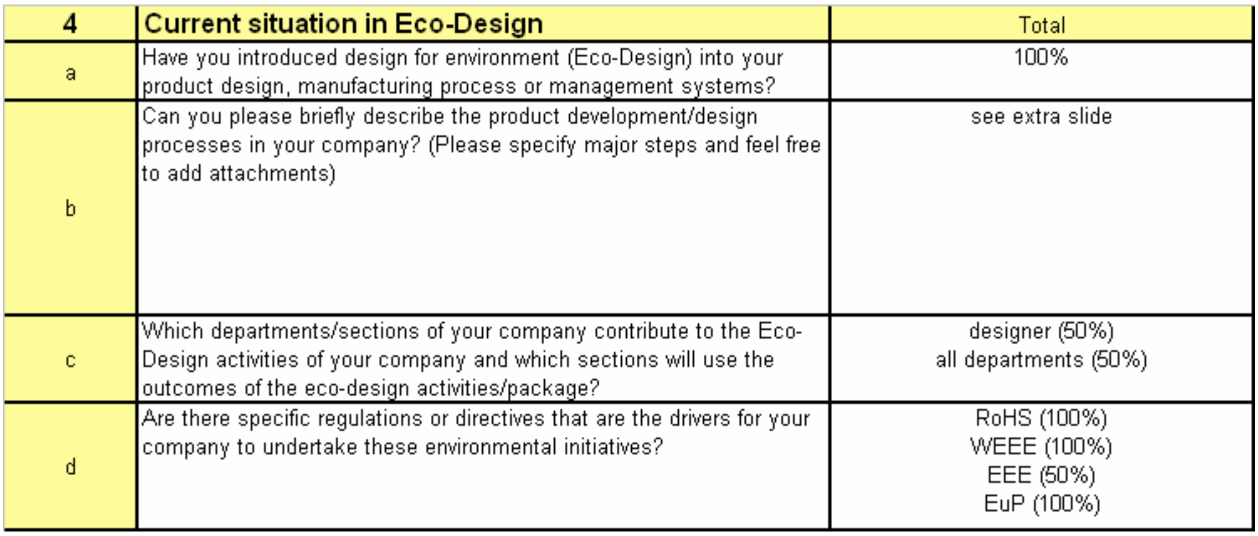
Section	Questions	Electronic
		Total
3	**Information on current company status referring to overall environmental management**	
a	What is the status of the Environmental Management System (EMS) within your company?	
	Certified	75%, but no completely all production sites due to the move of production to the east
	EMS in preparation	25%
	None	
b	Does your company have an environmental policy?	
	Yes, implemented since ………	one in the 70s; 2 in 90s; 1 in 2002
	No	
c	What are the main reasons for your company to carry out environmental work?	
	Customer specific requirements	75%
	Environmental labelling requirements	0%
	Legislation and more strict regulations	50%
	Competitive advantage	50%
	Cost savings	25%
	Stakeholder satisfaction	25%
	Societal reasons	75%
	Others (please specify	50% to reduce the environmental effects of the production

Table 19: Overview on the use of environmental management systems within the white goods sector

The main motivations for the white goods companies to implement an EMS were customer specific requirements and societal demands (reported by 75 % of interviewed companies). Other drivers to employ an EMS were legislation and stricter regulations, competitive advantage (50 %) and cost savings and stakeholder satisfaction (25 %).

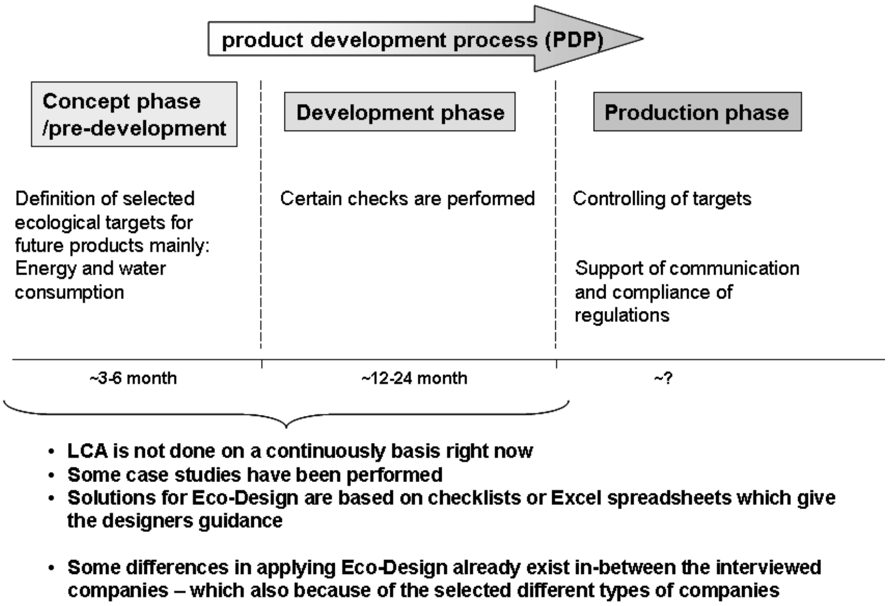
All of the interviewed companies said that they have Eco-Design implemented into their product development process. Nevertheless, during the interviews it was determined that this is not comparable with the procedure employed in the automotive industry. The current level of implementation of Eco-Design in the white goods sector is such that there are exact guidelines which must be followed but in terms of quantifying the environmental performance, not every company is using LCA software tools. It was also reported that check lists are used which provide more qualitative information on the environmental indicators. Nevertheless, all interviewed experts from the white goods sector indicated that they are convinced that LCA will become a more important tool for them during the product design and development process.

At present, it is mainly the designers that deal with the environmental issues. The most important regulations in the industry currently are RoHS (Restriction of Hazardous Substances) and WEEE (Waste Electrical and Electronic Equipment).



4	Current situation in Eco-Design	Total
a	Have you introduced design for environment (Eco-Design) into your product design, manufacturing process or management systems?	100%
b	Can you please briefly describe the product development/design processes in your company? (Please specify major steps and feel free to add attachments)	see extra slide
c	Which departments/sections of your company contribute to the Eco-Design activities of your company and which sections will use the outcomes of the eco-design activities/package?	designer (50%) all departments (50%)
d	Are there specific regulations or directives that are the drivers for your company to undertake these environmental initiatives?	RoHS (100%) WEEE (100%) EEE (50%) EuP (100%)

Table 20: Status on currently applied Eco-Design practice within the white goods sector



Definition of selected ecological targets for future products mainly: Energy and water consumption

Certain checks are performed

Controlling of targets

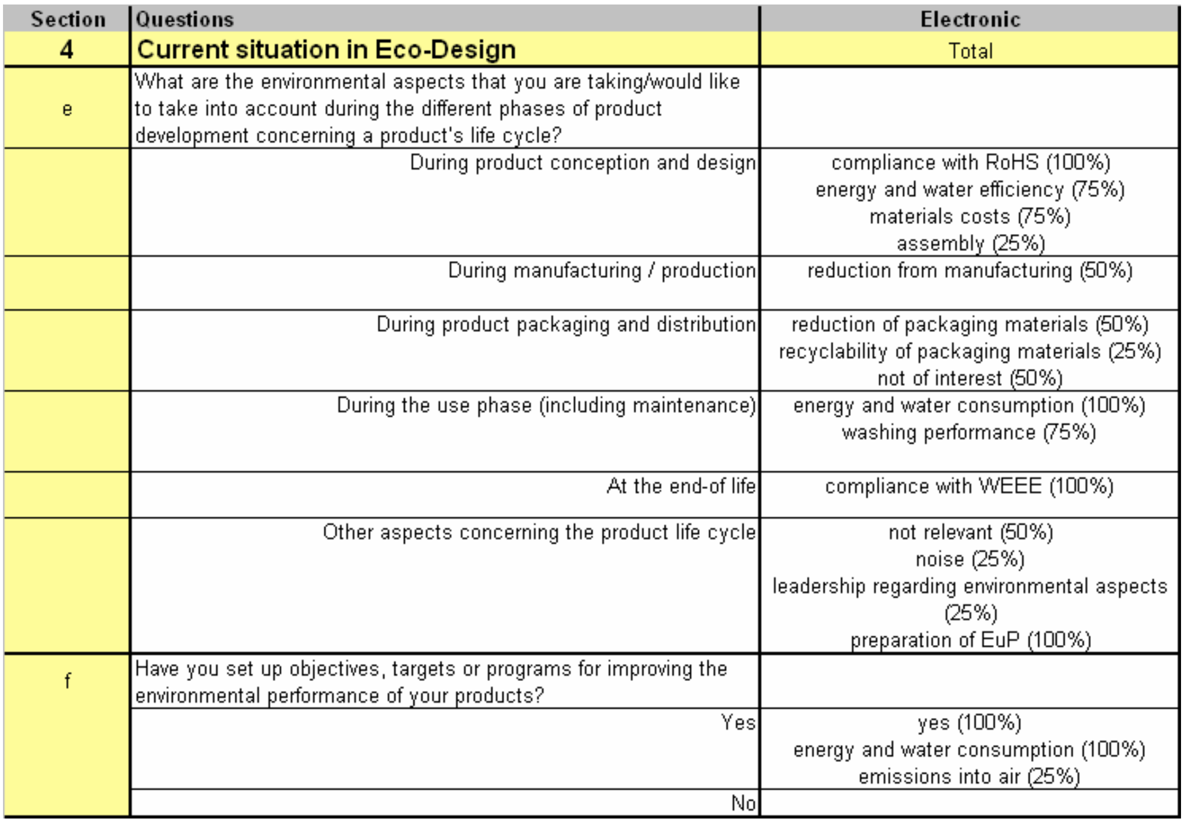
Support of communication and compliance of regulations

- **LCA is not done on a continuously basis right now**
- **Some case studies have been performed**
- **Solutions for Eco-Design are based on checklists or Excel spreadsheets which give the designers guidance**
- **Some differences in applying Eco-Design already exist in-between the interviewed companies – which also because of the selected different types of companies**

Figure 32: Integration of environmental aspects (Eco-Design) into the product development process within the white goods sector

Figure 32 shows the product development process within the white goods sector whereby the major difference is the shorter periods for the single design phases.

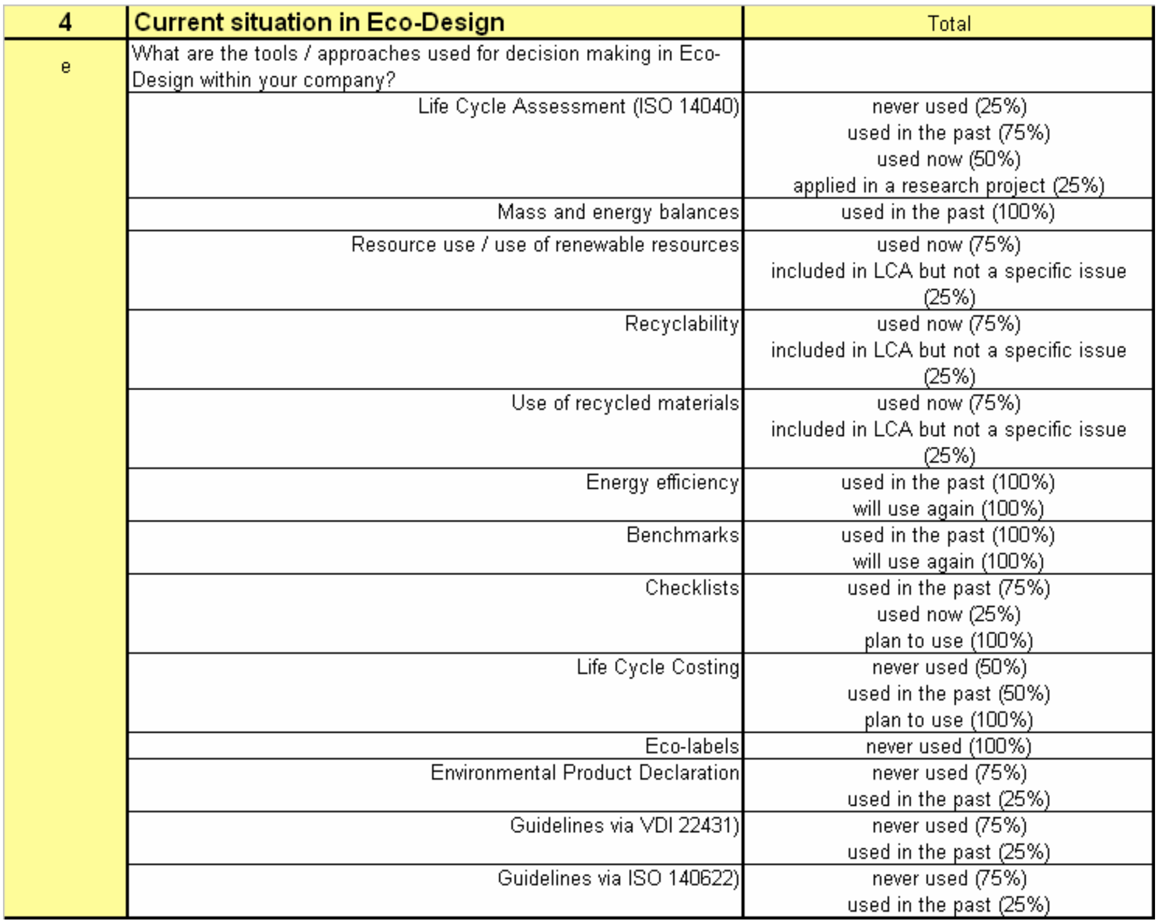
Table 21 provides an overview of the most important regulations or environmental aspects which have to be fulfilled or focused on during the different life cycle phases of white goods products. The most important aspects are the energy and water consumption. A label already exists for this (energy efficiency classes A+, A, B, etc.) which must be specified for every product sold.



Section	Questions	Electronic
4	**Current situation in Eco-Design**	Total
e	What are the environmental aspects that you are taking/would like to take into account during the different phases of product development concerning a product's life cycle?	
	During product conception and design	compliance with RoHS (100%) energy and water efficiency (75%) materials costs (75%) assembly (25%)
	During manufacturing / production	reduction from manufacturing (50%)
	During product packaging and distribution	reduction of packaging materials (50%) recyclability of packaging materials (25%) not of interest (50%)
	During the use phase (including maintenance)	energy and water consumption (100%) washing performance (75%)
	At the end-of life	compliance with WEEE (100%)
	Other aspects concerning the product life cycle	not relevant (50%) noise (25%) leadership regarding environmental aspects (25%) preparation of EuP (100%)
f	Have you set up objectives, targets or programs for improving the environmental performance of your products?	
	Yes	yes (100%) energy and water consumption (100%) emissions into air (25%)
	No	

Table 21: Status on currently applied Eco-Design practice within the white goods sector (continued)

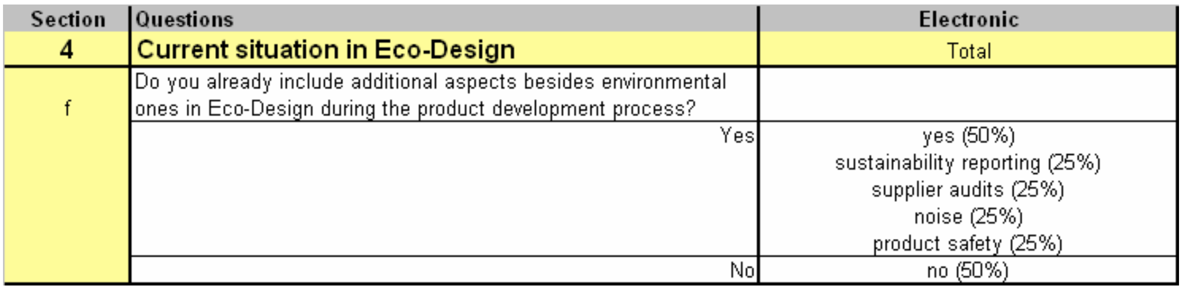
The analysis of tools and methods used in the past and still today shows that within the white goods sector, energy efficiency was and is always analysed. Benchmarks with competitor products are also performed continuously to ensure that internal products are showing comparable characteristics. The situation shows that software tools such as LCA expert systems are used nowadays and have been used in the past but it was indicated that LCA was conducted only on single case studies and not systematically throughout the product spectrum. However, it was reported that LCA is not used as a standardised approach to systematically analyse all product developments.



4	Current situation in Eco-Design	Total
e	What are the tools / approaches used for decision making in Eco-Design within your company?	
	Life Cycle Assessment (ISO 14040)	never used (25%) used in the past (75%) used now (50%) applied in a research project (25%)
	Mass and energy balances	used in the past (100%)
	Resource use / use of renewable resources	used now (75%) included in LCA but not a specific issue (25%)
	Recyclability	used now (75%) included in LCA but not a specific issue (25%)
	Use of recycled materials	used now (75%) included in LCA but not a specific issue (25%)
	Energy efficiency	used in the past (100%) will use again (100%)
	Benchmarks	used in the past (100%) will use again (100%)
	Checklists	used in the past (75%) used now (25%) plan to use (100%)
	Life Cycle Costing	never used (50%) used in the past (50%) plan to use (100%)
	Eco-labels	never used (100%)
	Environmental Product Declaration	never used (75%) used in the past (25%)
	Guidelines via VDI 22431)	never used (75%) used in the past (25%)
	Guidelines via ISO 140622)	never used (75%) used in the past (25%)

Table 22: Tools and approaches used within the Eco-Design process

There was no clear picture given by the experts as to whether aspects other than environmental ones are analysed within Eco-Design, as illustrated in Table 23.

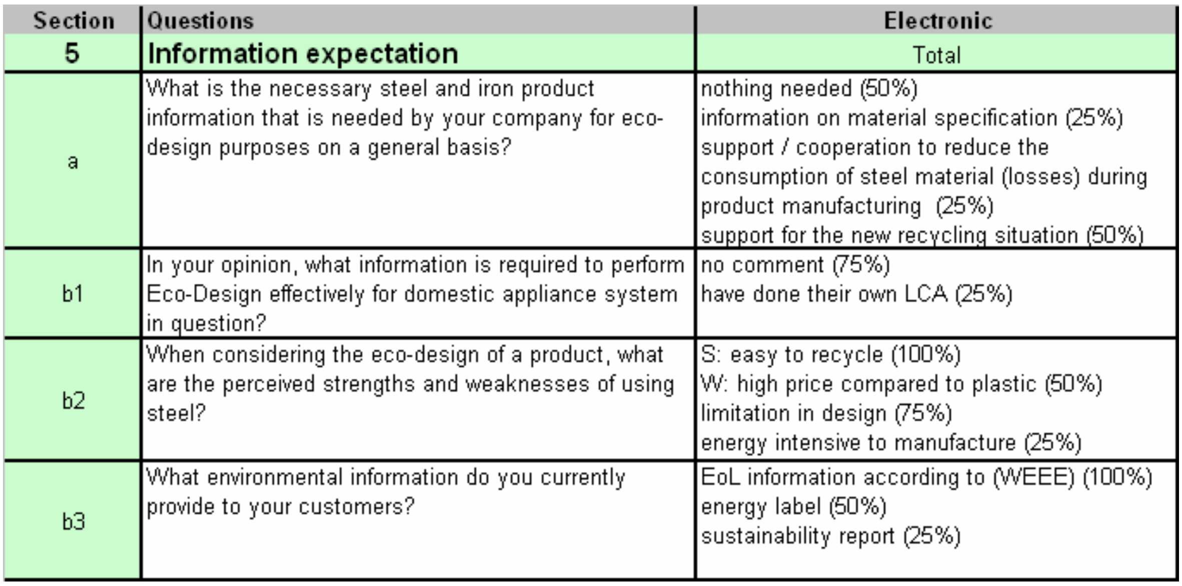


Section	Questions	Electronic
4	Current situation in Eco-Design	Total
f	Do you already include additional aspects besides environmental ones in Eco-Design during the product development process?	
	Yes	yes (50%) sustainability reporting (25%) supplier audits (25%) noise (25%) product safety (25%)
	No	no (50%)

Table 23: Tools and approaches used within the Eco-Design process (continued)

Expectations/wishes from the white goods sector mentioned during the interviews cover the following areas:

- There is a need for better communication regarding the recycling of steel products especially with respect to new regulations such as the WEEE Directive
- There were only a few comments on what is needed to perform Eco-Design effectively within the white goods sector
- The experts from the white goods sector like steel material because of its very good recyclability. On the other hand, steel was criticised because of its relatively high price compared to plastic and its limitations in terms of design potential.



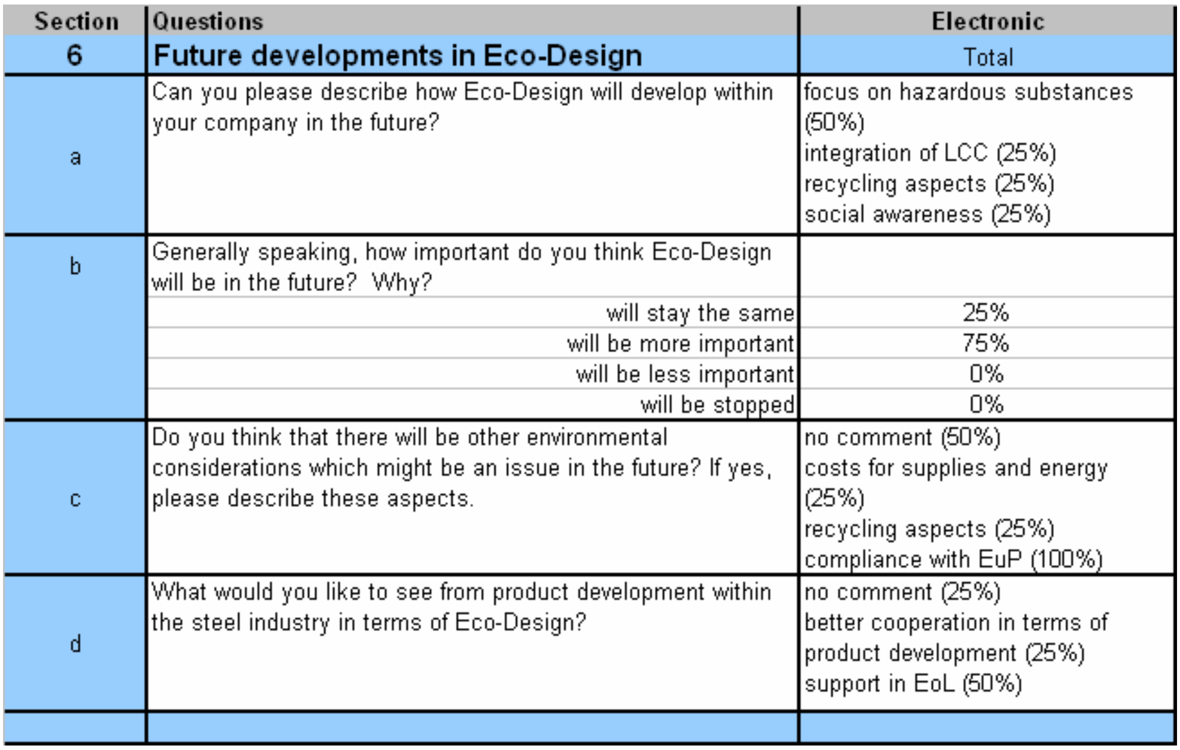
Section	Questions	Electronic
5	Information expectation	Total
a	What is the necessary steel and iron product information that is needed by your company for eco-design purposes on a general basis?	nothing needed (50%) information on material specification (25%) support / cooperation to reduce the consumption of steel material (losses) during product manufacturing (25%) support for the new recycling situation (50%)
b1	In your opinion, what information is required to perform Eco-Design effectively for domestic appliance system in question?	no comment (75%) have done their own LCA (25%)
b2	When considering the eco-design of a product, what are the perceived strengths and weaknesses of using steel?	S: easy to recycle (100%) W: high price compared to plastic (50%) limitation in design (75%) energy intensive to manufacture (25%)
b3	What environmental information do you currently provide to your customers?	EoL information according to (WEEE) (100%) energy label (50%) sustainability report (25%)

Table 24: Expectations from the white goods sector regarding the steel industry

The interviewed experts from the electronics industry speculate that in the future Eco-Design within their own companies will develop quite differently. 50 % think that there will be more focus on the hazardous substances included in their products, whereas 25 % think that Life Cycle Costing (LCC) will be more important and 25% think that additional recycling aspects and social awareness in general will be focused on more precisely.

In general there is a good common understanding and an expectation that Eco-Design will become more important in the future. All of the interviewees agreed that compliance with the EuP directive (which is currently in its final development step) will be an absolute requirement.

In terms of the requirements of future co-operation between the steel industry and the white goods sector, the white goods producers report that most improvements are needed regarding the recycling of steel in their products and that the communication on this could be improved.



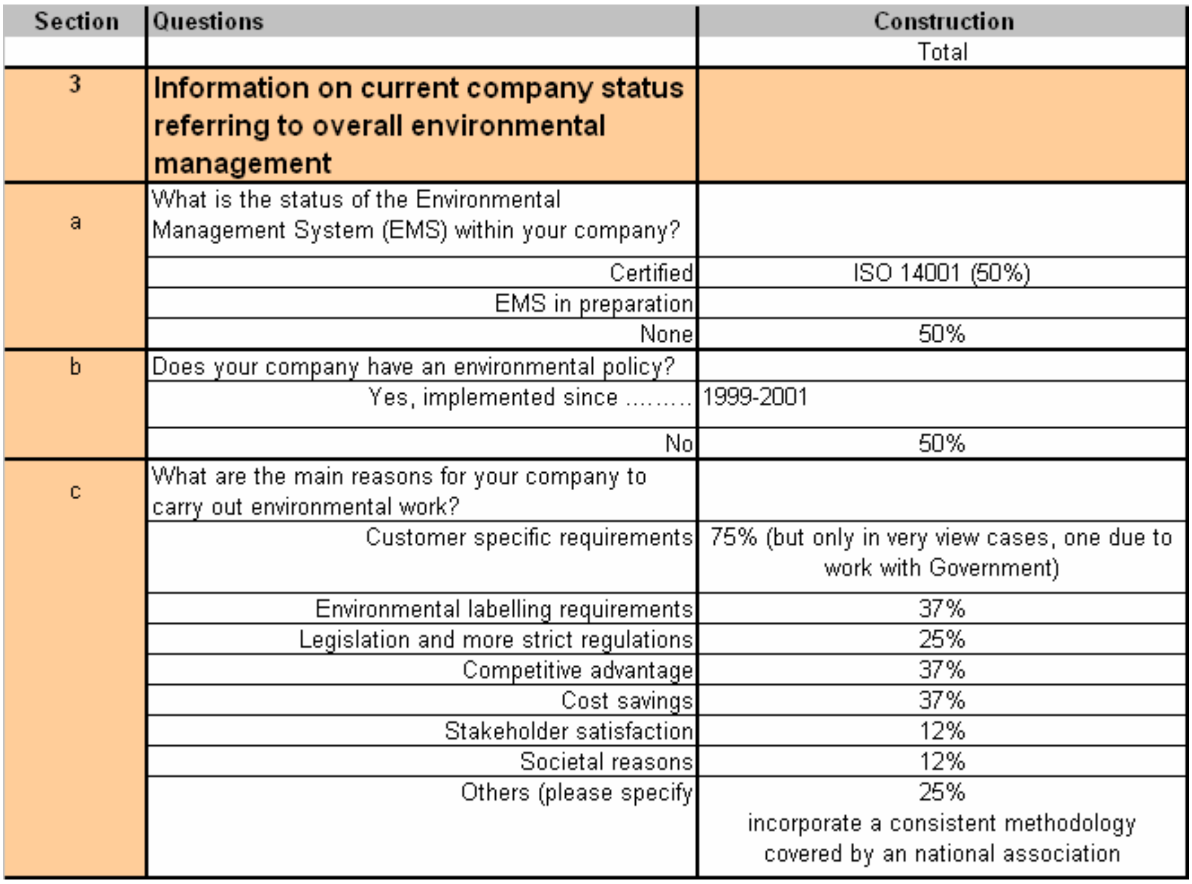
Section	Questions	Electronic
6	**Future developments in Eco-Design**	Total
a	Can you please describe how Eco-Design will develop within your company in the future?	focus on hazardous substances (50%) integration of LCC (25%) recycling aspects (25%) social awareness (25%)
b	Generally speaking, how important do you think Eco-Design will be in the future? Why?	
	will stay the same	25%
	will be more important	75%
	will be less important	0%
	will be stopped	0%
c	Do you think that there will be other environmental considerations which might be an issue in the future? If yes, please describe these aspects.	no comment (50%) costs for supplies and energy (25%) recycling aspects (25%) compliance with EuP (100%)
d	What would you like to see from product development within the steel industry in terms of Eco-Design?	no comment (25%) better cooperation in terms of product development (25%) support in EoL (50%)

Table 25: Expectations on future developments regarding Eco-Design in the white goods sector

17.2.3. Construction industry

In the following section, the results of the interviews held within the construction sector are discussed.

From the construction companies interviewed only 50 % show that they are certified according to ISO 14001. None of the interviewed companies have implemented an environmental management system (EMS). Only 50 % of the companies have a defined environmental policy. The main motivation for the companies in the construction industry to focus on environmental aspects is to co-operate with the government. Other drivers include environmental labelling requirements, cost savings; an overview is presented in Table 26.

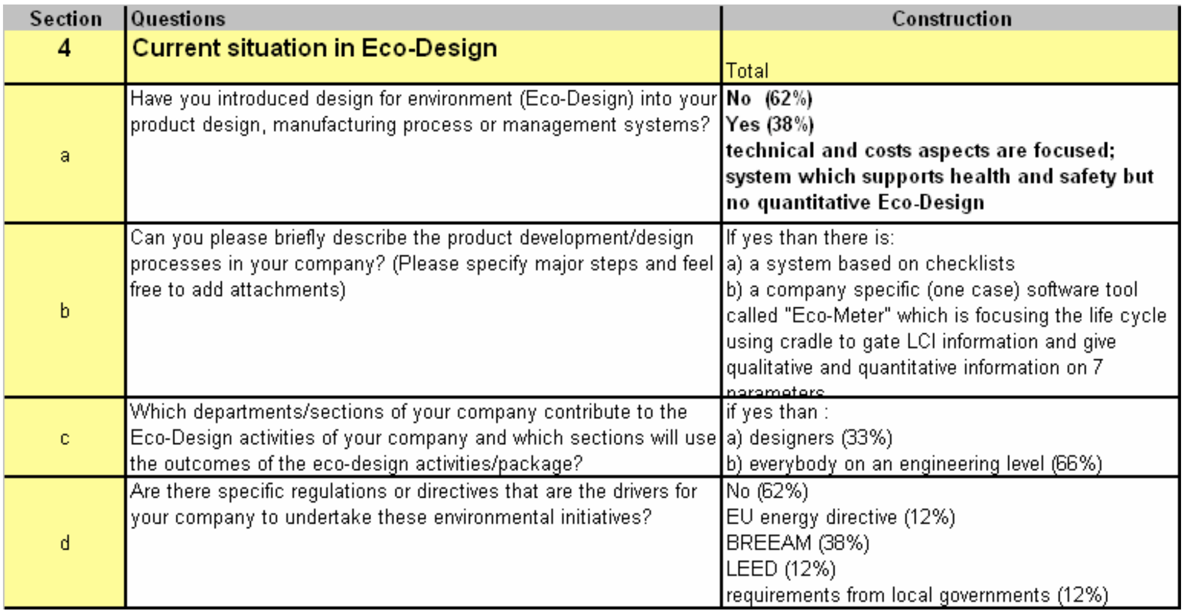


Section	Questions	Construction
		Total
3	**Information on current company status referring to overall environmental management**	
a	What is the status of the Environmental Management System (EMS) within your company?	
	Certified	ISO 14001 (50%)
	EMS in preparation	
	None	50%
b	Does your company have an environmental policy?	
	Yes, implemented since ………	1999-2001
	No	50%
c	What are the main reasons for your company to carry out environmental work?	
	Customer specific requirements	75% (but only in very view cases, one due to work with Government)
	Environmental labelling requirements	37%
	Legislation and more strict regulations	25%
	Competitive advantage	37%
	Cost savings	37%
	Stakeholder satisfaction	12%
	Societal reasons	12%
	Others (please specify	25% incorporate a consistent methodology covered by an national association

Table 26: Overview of the use of environmental management systems within the construction industry

Regarding the level of implementation of Eco-Design in the design process of new construction developments or buildings, two thirds of the companies interviewed said that they have not yet introduced Eco-Design. The other third considers some environmental aspects during product design. It was clearly stated that costs and technical aspects are currently the focus of the design process.

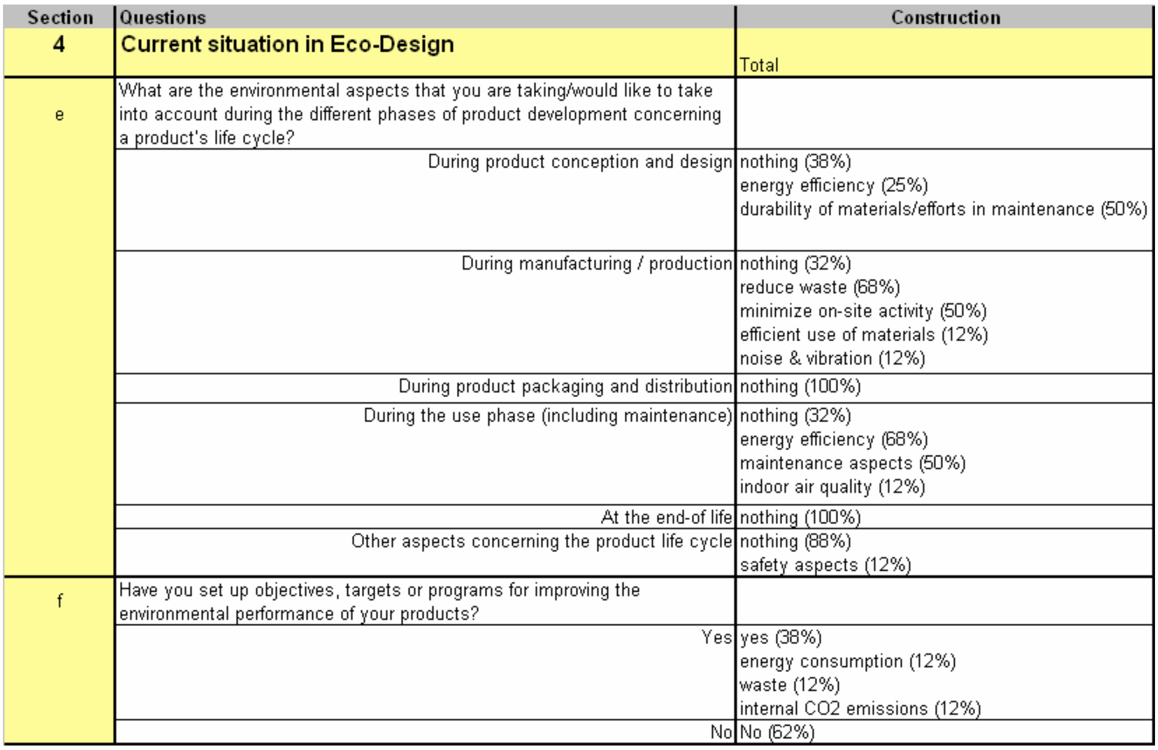
Where an Eco-Design system exists, it is normally based on checklists providing some guideline. Only in one of the interviewed companies has a company developed a software-based system which allows analysis of the whole life cycle of the construction development or buildings. Usually engineers are involved in this type of Eco-Design process using existing tools.



Section	Questions	Construction
4	**Current situation in Eco-Design**	Total
a	Have you introduced design for environment (Eco-Design) into your product design, manufacturing process or management systems?	**No (62%)** **Yes (38%)** **technical and costs aspects are focused; system which supports health and safety but no quantitative Eco-Design**
b	Can you please briefly describe the product development/design processes in your company? (Please specify major steps and feel free to add attachments)	If yes than there is: a) a system based on checklists b) a company specific (one case) software tool called "Eco-Meter" which is focusing the life cycle using cradle to gate LCI information and give qualitative and quantitative information on 7 parameters
c	Which departments/sections of your company contribute to the Eco-Design activities of your company and which sections will use the outcomes of the eco-design activities/package?	if yes than : a) designers (33%) b) everybody on an engineering level (66%)
d	Are there specific regulations or directives that are the drivers for your company to undertake these environmental initiatives?	No (62%) EU energy directive (12%) BREEAM (38%) LEED (12%) requirements from local governments (12%)

Table 27: Status on currently applied Eco-Design practices within the construction sector

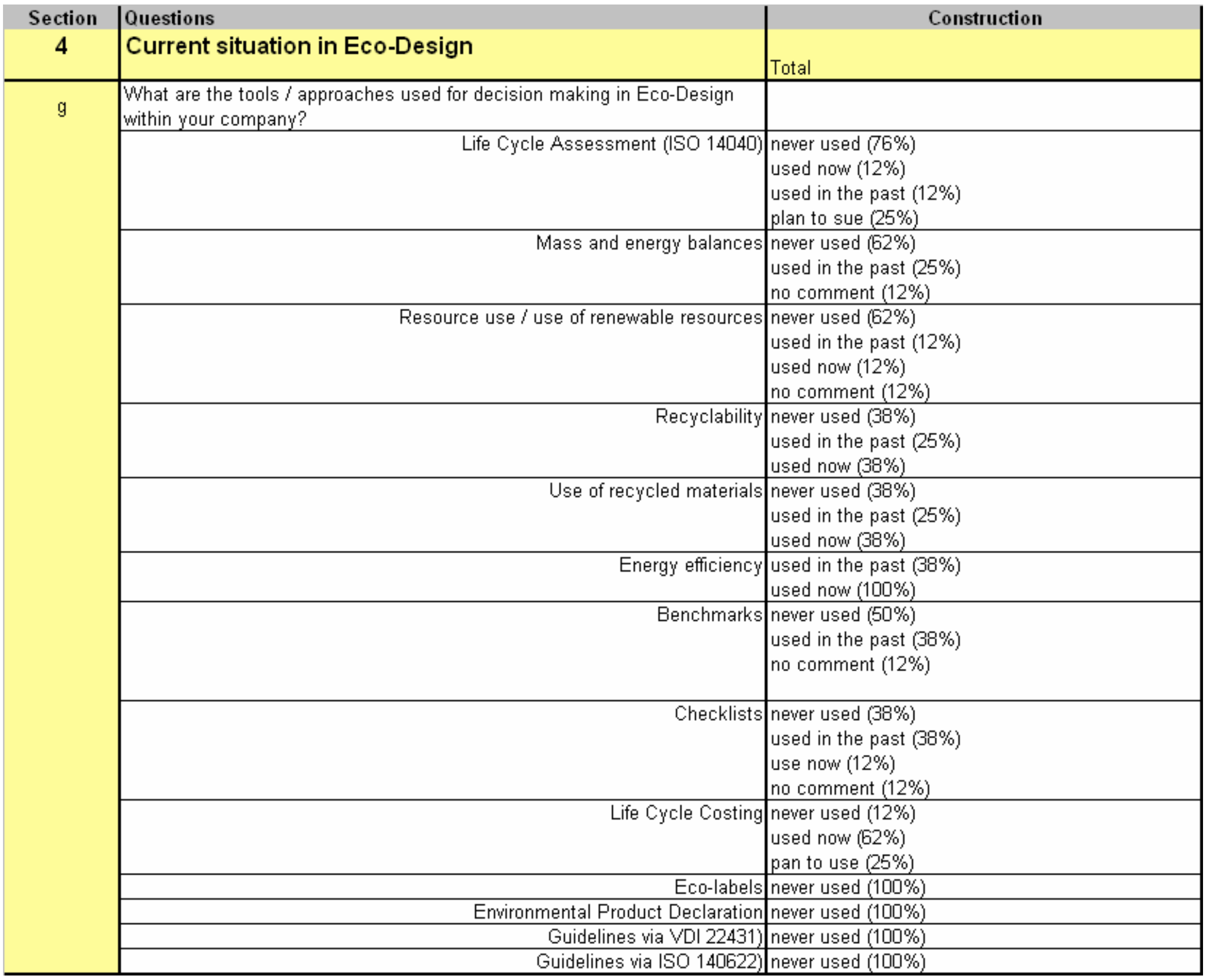
In comparison to the other industrial sectors interviewed, the construction industry shows a very diverse picture regarding the importance of environmental aspects during the design process. This is on the one hand because of the larger difference in size of the interviewed companies but on the other hand also due to the fact that there are not specific regulations that exist which require environmental aspects to be addressed specifically during the development process and those that do exist are not very strict.



Section	Questions	Construction
4	**Current situation in Eco-Design**	Total
e	What are the environmental aspects that you are taking/would like to take into account during the different phases of product development concerning a product's life cycle?	
	During product conception and design	nothing (38%) energy efficiency (25%) durability of materials/efforts in maintenance (50%)
	During manufacturing / production	nothing (32%) reduce waste (68%) minimize on-site activity (50%) efficient use of materials (12%) noise & vibration (12%)
	During product packaging and distribution	nothing (100%)
	During the use phase (including maintenance)	nothing (32%) energy efficiency (68%) maintenance aspects (50%) indoor air quality (12%)
	At the end-of life	nothing (100%)
	Other aspects concerning the product life cycle	nothing (88%) safety aspects (12%)
f	Have you set up objectives, targets or programs for improving the environmental performance of your products?	
	Yes	yes (38%) energy consumption (12%) waste (12%) internal CO2 emissions (12%)
	No	No (62%)

Table 28: Status on currently applied Eco-Design practice within the construction sector (continued)

Table 28 provides an overview of the most important environmental aspects which are analysed or focused on during the different life cycle phases. Most of them are listed because they clearly offer a cost saving potential. It must be understood that environmental reasons are not the major drivers for the selected and therefore presented criteria.



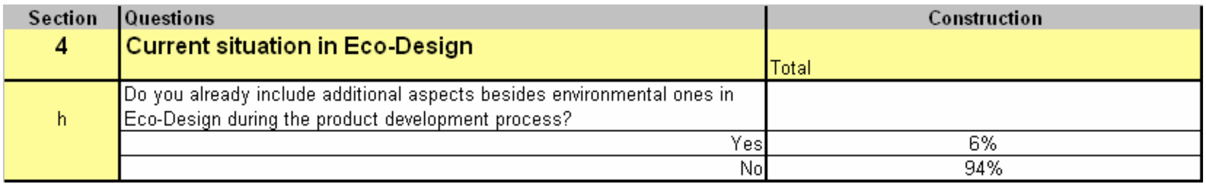
Section	Questions	Construction
4	**Current situation in Eco-Design**	Total
g	What are the tools / approaches used for decision making in Eco-Design within your company?	
	Life Cycle Assessment (ISO 14040)	never used (76%) used now (12%) used in the past (12%) plan to sue (25%)
	Mass and energy balances	never used (62%) used in the past (25%) no comment (12%)
	Resource use / use of renewable resources	never used (62%) used in the past (12%) used now (12%) no comment (12%)
	Recyclability	never used (38%) used in the past (25%) used now (38%)
	Use of recycled materials	never used (38%) used in the past (25%) used now (38%)
	Energy efficiency	used in the past (38%) used now (100%)
	Benchmarks	never used (50%) used in the past (38%) no comment (12%)
	Checklists	never used (38%) used in the past (38%) use now (12%) no comment (12%)
	Life Cycle Costing	never used (12%) used now (62%) pan to use (25%)
	Eco-labels	never used (100%)
	Environmental Product Declaration	never used (100%)
	Guidelines via VDI 22431)	never used (100%)
	Guidelines via ISO 140622)	never used (100%)

Table 29: Tools and approaches used within the Eco-Design process

Table 29 provides an overview of applied and/or available tools and methods within companies in the construction sector. Again it seems to be that a systematic analysis of environmental aspects on the basis of tools and approaches providing quantitative information is not really applied. Only one company seems to apply approaches like LCA regularly.

The interviewed companies reported that, at this time, there are no other aspects considered to be included in their general procedure to develop new constructions or buildings. This might change in the near future, because at the time of the interviews (early 2006) country-specific developments on measures such as an “energy pass” for houses and apartments in Germany have been discussed and will increase the awareness of the environmental relevance of buildings.

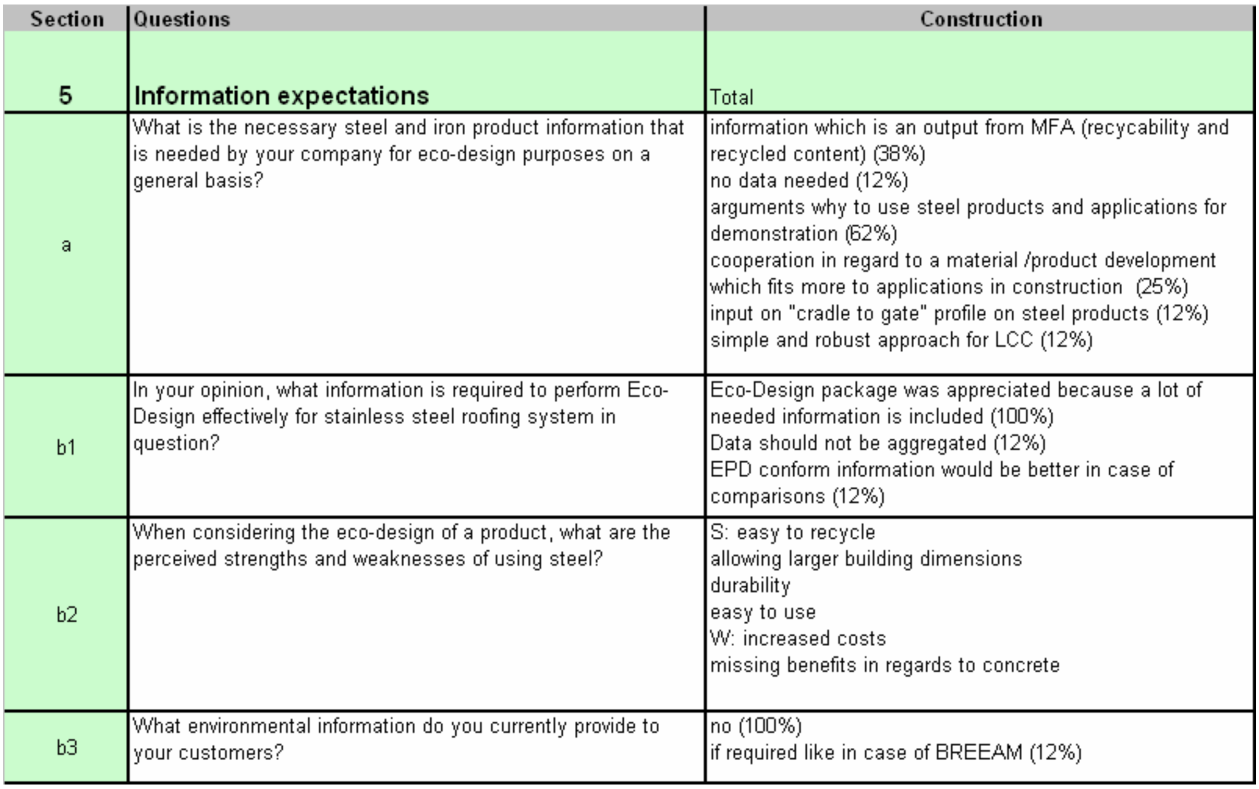
Furthermore, the current discussion on CO_2 emissions will probably lead to new regulations that will drive the energy efficiency of buildings to be more important. When this occurs, a system analysis approach like LCA will offer the opportunity to identify the most suitable and therefore environmentally beneficial options.



Section	Questions	Construction
4	**Current situation in Eco-Design**	Total
h	Do you already include additional aspects besides environmental ones in Eco-Design during the product development process?	
	Yes	6%
	No	94%

Table 30: Tools and approaches used within the Eco-Design process (continued)

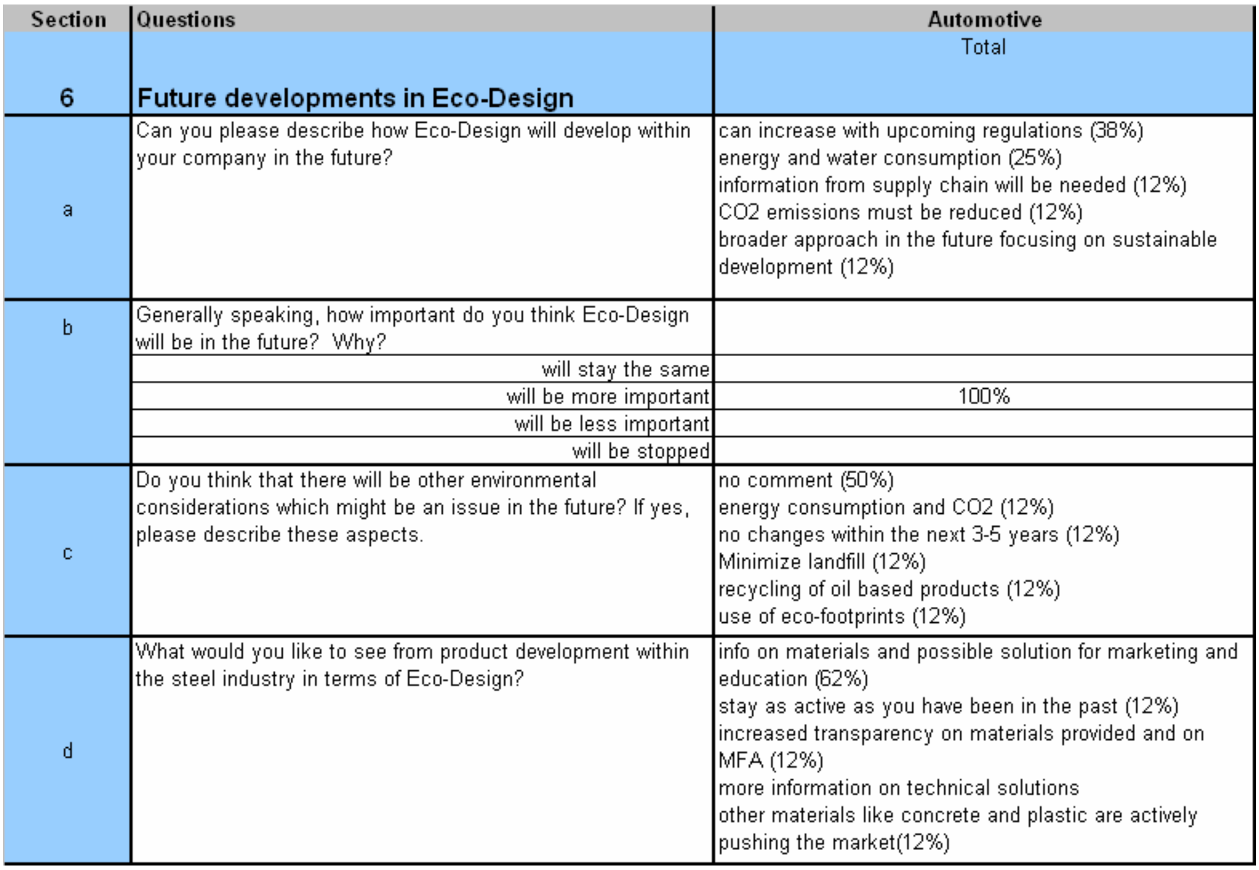
The interviews identified that the construction industry sees a variety of opportunities to improve the communication and / or the cooperation with the steel industry. These are listed in Table 31. Here it must also be kept in mind that the interviewed companies differ a lot in size and also, the field of activity. Therefore, the feedback needs to be considered in this context. Nevertheless, there was a relatively clear message that other material associations provide more marketing materials and provide these continuously, showing potential construction applications. For this reason the Eco-Design packages have been seen as a very good step in the right direction providing an overview of existing information, and should be developed further.



Section	Questions	Construction
5	**Information expectations**	Total
a	What is the necessary steel and iron product information that is needed by your company for eco-design purposes on a general basis?	information which is an output from MFA (recycability and recycled content) (38%) no data needed (12%) arguments why to use steel products and applications for demonstration (62%) cooperation in regard to a material /product development which fits more to applications in construction (25%) input on "cradle to gate" profile on steel products (12%) simple and robust approach for LCC (12%)
b1	In your opinion, what information is required to perform Eco-Design effectively for stainless steel roofing system in question?	Eco-Design package was appreciated because a lot of needed information is included (100%) Data should not be aggregated (12%) EPD conform information would be better in case of comparisons (12%)
b2	When considering the eco-design of a product, what are the perceived strengths and weaknesses of using steel?	S: easy to recycle allowing larger building dimensions durability easy to use W: increased costs missing benefits in regards to concrete
b3	What environmental information do you currently provide to your customers?	no (100%) if required like in case of BREEAM (12%)

Table 31: Expectations of the construction industry on the steel industry

The discussion on the future of Eco-Design within the construction industry showed a clear direction. All companies have agreed that they expect environmental or sustainability parameters to become more important in the future and that there will be a need to focus on available information to address them (see section 6b of Table 32).



Section	Questions	Automotive
6	**Future developments in Eco-Design**	Total
a	Can you please describe how Eco-Design will develop within your company in the future?	can increase with upcoming regulations (38%) energy and water consumption (25%) information from supply chain will be needed (12%) CO2 emissions must be reduced (12%) broader approach in the future focusing on sustainable development (12%)
b	Generally speaking, how important do you think Eco-Design will be in the future? Why?	
	will stay the same	
	will be more important	100%
	will be less important	
	will be stopped	
c	Do you think that there will be other environmental considerations which might be an issue in the future? If yes, please describe these aspects.	no comment (50%) energy consumption and CO2 (12%) no changes within the next 3-5 years (12%) Minimize landfill (12%) recycling of oil based products (12%) use of eco-footprints (12%)
d	What would you like to see from product development within the steel industry in terms of Eco-Design?	info on materials and possible solution for marketing and education (62%) stay as active as you have been in the past (12%) increased transparency on materials provided and on MFA (12%) more information on technical solutions other materials like concrete and plastic are actively pushing the market(12%)

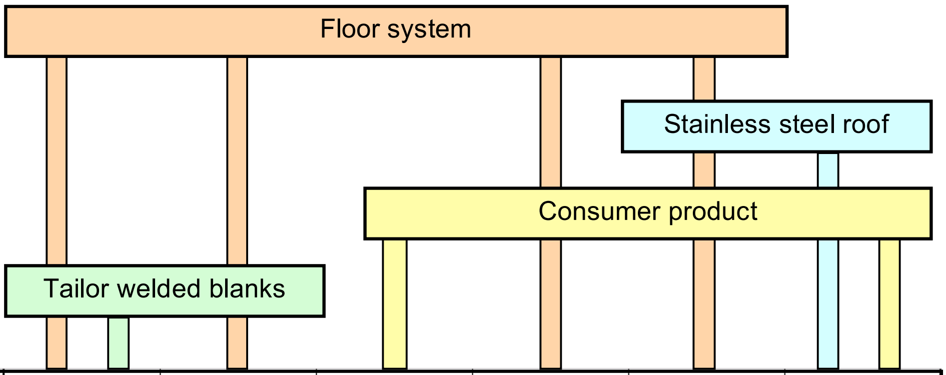
Table 32: Expectations of future developments regarding Eco-Design in the construction sector

17.3. LCA Case Studies

In the following section, the system boundaries for the selected case studies are described as well as selected results will be presented and discussed. Chapter 17.3.1 gives an overview on major ecological parameters for steel types used within the selected case study products.

17.3.1. Ecological Parameters of considered Steel Types

As shown in Figure 33, the tailor welded blank case study and the composite flooring system deal with carbon steel, the stainless steel roof case study focuses on stainless steel and the consumer product are produced using both carbon and stainless steel.



	EU: Electrogalvanised coil BF (IISI), 1kg	EU: Hot dip galvanized coil BF (IISI), 1kg	EU: Organic coated coil BF (IISI), 1kg	World: Rebar EAF/BF (IISI), 1kg	World: Sections EAF/BF (IISI), 1kg	World: Stainless Steel (304 2B, IISI), 1kg
Total primary energy [MJ]	33,56	32,79	33,99	20,09	19,23	54,04
CO2 emission in air [kg]	2,54	2,59	2,55	1,68	1,44	6,10
CML2001, GWP [kg CO2-Equiv.]	2,61	2,66	2,62	1,71	1,47	6,10
CML2001, AP [kg SO2-Equiv.]	0,007	0,007	0,007	0,004	0,004	0,056
CML2001, EP [kg Phosphate-Equiv.]	0,001	0,001	0,001	0,000	0,000	0,002
CML2001, POCP [kg Ethene-Equiv.]	0,002	0,001	0,001	0,001	0,001	0,003

Figure 33: Overview on used steel types within selected case studies

The table within Figure 33 provides an overview on characteristic values describing selected ecological Life cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) parameters for the different steel types consumed in the case study products.

LCI parameters presented are the total primary energy demand in MJ and the resulting carbon dioxide emission to air in kg for the production of 1 kg steel.

Selected LCIA criteria are based on the methodology developed by the Centre of Millieukunde (Netherlands, CML 2001). This selection covers the:

- Global warming potential (GWP) in kg CO_2 equivalents
- Acidification potential (AP) in kg SO_2 equivalents
- Eutrophication Potential in kg phosphate-equivalents (PO_4-eq.)
- Photochemical Ozone Creation Potential (POCP) potential in kg ethylene-equivalents (C_2H4-eq.)

The overview shows that for the selected ecological parameters the values can differ quite a lot which is due to the different steel materials and required amount of alloying elements. At this stage it is clearly mentioned that a comparison of the ecological performance of different steel types on the basis of 1 kg material is not a sufficient approach. Furthermore a comparison of different alternatives must always be build on the same functional unit provided.

17.3.2. Life Cycle Assessment (LCA) of a composite flooring systems

This chapter provides a detailed description of the system boundaries defined to analyse the life cycle of a composite flooring system.

17.3.2.1. Goal and Scope definition

The goal of this case study is to gain an understanding about what information regarding steel products is requested, if an LCA of a product containing steel is performed, as well as to demonstrate typical results from an LCA case study.

The functional unit of this case study is a composite flooring system, 7.5 x 7.5 m (without columns) as illustrated in Figure 34, including:

- steel beams (intumescent coating on 3 sides): 1228.5 kg
- profiled sheet decking (galvanized, 20 µm): 707.5 kg
- steel reinforcement bars: 228.2 kg
- steel shear studs: 23.6 kg
- concrete (LCW): 9 720 kg
- coating: 96.9 kg

The most frequently applied combination of construction materials for buildings as well as bridges is that of structural steel and concrete. The composite flooring system is easily constructed by pouring light-weight concrete (LWC) onto a steel decking that has been laid across the steel joists / steel beams. Shear studs are fixed to the top flange of the steel beams through holes in the steel decking (they can either be bolted or welded onto the beam). Reinforcing steel bars are laid over the decking and the concrete is poured in situ. The large number of shear studs protruding into the concrete causes the underlying steel joists, decking and the concrete to act compositely as one unit.

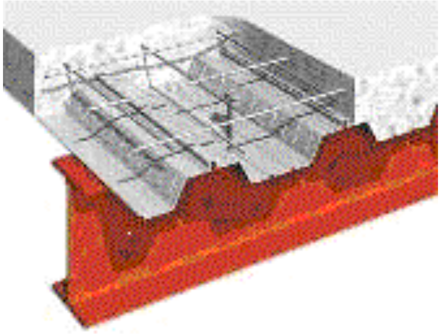


Figure 34 Schematic illustration of a composite flooring system

The scope of the case study focuses on EU system boundaries for materials and energy carriers. The following life cycle data sets, as well as the manufacturing process, are included in the LCA model:

Production phase:

- beam production based on IISI LCI profile: steel sections, transportation (truck 40t total payload, 350km), no processing, no assembly

- profiled sheet decking production based on IISI LCI profile: hot dip galvanised steel, transportation (truck 40t total payload, 350km), profiling as processing included, no assembly
- reinforcement bar production based on IISI LCI profile: rebar steel, transportation (truck 40t total payload, 350km), no processing, no assembly
- steel shear studs production (IISI LCI profile: electro-galvanised steel), transportation (truck 40t total payload, 350km), no processing, no assembly
- concrete (LWC) production, transportation (truck 40t total payload, 50km) and installation (concrete pumping)

Exceptions:

- concrete and coating → based on German country specific settings
- rebar and sections steel → based on world system boundaries

Use phase / maintenance:

As a general definition the use phase of the case study products is generally not included within the scope of the studies. Only any maintenance efforts have been of interest. For the composite flooring system no maintenance processes are necessary.

End of life:

The end of life scenario of composite flooring system includes the demolishment and the related preparation of the recycled materials steel and concrete.

- Demolition of floor and separation (based on EU specific settings)
- Recycling of steel according to IISI recycling methodology = credit system (based on EU specific settings)
- Recovery of concrete, use of recycling good as gravel = credit system (based on German country specific settings)

17.3.2.2. Modelling within the GaBi4 software system

As illustrated in Figure 35, the life cycle of the composite flooring system includes the manufacturing phase, the use phase and the end of life phase. As already said the use phase only includes maintenance efforts, which in the case of the composite flooring system, does not exist.

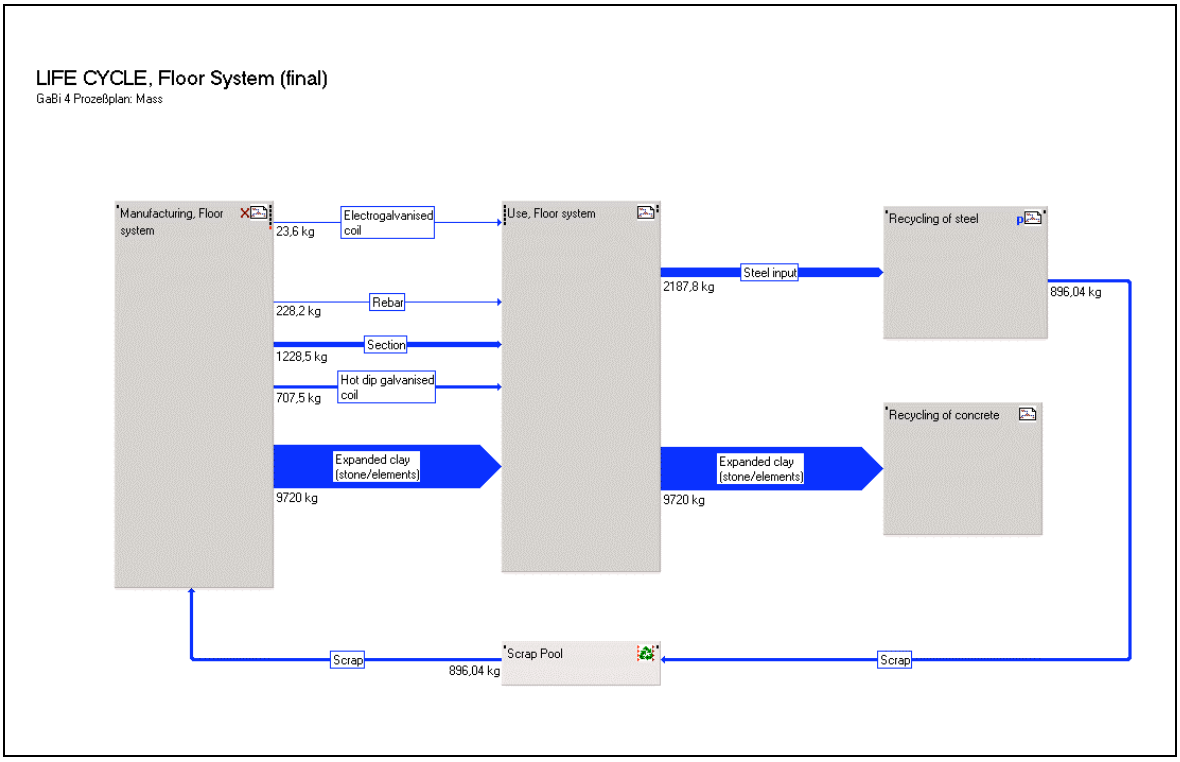


Figure 35: Model of the life cycle of the composite flooring system in GaBi 4

Manufacturing phase

The manufacturing phase for the composite flooring system includes the following aspects:

- Production of the consumed material (e.g. electro-galvanised steel, lightweight concrete, etc) on the basis of “cradle to gate” inventories. This includes all major production steps from the exploration of resources to the final material conversion.
- Transportation on the basis of average information on the distance from the material manufacturing location to the construction site. For steel, transportation is an average distance of 350 km and for concrete 50 km was defined (from material production site to construction site).
- Major processing steps on-site are included. This focuses mainly on the pumping of the concrete

Analysis of manufacturing can be divided into:

- steel
- concrete
- coating
- transport
- processing

Figure 36 shows the detailed information on the model of the manufacturing phase within the software system, GaBi 4. Each of the grey boxes (e.g. beams) includes detailed information on the material production as well as needed transportation.

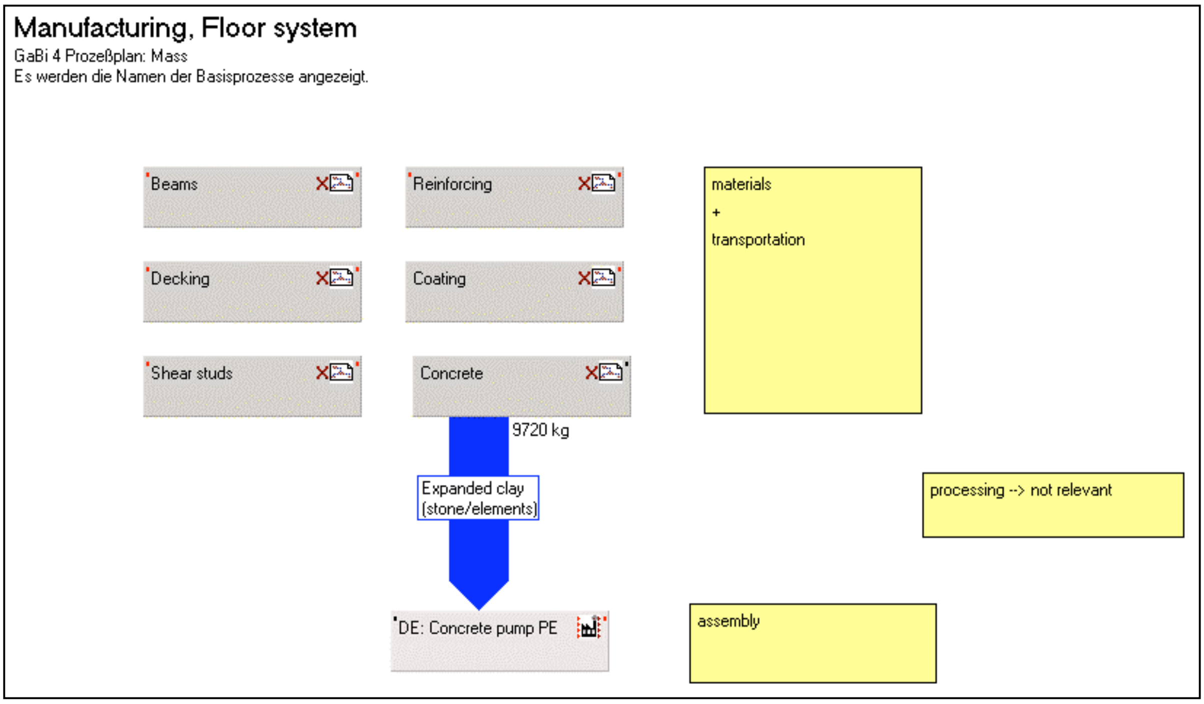


Figure 36: Details of the model for the manufacturing phase

End of life phase

The end of life phase of the composite flooring system includes the demolition of the construction as well as the related treatment of the materials. From the resulting amount of steel scrap, the required portion is taken to fulfil the scrap consumption of the manufacturing phase (indicated by the grey box “scrap loop”). For the remaining amount of scrap, a credit is given based on the recycling method from IISI (Appendix 17.4).

For the end of life scenario, the recycling rate of the steel products used within the construction sector, based on information from IISI, is 85 %.

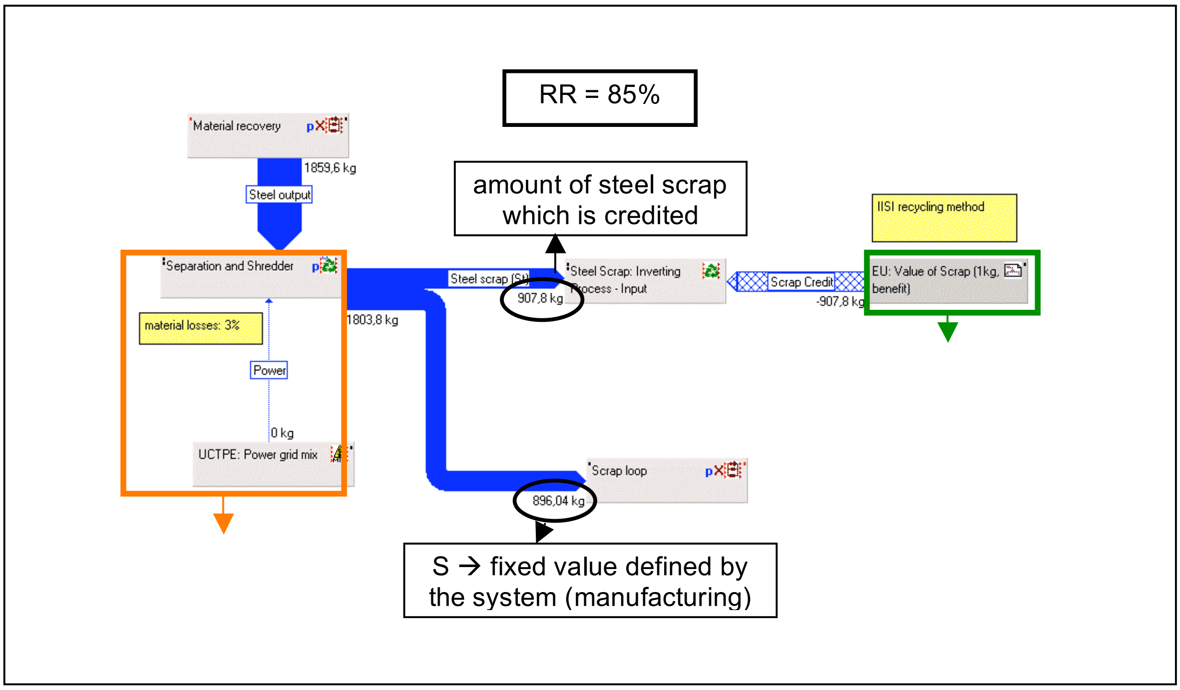
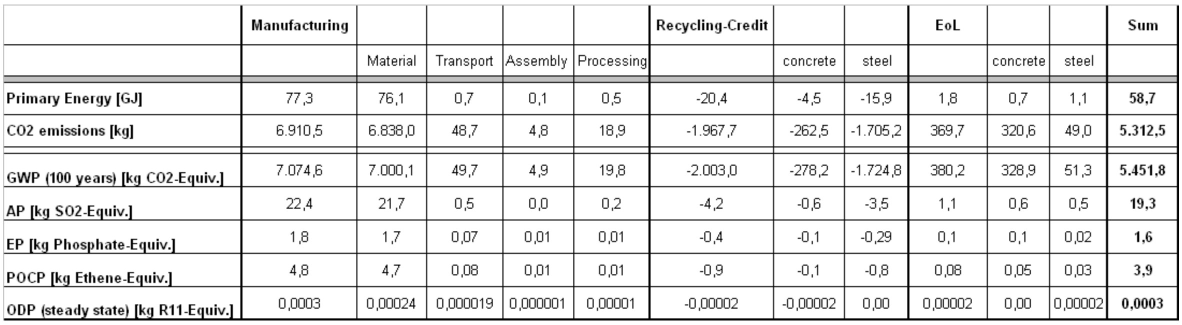


Figure 37: Details of the model for the end of life phase

17.3.2.3. Results

In Table 33, the results for the LCA of the composite flooring system are presented. The selected results cover the most important inventory parameters (carbon dioxide emissions as well as primary energy demand) as well as impact indicators like GWP, AP, EP, POCP and ODP. The five impact categories are accepted within the metals industry.



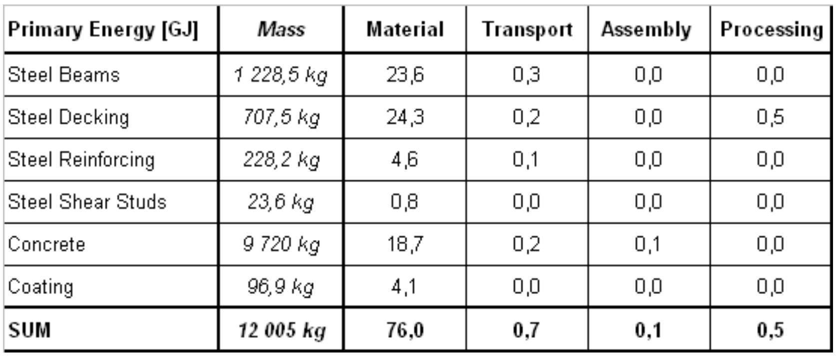
	Manufacturing					Recycling-Credit			EoL			Sum
		Material	Transport	Assembly	Processing		concrete	steel		concrete	steel	
Primary Energy [GJ]	77,3	76,1	0,7	0,1	0,5	-20,4	-4,5	-15,9	1,8	0,7	1,1	**58,7**
CO2 emissions [kg]	6.910,5	6.838,0	48,7	4,8	18,9	-1.967,7	-262,5	-1.705,2	369,7	320,6	49,0	**5.312,5**
GWP (100 years) [kg CO2-Equiv.]	7.074,6	7.000,1	49,7	4,9	19,8	-2.003,0	-278,2	-1.724,8	380,2	328,9	51,3	**5.451,8**
AP [kg SO2-Equiv.]	22,4	21,7	0,5	0,0	0,2	-4,2	-0,6	-3,5	1,1	0,6	0,5	**19,3**
EP [kg Phosphate-Equiv.]	1,8	1,7	0,07	0,01	0,01	-0,4	-0,1	-0,29	0,1	0,1	0,02	**1,6**
POCP [kg Ethene-Equiv.]	4,8	4,7	0,08	0,01	0,01	-0,9	-0,1	-0,8	0,08	0,05	0,03	**3,9**
ODP (steady state) [kg R11-Equiv.]	0,0003	0,00024	0,000019	0,000001	0,00001	-0,00002	-0,00002	0,00	0,00002	0,00	0,00002	**0,0003**

Table 33: Selected results for the whole life cycle and the single life cycle phases of the composite flooring system

Table 33 provides results for each life cycle phase as well as the total result of the life cycle analysis. The results show that the burden related to the manufacturing phase is dominating the results. This is obvious due to the definition of the scope of the case studies that the utilisation phase is not included. Usually the use phase, with the related energy consumption over a period of more than 30-50 years, is the most characteristic phase when analysing the complete lifetime of a building.

The end-of-life processing is only of minor relevance within the life cycle consideration. Therefore, the resulting recycling credit shows that about 20-25 % of the initial environmental burden can be reduced by the credit which is given due to a potential second application of the resulting steel scrap.

Table 34 gives a more detailed overview on the primary energy demand within the manufacturing phase.



Primary Energy [GJ]	*Mass*	Material	Transport	Assembly	Processing
Steel Beams	*1 228,5 kg*	23,6	0,3	0,0	0,0
Steel Decking	*707,5 kg*	24,3	0,2	0,0	0,5
Steel Reinforcing	*228,2 kg*	4,6	0,1	0,0	0,0
Steel Shear Studs	*23,6 kg*	0,8	0,0	0,0	0,0
Concrete	*9 720 kg*	18,7	0,2	0,1	0,0
Coating	*96,9 kg*	4,1	0,0	0,0	0,0
SUM	***12 005 kg***	**76,0**	**0,7**	**0,1**	**0,5**

Table 34: Detailed results on primary energy demand for the manufacturing phase

Table 35 provides a transparent overview on the carbon dioxide emissions to air related to the manufacturing phase of the composite flooring system. Both tables (Table 34 and Table 35) show that the material production (column “Material”) is clearly dominating the manufacturing phase.

CO2 emissions [kg]	*Mass*	Material	Transport	Assembly	Processing
Steel Beams	*1 228,5 kg*	1.769,0	19,6	0,0	0,0
Steel Decking	*707,5 kg*	1.922,2	11,8	0,0	18,9
Steel Reinforcing	*228,2 kg*	383,4	3,6	0,0	0,0
Steel Shear Studs	*23,6 kg*	59,9	0,4	0,0	0,0
Concrete	*9 720 kg*	2.535,3	13,3	4,8	0,0
Coating	*96,9 kg*	168,2	0,0	0,0	0,0
SUM	***12 005 kg***	**6.838,0**	**48,7**	**4,8**	**18,9**

Table 35: Detailed results on carbon dioxide emissions to air for the manufacturing phase

In Figure 38, carbon dioxide emissions to air are illustrated, which arise during the different life cycle phases.

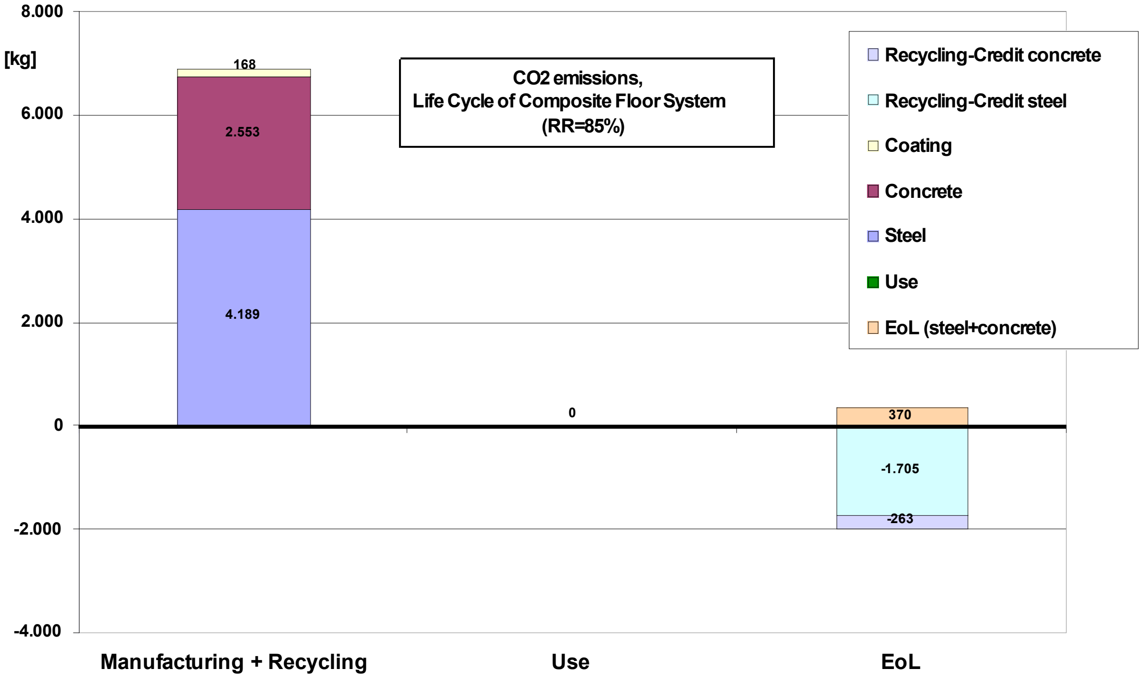


Figure 38: Carbon dioxide emissions to air per life cycle phase

The negative values in the end of life (EoL) column indicate the credit which is given for the resulting scrap within this life cycle. Figure 39 provides an overview of the CO_2 emissions during the production of the different components in the manufacturing phase.

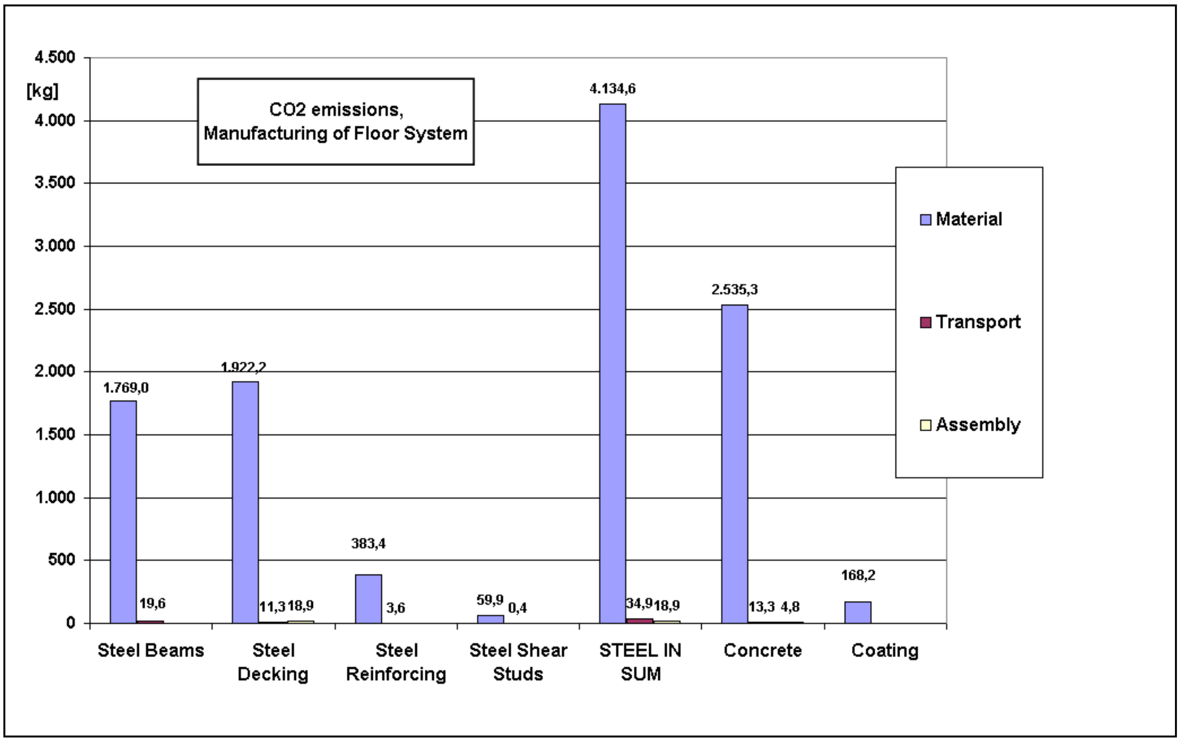


Figure 39: Detailed breakdown of carbon dioxide emissions to air focussing on consumed materials during manufacturing

The primary energy demand resulting for the life cycle assessment for the composite flooring system is shown in Figure 40. The negative values within the column ‘end-of-life’ indicate the credit given due to the recovery of the scrap.

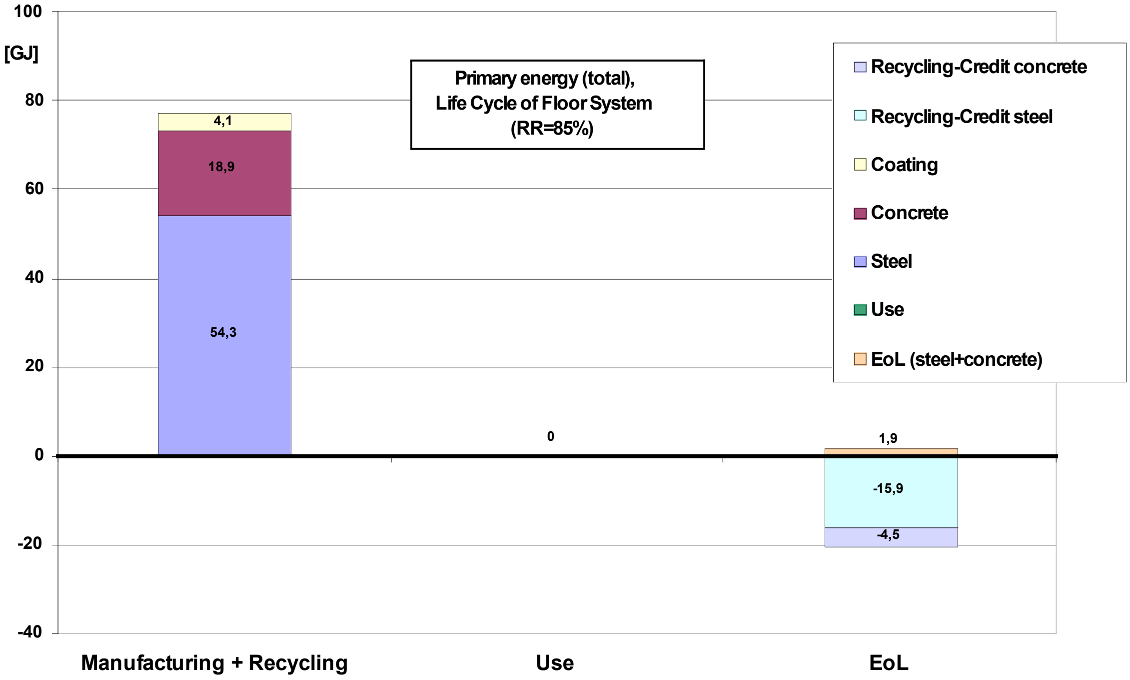


Figure 40: Primary energy demand within life cycle phases

17.3.3. Life Cycle Assessment (LCA) for a stainless steel roof

This chapter provides a detailed description of the system boundaries defined to analyse the life cycle of a stainless steel roofing system.

17.3.3.1. Goal and Scope

The functional unit of this case study is 1 m2 of a stainless steel roof, as illustrated in Figure 41, including:

♦ stainless steel cover (304 2B), 0.4mm thick	3.45 kg
♦ fittings (stainless steel clips and steel nails)	0.1 kg

As shown, the stainless steel roof is normally laid on a supporting structure which is commonly constructed from wood, concrete or carbon steel. An insulation layer between the support and the stainless roof is also provided, for purposes such as energy preservation or noise insulation. Within the scope of this study the supporting structure is not included.

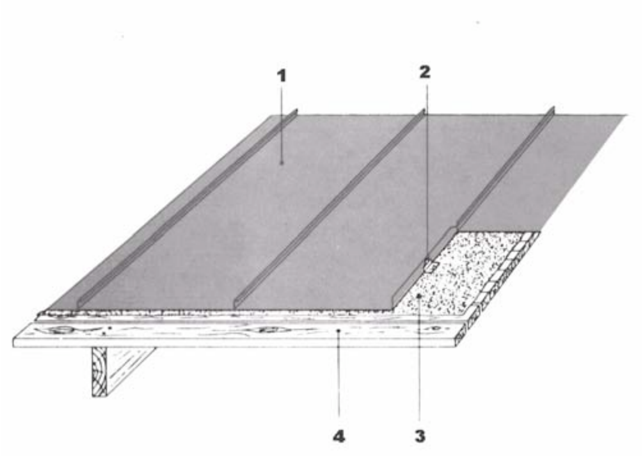


Figure 41: Example of a typical construction of a stainless steel roof.

The scope of the case study focuses on EU system boundaries for materials and energy carriers. The following data sets as well as manufacturing process are included in the modelling of the life cycle:

- stainless steel used for the roof is based on world specific settings
- energy supplies are based on European average grid mix information

Manufacturing phase:

Within the manufacturing phase of the stainless steel roof the following aspects have been considered:

- stainless steel sheet production, LCI profile based on information from ISSF: (stainless steel, 304 2B), transportation (truck 40t total payload, 350km)
- manufacturing processes for the roof installation focusing on stamping, bending and folding of the stainless steel sheets
- for the fittings, information from the GaBi 4 databases (2006) have been used

Use phase:

The advantage of this self-repair capability of stainless steel ensures that the maintenance efforts for stainless steel roofing are negligible and that environmental impacts in the use phase can be neglected.

End of Life phase:

For the end of life phase the following aspects have been considered to be included in the scope of the study:

- Demolishing of roof and separation based on EU specific settings
- Recycling of stainless steel according to ISSF recycling methodology = credit system (based on EU specific settings)

17.3.3.2. Modelling of the life cycle of the stainless steel roofing system

Figure 42 shows the system model of the stainless steel roofing system in the LCA GaBi 4 software. It illustrates that also in the case of stainless steel, there is a loop of stainless steel scrap from the end of life phase to the manufacturing phase to fulfill the need of scrap in the manufacturing process of stainless steel. In addition, it is shown that the needed carbon steel scrap within the manufacturing phase is provided to the stainless steel roofing system.

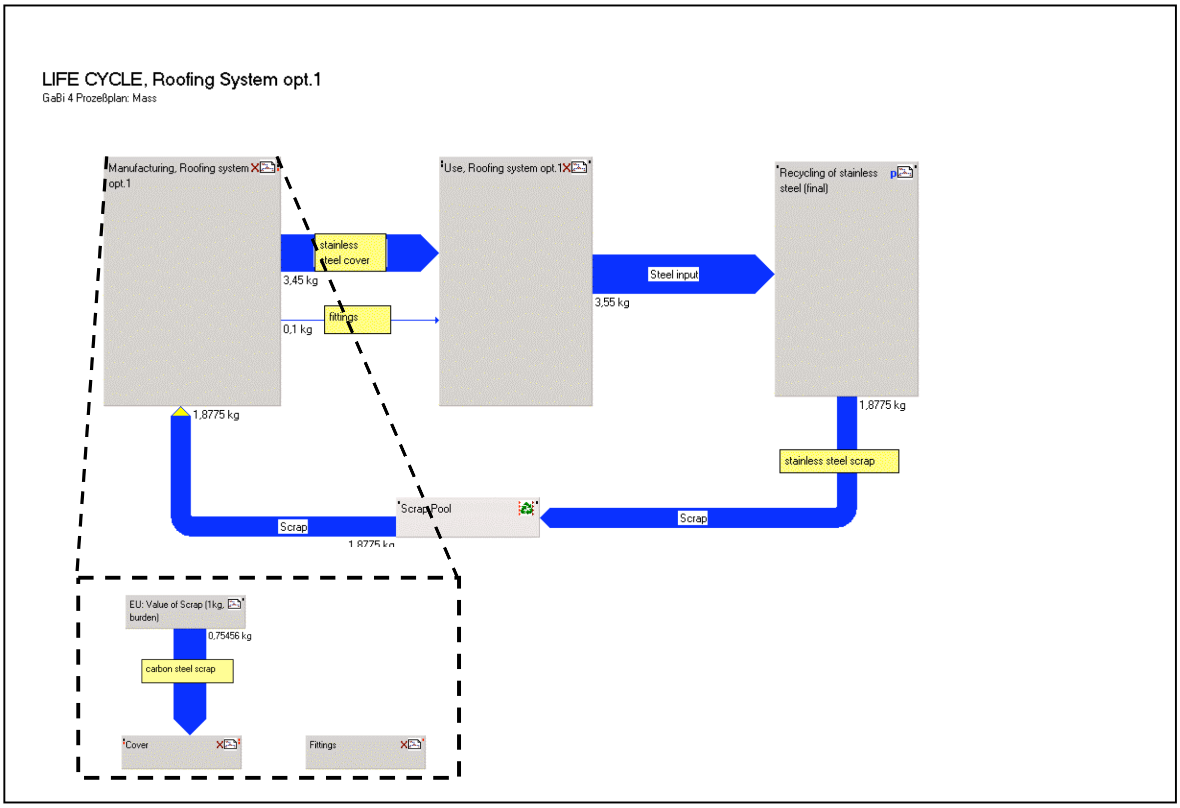


Figure 42: Life cycle model of the stainless steel roof in GaBi 4

The modelling of the end of life phase is shown in Figure 42. The model is divided into two parts. The first part covers the end of life processing which is the demolition of the stainless steel roof and the separation of materials. For the calculation of the resulting amount of stainless steel scrap, the sector specific recycling rate is 90 % (based on information from ISSF). The yield within the end of life processing is also included.

The second part is the calculation of the credit of the scrap. Therefore, only the remaining amount of stainless steel scrap is used which is due to the fact that stainless steel is made from 60 % scrap, lower than the same route within the carbon steel making process. This indicates at the same time that stainless steel is a material which shows the signs of closed recycling loop.

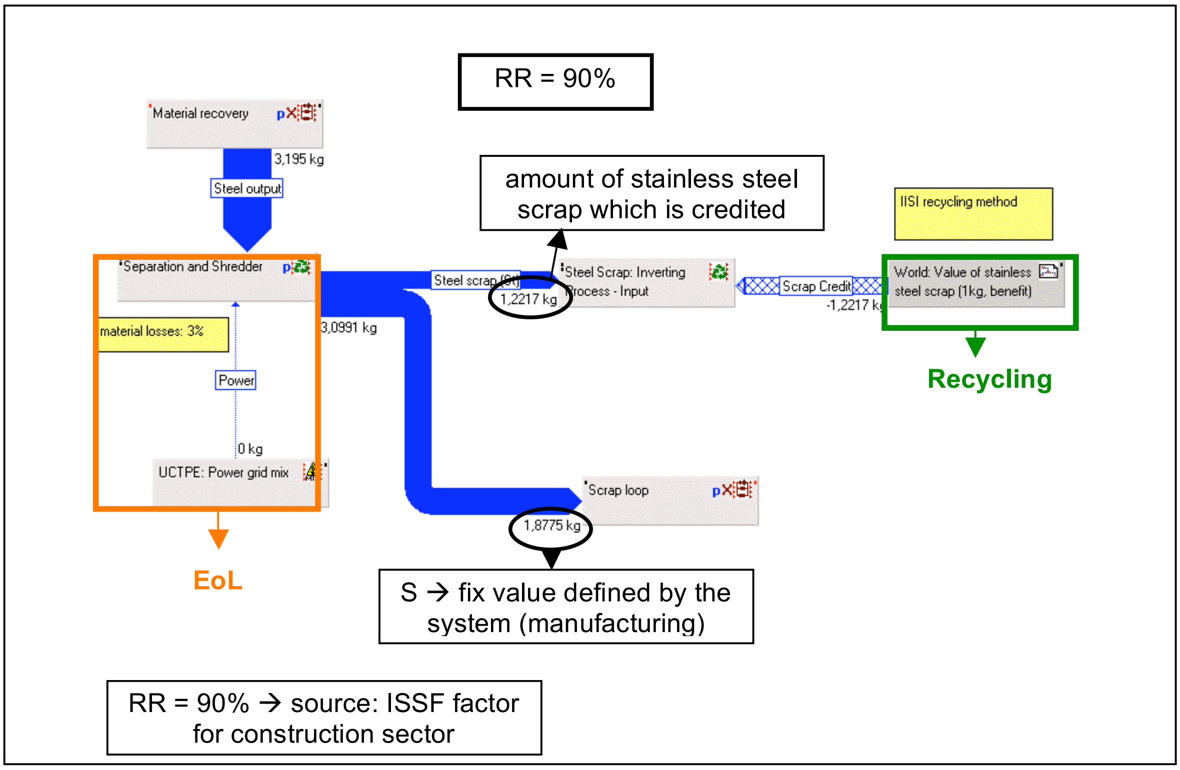


Figure 43: End of life phase modelling of the stainless steel roofing system

17.3.3.3. Results

Table 36 shows the results for the LCA of the roofing system. The selected results cover the most important inventory parameters (carbon dioxide emissions as well as primary energy demand) and the impact indicators such as GWP, AP, EP, POCP and ODP. The five impact categories are accepted within the metal industry.

	Manufacturing					**Recycling-Credit**		**EoL**		**Sum**
		Material	Transport	Assembly	Processing		steel		steel	
Primary Energy [MJ]	216,3	212,9	0,8	0,3	2,3	-59,5	-59,5	2,1	2,1	**158,9**
CO2 emissions [kg]	24,0	23,8	0,1	0,0	0,1	-4,0	-4,0	0,1	0,1	**20,1**
GWP (100 years) [kg CO2-Equiv.]	24,0	23,8	0,059	0,011	0,097	-4,0	-4,0	0,088	0,088	**20,1**
AP [kg SO2-Equiv.]	0,21	0,2	0,0005	0,0001	0,0009	-0,03103	-0,03103	0,0008	0,001	**0,18**
EP [kg Phosphate-Equiv.]	0,009	0,009	0,000088	0,000004	0,000035	-0,00193	-0,00193	0,00003	0,00003	**0,007**
POCP [kg Ethene-Equiv.]	0,011	0,011	0,000091	0,000006	0,000059	-0,00169	-0,00169	0,00005	0,00005	**0,010**
ODP (steady state) [kg R11-Equiv.]	0,00000007	0,000000016	0,000000022	0,000000003	0,000000032	0,0	0,0	0,00000003	0,00000003	**0,0000001**

Table 36: Selected results for the whole life cycle and the single life cycle phases of the stainless steel roofing system

The results for the stainless steel roof demonstrate that again the material production is the most important contribution to the overall results for the selected system boundaries which do not cover the effects of the use phase (use of a heating system).

The processing and transportation of the stainless steel sheets used for the roofing system are about 1 % compared to the material production.

Figure 44 shows the carbon dioxide emissions to air resulting from the analysis of the life cycle of the stainless steel roofing system.

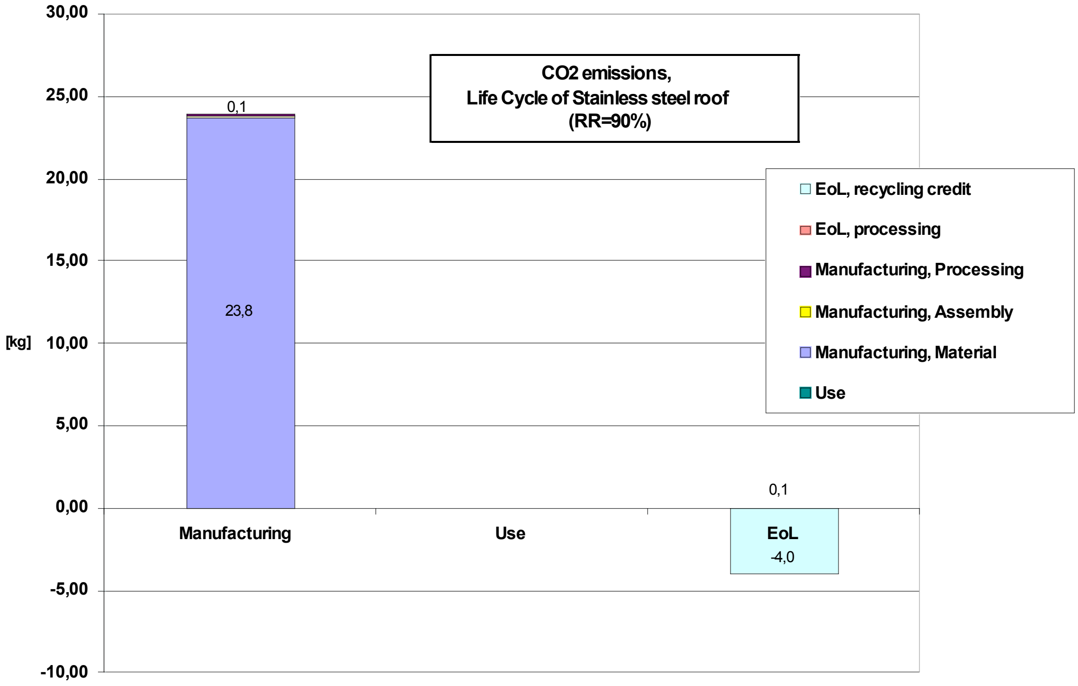


Figure 44: Carbon dioxide emissions to air within the life cycle per m^2 of stainless steel roof

Figure 45Figure 44 shows the primary energy demand resulting from the analysis of the life cycle of the stainless steel roofing system.

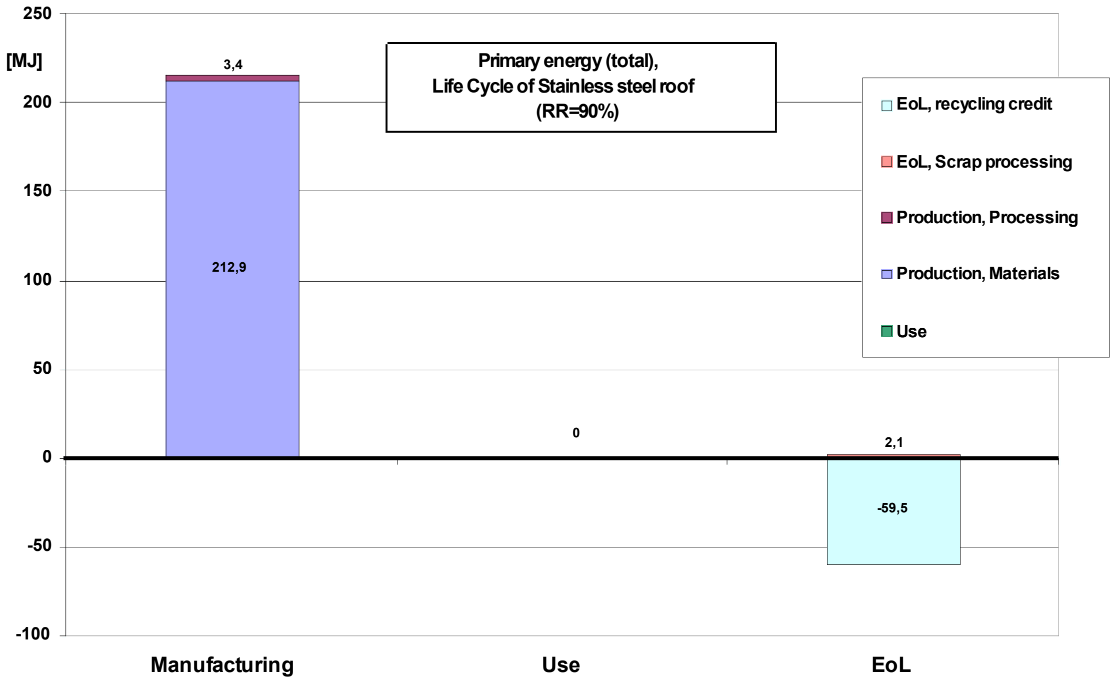


Figure 45: Primary energy demand within the life cycle per m^2 of stainless steel roof

17.3.4. Life cycle Assessment (LCA) for a white goods product

This chapter provides a detailed description of the system boundaries defined to analyse the life cycle of a white goods product. Therefore a dishwasher casing was selected.

17.3.4.1. Goal and Scope

The functional unit of this case study is each 1 m^2 of carbon steel sheet and stainless steel sheet with the following characteristics:

- organic coated carbon steel (1 m^2), 0.7mm thick, weight of 5.50 kg and to be understood as the external housing of the dishwasher
- stainless steel (304 2B) (1 m^2), 0.7mm thick, weight of 5.60 kg and to be understood as the interior housing of the dishwasher

Figure 46: Analysis of white goods product = selected parts of a washing machine

The scope of the case study focuses on EU system boundaries for materials and energy carriers. The following data sets as well as manufacturing process are included in the modelling of the life cycle

- EU system boundaries for materials and energy carrier.

Exceptions:

- stainless steel → based on world specific settings

Manufacturing phase:

Within the manufacturing phase of the white goods product the following aspects have been considered:

- stainless steel sheets production, LCI profile based on information from ISSF: (stainless steel, 304 2B), transportation (truck 40 t total payload, 350km),
- the manufacturing process of the interior housing is characterised by a deep drawing process.
- organic coated steel production, LCI profile based on information from IISI, transportation (truck 40 t total payload, 350km),
- the manufacturing process of the external housing is characterised by stamping and bending of the steel sheet

Use phase:

The use phase of the white goods product, namely the dishwasher, was not considered to be part of the scope of this LCA case study since the focus of EUROFER is on the steel parts.

End of Life phase:

The end of life scenario of the white goods product includes the collection and separation of the dishwasher. This covers the flowing aspects:

- Disassembly of steel parts and shredding (based on EU specific settings)
- Recycling of carbon steel according to IISI recycling methodology = credit system (based on EU specific settings)
- Recycling of stainless steel according to ISSF recycling methodology = credit system (based on EU specific settings)

17.3.4.2. Modelling of the white goods product life cycle

Within the life cycle modeling of the white goods product, carbon steel as well as stainless steel consumption are illustrated. Figure 47 therefore shows the major material flows leaving the manufacturing phase. As a consequence of this, the life cycle model contains two end of life modules, one for each steel type.

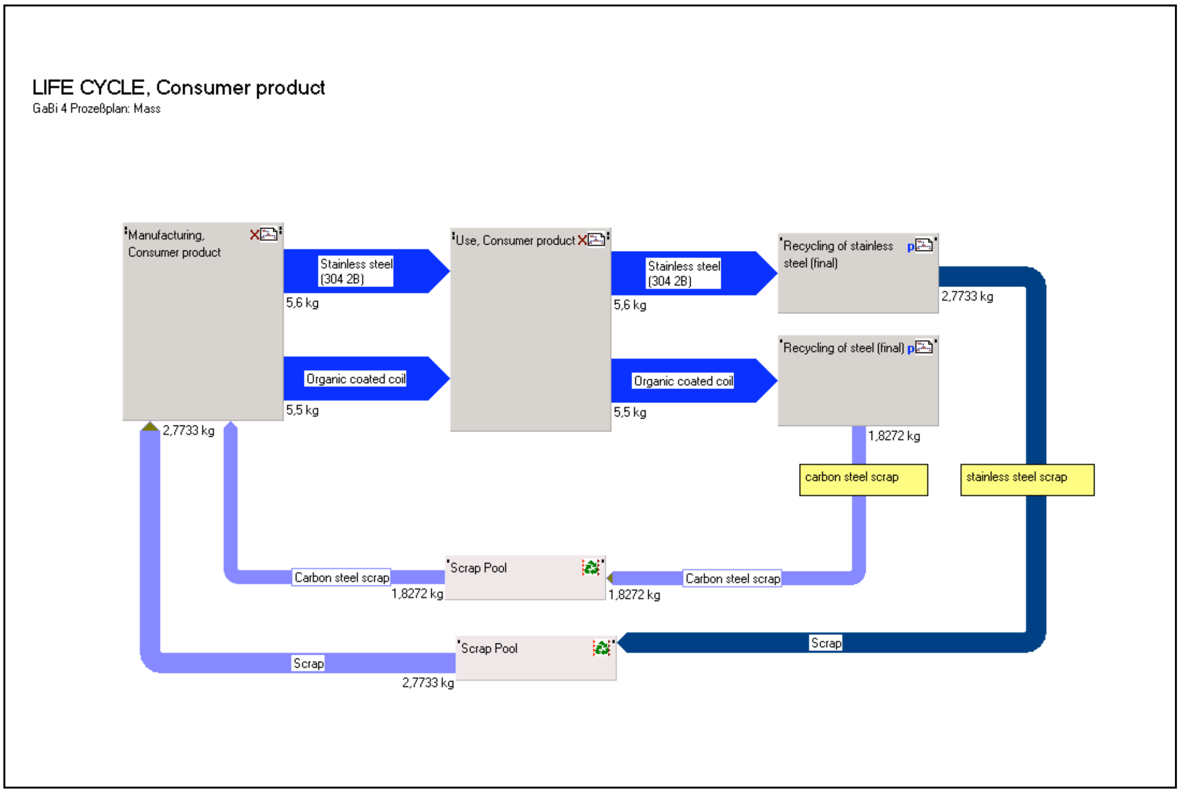


Figure 47: Life cycle model of the white goods product

Figure 48 illustrates the end of life for the carbon steel part of the dishwasher. In the model the separation and shredding of the carbon steel part is included. The calculation of the resulting amount of carbon scrap includes a recycling rate of 97 % (this rate represents steel recovery within the electronic industry based on information from ISSF) as well as the yield of the end of life processing. Further the figure shows that carbon steel scrap is given to the scrap loop and for the remaining carbon steel scrap a credit is given according to the recycling method developed by IISI.

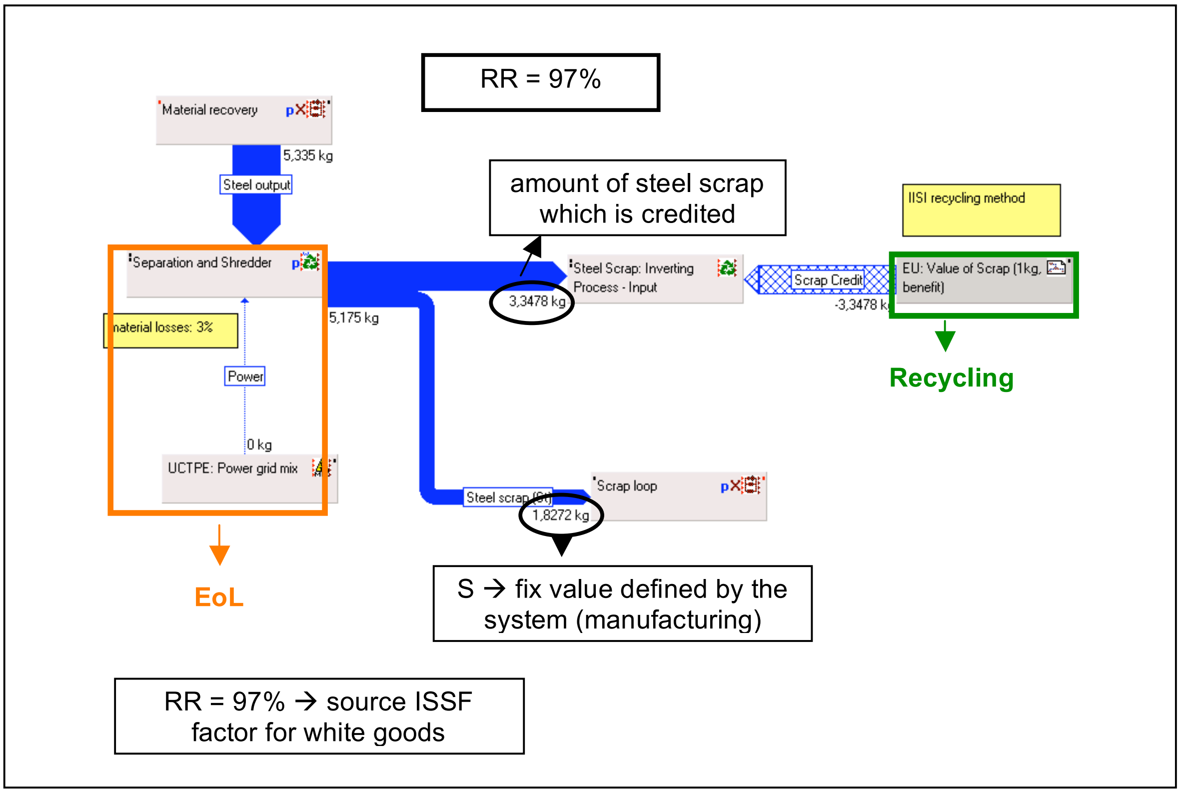
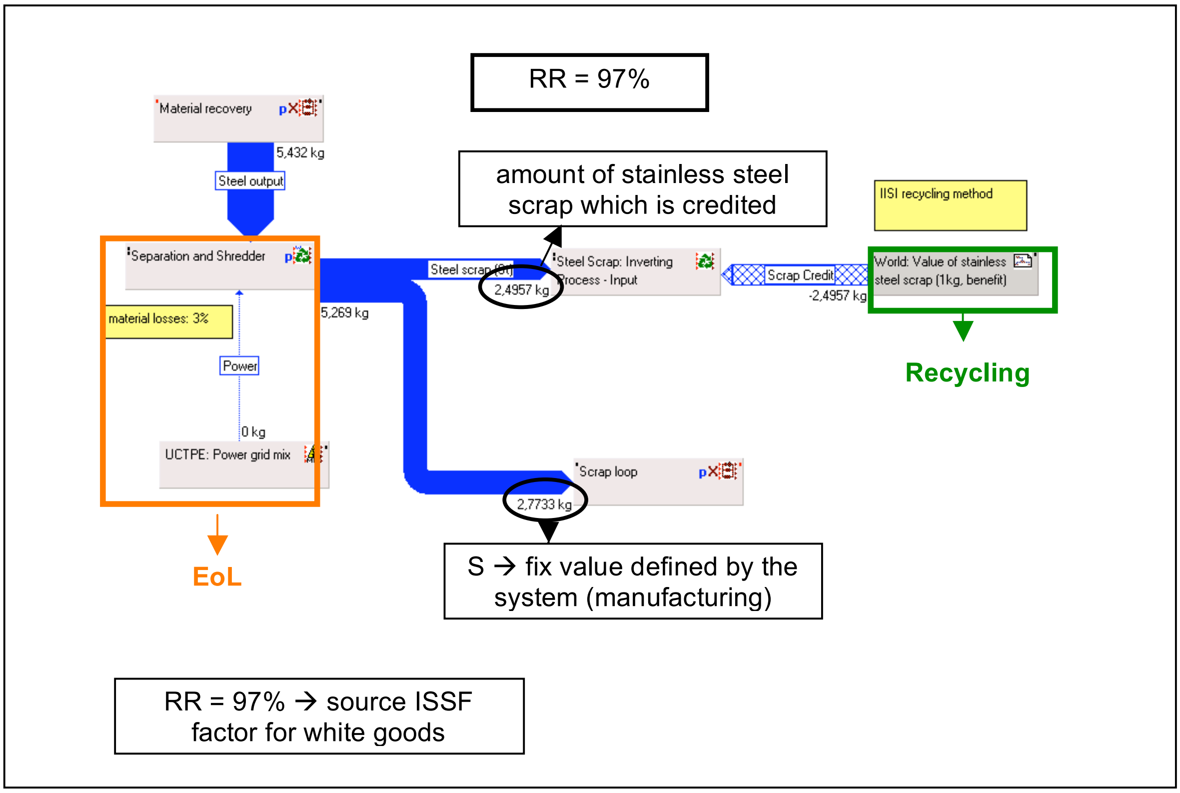


Figure 48: End of life phase model focusing on carbon steel scrap

Figure 49 shows the end of life model for the stainless steel part of the dishwasher. Also in this case the recycling rate is 97 %. Since the production of the stainless steel sheets requires much more scrap as input material, the amount given to the recycling loop is much larger than in the case of carbon steel. For the remaining amount of stainless steel scrap, a credit is given as well based on the recycling method from ISSF.



RR = 97%

amount of stainless steel scrap which is credited

S → fix value defined by the system (manufacturing)

RR = 97% → source ISSF factor for white goods

Figure 49: End of life phase model focusing stainless steel scrap

17.3.4.3. Results

Table 37 shows the results for the LCA of the white goods product. The selected results cover the most important inventory parameters (carbon dioxide emissions as well as primary energy demand) and impact indicators like GWP, AP, EP, POCP and ODP. The five impact categories selected are accepted within the metal industry.

	Manufacturing					**Recycling-Credit**			**EoL**		**Sum**
		Material carbon steel	Material stainless st.	Transport	Processing		carbon steel	stainless steel		steel	
Primary Energy [MJ]	523,5	196,1	317,4	2,6	7,4	-180,0	-58,5	-121,5	7,0	7,0	**350,5**
CO2 emissions [kg]	51,0	14,7	35,8	0,2	0,3	-14,4	-6,3	-8,1	0,3	0,3	**36,9**
GWP (100 years) [kg CO2-Equiv.]	51,5	51,0		0,190	0,31	-14,46	-14,46		0,297	0,297	**37,3**
AP [kg SO2-Equiv.]	0,38	0,37		0,0018	0,003	-0,07635	-0,076		0,0027	0,003	**0,30**
EP [kg Phosphate-Equiv.]	0,017	0,017		0,00028	0,0001	-0,00501	-0,005		0,00011	0,00011	**0,012**
POCP [kg Ethene-Equiv.]	0,026	0,026		0,00029	0,0002	-0,00650	-0,006		0,00018	0,00018	**0,020**
ODP (steady state) [kg R11-Equiv.]	0,00000018	0,0		0,000000072	0,0000001	0,0	0,0		0,0000000	0,0000000	**0,0000002**

Table 37: Selected results for the whole life cycle and the single life cycle phase of the dishwasher

Table 37 shows the results for the LCA case study on the white goods product. Also in this case the manufacturing of the materials dominates the overall results.

Figure 50 provides an overview of the primary energy demand during the life cycle of the white goods product.

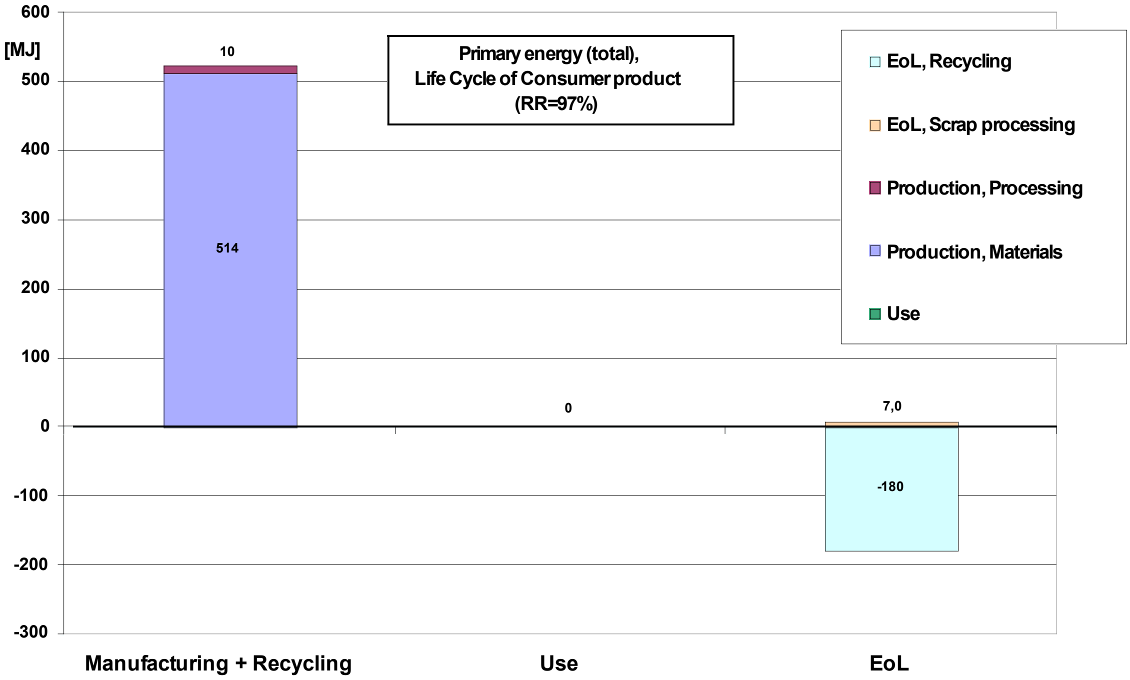


Figure 50: Primary energy demand from different life cycle phase of the white goods product

Figure 51 shows the carbon dioxide emissions arising from the different life cycle phase are shown.

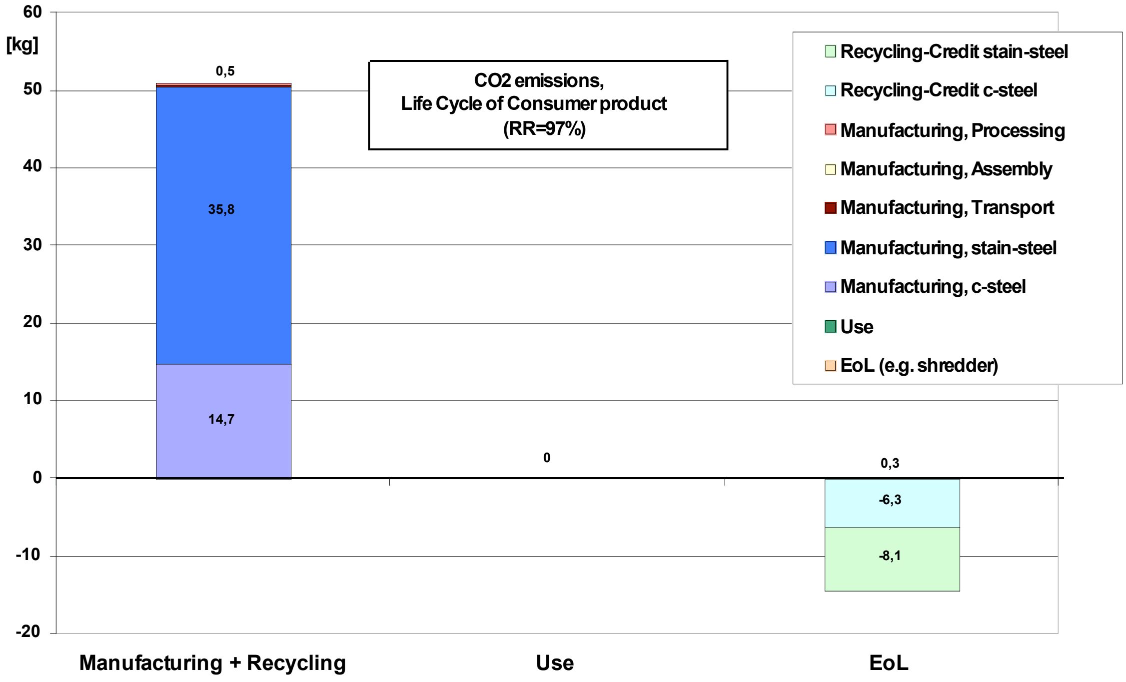


Figure 51: CO_2 emissions to air from different life cycle phases of the white goods product

17.3.5. Life Cycle Assessment (LCA) for a tailor welded blank application (TWB)

This section provides a detailed description of the system boundaries defined to analyse the life cycle of a tailor welded blank application within the automotive industry.

17.3.5.1. Goal and Scope

The functional unit of this case study is a generic application of tailor welded blank used in the automotive industry and specified by the following parameters:

- generic steel part with a final weight of 12.3 kg and a gross steel sheet input of 16.5 kg
- four electrolytic galvanized steel sheet parts
- different steel sheet thickness: 0.67 – 1.47mm

Figure 52: Characteristic picture of a tailor welded blank application

TWBs are steel sheets of different thicknesses and grades which are laser welded into a single flat blank prior to pressing to achieve optimal material arrangement and weight reduction for vehicles. Their use/production also increases process efficiency and machine flexibility.

The benefits of using TWBs are vehicle weight savings, part-count reduction, an improved stiffness/weight ratio, enhanced crash energy management, and an overall reduction in manufacturing costs.

The scope of the case study focuses on EU system boundaries for materials and energy carrier. The following data sets as well as manufacturing process are included in the modelling of the life cycle

- EU system boundaries for materials and energy carrier.

Manufacturing phase:

The manufacturing phase includes the following aspects:

- steel sheet production, LCI profile characterising electro-galvanised steel based on information from IISI:, transportation (truck 40 t total payload, 350km)
- cutting process of steel sheets (processing) and a resulting amount of 4.2 kg prompt scrap
- laser welding process to weld the four different steel sheets together (assembly)

In this case study the tailor welded blank application is compared to a conventional steel sheet solution providing the functional equivalent part. The overall weight of this conventional steel part would be 16.4kg. This results in the TWB equivalent part having a reduced weight of around 25 % compared to the conventional part.

Use phase:

For the use phase, a comparison of the tailor welded blank part and the conventional part is carried out. The TWB application shows a resulting weight reduction of 4.1 kg compared to a conventional application. Assuming that a mid size car has an average running distance of 180,000 km during its life time, a potential fuel saving can be calculated. This calculation of fuel saving potential is based on the rule that by reducing the weight of a vehicle by 100 kg, this can lead to a fuel saving in-between 0.1 litres (without modification of rear axle transmission ratio) and 0.55 litres (with modification of rear axle transmission ratio) per 100 km. For the exemplary calculation a very conservative approach has been selected. Therefore, the fuel reduction factor was set to 0.128 litres / 100km, 100kg (mean value, NEDC) / EBERLE/. This results in 8.8 kg of fuel savings and 26.7 kg of savings in carbon dioxide emission to air.

End of Life:

For the end of the tailor welded blank application within the automotive industry the following aspects are included:

- Disassembly of steel parts and shredding (based on EU specific settings)
- Recycling of steel according to IISI recycling methodology = credit system (based on EU specific settings)

17.3.5.2. Modelling of the life cycle of the tailor welded blank application

Figure 53 shows the life cycle of the tailor welded blank application. The figure shows further that the resulting prompt scrap within the manufacturing phase is given to scrap recycling as well, which results in a credit for the life cycle.

Also in this case study the use phase is not included. The comparison of the TWB and the conventional part described before is only a relative comparison, whereas the case study leads to absolute results.

From the end of life phase, scrap is looped to the manufacturing phase to satisfy the need of carbon steel scrap during the production of the steel sheets.

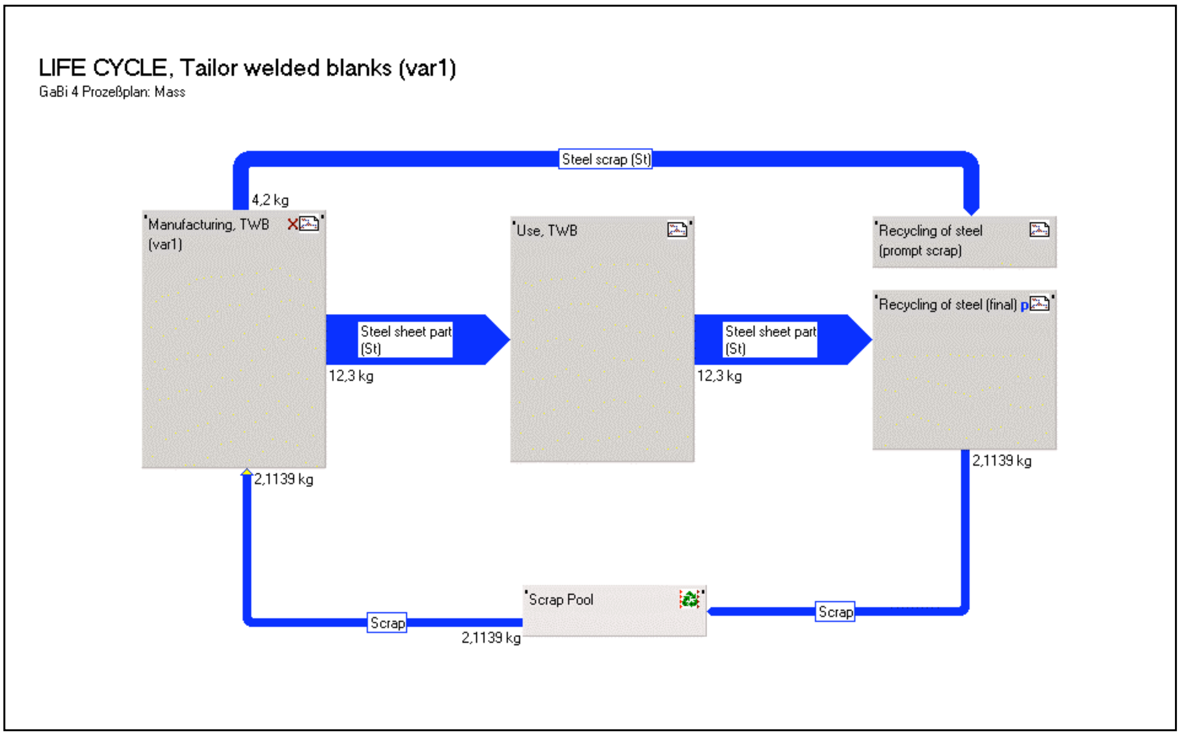


Figure 53: Modelling of the life cycle of the tailor welded blank application in the automotive industry

Figure 54 shows the end of life phase of the tailored welded blank application in detail. For the automotive sector a recycling rate of 95 % is realised. About 3 % losses in steel material result from the shredding process. From the remaining carbon steel scrap a certain amount is given to the scrap loop to satisfy the needed input of scrap to the manufacturing phase. For the finally available amount of carbon scrap, a credit is given according to the IISI recycling methodology (Section 17.4).

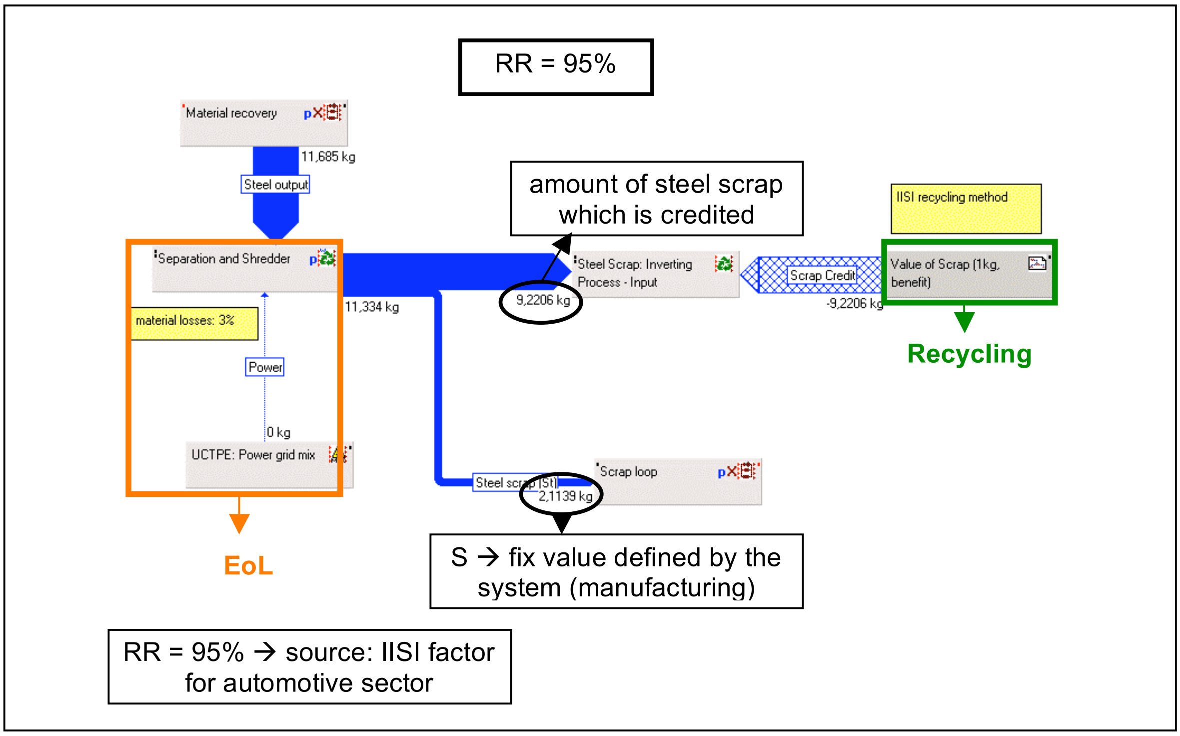


Figure 54: End of life phase modelling of the tailor welded blank allocation

17.3.5.3. Results

In Table 38, the following results for the LCA of the white goods product are presented. The selected results cover the most important inventory parameters (carbon dioxide emissions as well as primary energy demand) and impact indicators like GWP, AP, EP, POCP and ODP. The five impact categories selected are accepted within the metal industry.

	Manufacturing					**Recycling-Credit**		**EoL**		**Sum**
		Material	Transport	Assembly	Processing		steel		steel	
Primary Energy [MJ]	611,3	553,7	3,7	11,7	42,1	-234,5	-234,5	7,6	7,6	**384,3**
CO2 emissions [kg]	44,4	41,9	0,3	0,5	1,7	-25,2	-25,2	0,3	0,3	**19,5**
GWP (100 years) [kg CO2-Equiv.]	45,6	43,1	0,27	0,50	1,79	-25,50	-25,50	0,32	0,32	**20,4**
AP [kg SO2-Equiv.]	0,14	0,1	0,0025	0,0045	0,0161	-0,052	-0,052	0,003	0,003	**0,09**
EP [kg Phosphate-Equiv.]	0,012	0,011	0,0004	0,0002	0,0006	-0,0042	-0,0042	0,0001	0,0001	**0,008**
POCP [kg Ethene-Equiv.]	0,027	0,025	0,0004	0,0003	0,0011	-0,0122	-0,0122	0,0002	0,0002	**0,015**
ODP (steady state) [kg R11-Equiv.]	0,0000009	0,00	0,0000001	0,0000002	0,0000006	0,0	0,0	0,0000001	0,0000001	**0,000001**

Table 38: Selected results for the whole life cycle and the single life cycle phases of the tailor welded blank application

Table 38 shows the results for the LCA case study on tailor welded blanks. The manufacturing of the consumed materials shows high relevance to the overall result. Nevertheless the more advanced manufacturing process of the tailor welded blank application results in a contribution to the overall result for the manufacturing phase of about 10 %. This shows that more complex processing can lead to quite substantial contributions to LCA results.

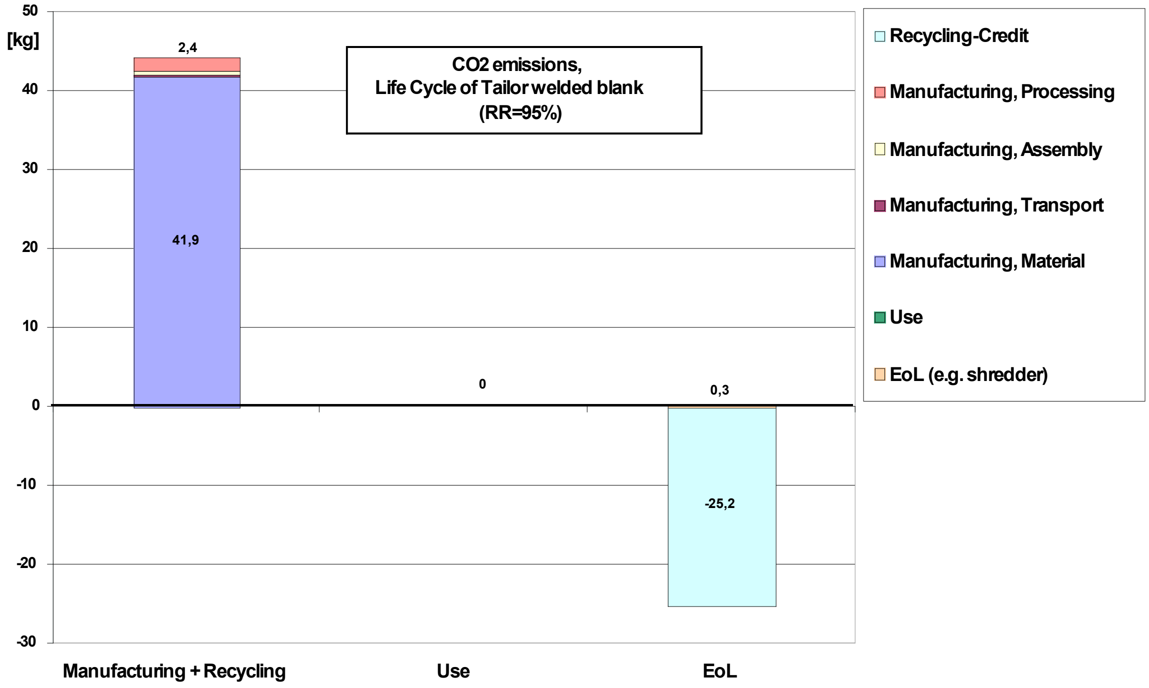


Figure 55: Carbon dioxide emissions to air from different life cycle phase of the TWB

The related carbon dioxide emissions to air from the analysis of the TWB life cycle are illustrated in Figure 55.

The result for the primary energy demand is illustrated in Figure 56.

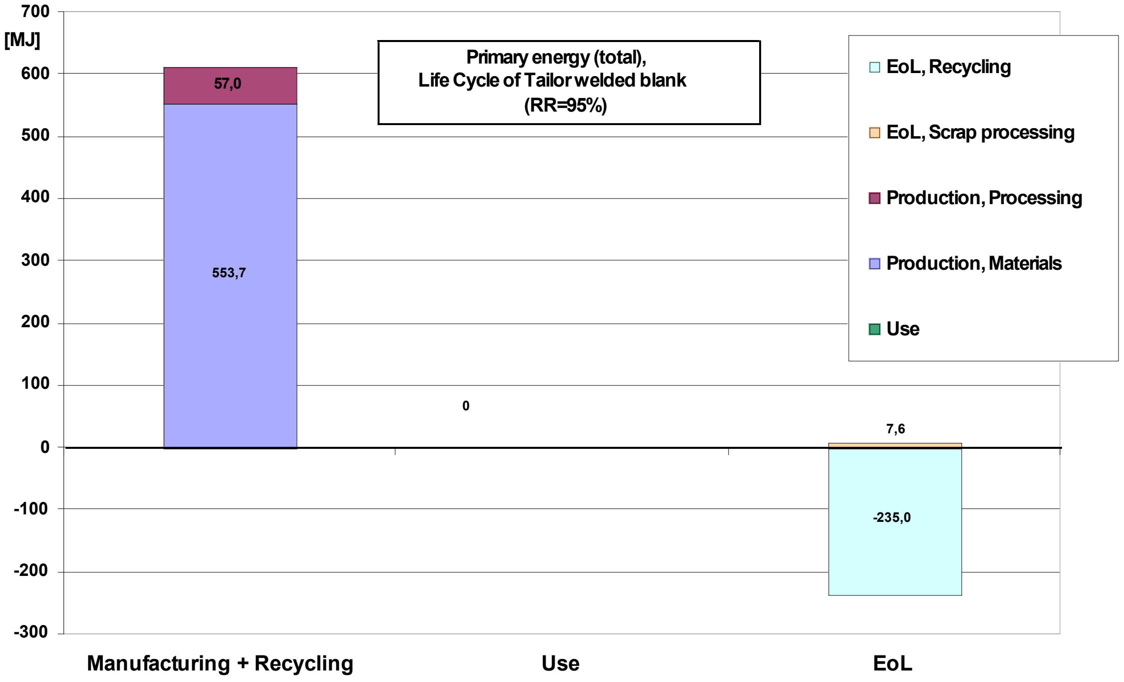


Figure 56: Primary energy demand from different life cycle phase of the TWB

17.4. Application of the IISI LCI Data to Recycling Scenarios

17.4.1. Introduction

Since the boundary of the IISI LCA study does not include the recycling of scrap and scrap allocation issues, this section explains how cradle to gate data for steel can be treated to account for recycling. In particular this appendix describes a number of approaches to account for recycling as follows:

1) Allocation for scrap outputs from whole life systems (e.g. scrap arising from an end of life building or automobile)

2) Allocation for scrap inputs to steelmaking and to account for processing via different production routes

3) Accounting for multiple recycling and reuse of steel components

Where systems have both scrap inputs and outputs it is necessary to apply consistent allocation procedures to each and in most cases approaches one and two above can be treated identically.

In formulating a recycling methodology, the IISI have taken guidance from the ISO 14040 series of Standards on LCA, which set out allocation procedures for reuse and recycling. Within these standards a distinction is made between open and closed loop recycling. Open loop recycling is used to describe open loop product systems where the material is recycled into a new product or where the inherent material properties change. Closed loop recycling applies to products which are recycled to produce the same product or where the inherent material properties do not change.

The majority of steel scrap recycling involves re-melting to produce new steels with little or no change in inherent properties and for most cases steel recycling can be regarded as closed loop. In this respect the Standards state that 'in such cases the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials'. This guidance provides the basis for the 'closed material loop' recycling methodology, which can be used to deal with approaches one and two above.

The third approach concerns multiple recycling and reuse. This approach can be useful to assess the potential for materials that can be recycled or reused again and again. The method calculates the net effect of materials selection over a number of use stages taking account of the initial primary production and the lower impacts of subsequent recycling stages. For this method the number of potential recycling stages must be estimated according to the material properties. In the case of steel there is no material degradation and with adequate collection systems and recovery rates steel can be recycled indefinitely. As a result of this the multiple and closed material loop methodologies for steel are mathematically equivalent, which is explained as part of this appendix.

To aid LCA practitioners to carry out full cradle to grave life cycle assessments, involving steel products, the IISI have developed an LCI database of steel products, which accounts for end of life recycling. The final part of this appendix explains how the closed material loop recycling methodology has been used to generate these LCIs.

The guidance given in this appendix is only advisory; other alternative methods may be valid depending upon the goals and scope of the LCA study.

17.4.2. Steel Recycling Practice

To help to understand the rationale behind the recycling methodology, it is useful to first explore steel recycling practice. In the manufacture of steel the term 'primary production' generally refers to the manufacture of iron (hot metal) from iron ore in a blast furnace (BF), which is subsequently processed in the basic oxygen furnace (BOF) to make steel. The secondary process or recycling route is typically the electric arc furnace (EAF) process, which converts scrap into new steel by remelting old steel. However, Primary steel production is not unique to the BF/BOF route and similarly secondary steel production is not unique to the EAF. For example, it is common practice to use 10-20% scrap in the BF/BOF route. Primary steel production occurs in the EAF route when pre-reduced iron is used as a feedstock to the EAF process. Figure 57 shows that both the EAF and BF/BOF processes produce primary and secondary steel.

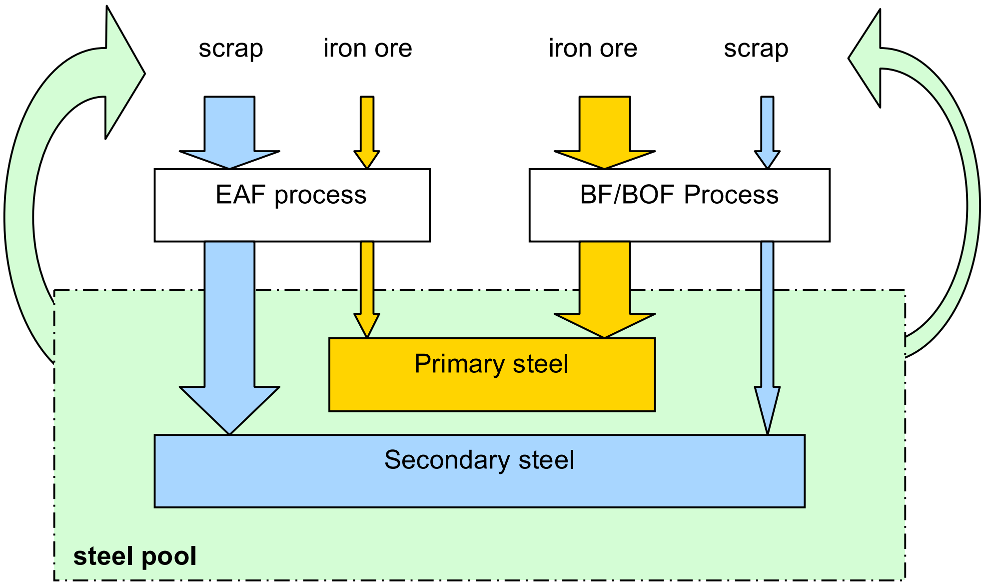


Figure 57: Connection between processes routes and primary/secondary steel production

Steel is 100% recyclable and scrap can be converted to the same (or higher or lower) quality steel depending upon the metallurgy and processing of the recycling route. Some recycled products such as rebar require minimal processing whilst the higher value engineering steels require more metallurgical and process controls to meet tighter specifications. The final economic value of the product is not determined by its recycled content and there are many examples of high value products that contain large amounts of recycled steel. Some steel products are principally sourced via the primary route mainly because the steel specifications require low residual elements and this can be most cost effectively achieved using primary material. Low residual scrap commands a higher market price owing to the ease of processing through the recycling routes.

The growing world demand for steel means that there is a consistent requirement for steel scrap. History has shown that there has not been enough scrap arising to manufacture all the steel required to satisfy the market. This is not a consequence of deficiencies in collecting scrap as demonstrated by the high recovery rates of steel products (Table 39).

Market Sector	Market size, % *	Deliveries based on a 1,000,000 t market, t (A)	Weight of final products, t (B)	Weight recovered of final product, t (C)	End-of-life recycling rate, % *	Prompt scrap from product, t (A – B)	Total weight of recovered scrap, t (A – B + C)	**Recovery rate, %** (*RR*) †
Packaging	5.5	55,000	49,500	30,690	62	5,500	36,190	65.8
Automotive	30.2	302,000	181,200	179,388	99	120,800	300,188	99.4
Domestic appliances	5.0	50,000	37,500	33,750	90	12,500	46,250	92.5
Construction	43.6	436,000	327,000	261,600	80	109,000	370,600	85.0
Machinery	15.7	157,000	141,300	127,170	90	15,700	142,870	91.0

Table 39: Recovery rates for steel products based on North American data from the Steel Recycling Institute. Scrap is recovered during manufacture of the product (e.g. a car door) and at the end of the life of the product. The recovery data excludes information on reuse which is considered as an extension of product life.

† Recovery Rate (*RR*) = Total weight recovered / Weight delivered = (A – B + C)/A x 100

17.4.3. Allocation for scrap inputs and outputs using the closed loop material recycling methodology

Depending upon the goal of an LCA study, when steel scrap is recovered for recycling it is usual to allocate a credit (or benefit) to this arising scrap. When scrap is used in the manufacture of a new product there is an allocation (or debit) associated with the scrap input. In this way the benefit of net scrap arising or the debit of net scrap input can be allocated. Based on guidance from ISO this scrap can be allocated a value associated with avoided impacts such as an alternative source of equivalent (virgin) ferrous metal as described below.

Secondary steel saves primary steel

In the case of steel, the best approximation for the virgin product replaced by using scrap is the first recognisable steel product, which is cast steel. In this case it can be argued that secondary steel from scrap (in the EAF route) avoids primary steel from the BOF route. With this approach the allocation for scrap needs to be adjusted to take account of the scrap/steel yield associated with secondary steel making.

Schematic Illustration of the allocation procedure for scrap outputs

The mathematical representation can be illustrated for a system being studied e.g. a building cradle-to-grave where scrap arises at end-of-life. The LCI allocated to the building can be derived from the following equation:

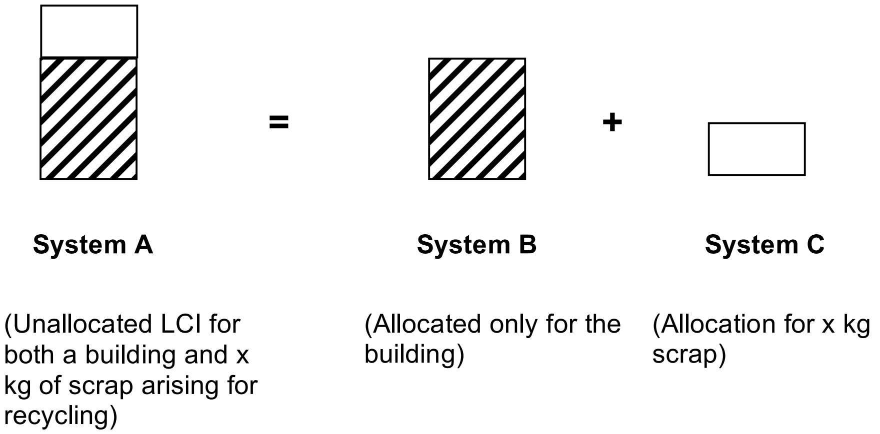


Figure 58 Schematic of scrap allocation for a building system.

Calculating the allocation for scrap and applying to steel product systems

Before looking at the mathematical analysis in detail, it is necessary to define a number of parameters relating to steel production and recycling.

Recovery rate (RR)

The recovery rate is the fraction of steel recovered as scrap during one life cycle of a steel product. Recovered scrap includes any scrap that is generated after manufacturing the steel product under analysis. For example, 100t of steel is used to construct a building, with 80t of steel recovered at end of life $RR = 0.80$. In practice to embody 100t of steel in a building may require 133t of primary steel. Provided that the additional 33t is returned for recycling then $RR = (80+33)/133 = 0.85\%$.

Metallic yield (Y)

The metallic yield refers to the efficiency of the secondary process in converting scrap into steel. It is the ratio of steel output/scrap input.

LCI for primary steel production (X_{pr})

The LCI for primary steel production refers to an LCI parameter or article relating to 100% primary steel production of a semi-finished product from iron ore.

LCI for secondary steel production (X_{re})

The LCI for secondary steel production is as above but relates to 100% secondary steel production from scrap.

Analysis

The first stage of the analysis is to define an LCI for scrap, which provides a mechanism for allocating for scrap inputs and outputs. Using the definitions given above, it is possible to arrive at an environmental burden (LCI) for scrap as shown in equation (1). If X_{re} is the LCI for the recycling route and X_{pr} is the LCI for the primary route then the LCI associated with scrap can be expressed as follows:

$$\text{LCI allocation for scrap} = Y(X_{pr}-X_{re}) \qquad (1)$$

That is to say that scrap in the making of new steel avoids this primary burden X_{pr} but consumes the recycling burden X_{re} with an adjustment for yield (Y). Since the recycling process is not 100% efficient, the LCI has to be adjusted for the metallic yield (Y) of the process. The IISI study showed that, on average, 1.05 kg of scrap is required to produce 1 kg of secondary steel.

The LCI allocation for scrap can be applied to systems, which produce and consume scrap. For example, consider two whole life systems A and B with LCI data and process yields for both the EAF and BF/BOF route each producing 1 kg of steel and with an assumed identical 'finishing, use and recovery' module (Figure 59).

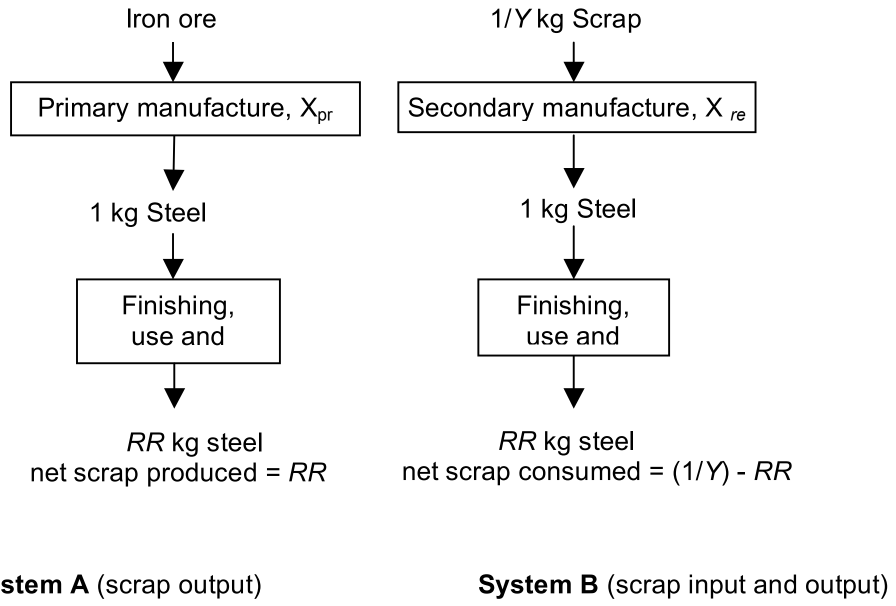


Figure 59 LCA systems diagrams for steel manufactured by primary and secondary routes

In System A there is a scrap output from the system, which is related to the amount of steel recovered for recycling (*RR* kg). The LCI for the 1 kg of steel, in this system, is the LCI for primary manufacture with a credit for the scrap produced as shown in Equation (2)

$$\text{LCI for 1 kg of steel including end of life} = X_{pr} - RRY(X_{pr}-X_{re}) \qquad (2)$$

A similar analysis can be carried out for System B, where 1 kg of secondary steel is used in the same product system and at the end of life *RR* kg of steel is recovered for recycling. In this example, of a secondary route to steel, there are both scrap inputs and outputs and the allocation should be based on the net scrap consumed as shown below.

$$\begin{aligned}\text{LCI for 1 kg of steel including end of life} &= X_{re} + (1/Y-RR)[Y(X_{pr}-X_{re})]\\ &= X_{re} + (X_{p}\mathrm{r}-X_{re}) - RRY(X_{pr}-X_{re})\\ &= X_{pr} - RRY(X_{pr}-X_{re}) \qquad (3)\end{aligned}$$

The general Life Cycle equation for the closed material loop recycling methodology is shown by equation (3) and is identical to equation (2). The equation indicates that the system LCI depends not upon the source of the material (primary or secondary) but on the recycling ratio of the steel at end of life and upon the process yield associated with the recycling process. Recycling will be beneficial as long as $X_{pr}>X_{re}$ as is clearly indicated for the major data categories in the IISI LCI data for the two process routes.

17.4.4. Multiple recycling and reuse of steel

The closed material loop methodology, described in the previous section, provides a practical method of generating LCI data that is representative of steel recycling practice. However, it is sometimes useful to explore recycling by considering the concept that steel is recycled many times. That is to say that primary steel from one product will ultimately end up in many different products and exhibit an environmental profile across many lives. As will be demonstrated, the closed material loop methodology includes this aspect of recycling, but multiple recycling can sometimes be a useful visualization tool for understanding the benefit of recycling or reuse.

To determine the total multicycle cost it is necessary to add up all the burdens from each life cycle. Consider a steel product in a closed loop, recycled again and again in the same application, with the same recycling rates and yield at each stage. If a primary process yields 1 kg of a product and this material is reused or recycled after use to produce *RRY* kg of product (where *RRY* equates to the overall recycling efficiency over 1 life cycle) then throughout n life cycle stages (where *n* =1 for the primary stage) the total mass of useful material available for society would be as follows:

$$\text{Total mass} = 1 + RRY + (RRY)^2 + ... + (RRY)^{n-1} \qquad RRY<1 \qquad (4)$$

The value of *RRY* takes into account yield losses during recycling such as inefficiencies of processing and material lost during recovery.

If to produce 1 kg of steel the primary process has an environmental cost of X_{pr} and the recycling process a cost of X_{re} then the total cost throughout n life cycle stages would be as follows

$$\text{Total cost} = X_{pr} + RRYX_{re} + (RRY)^2 X_{re} + ... + (RRY)^{n-1} X_{re} \qquad (5)$$

By dividing the total environmental cost (5) by the total mass of material (4) the net LCI per kg of useful material (*X*) can be expressed as follows.

$$\text{LCI for the whole system} \quad X = \frac{X_{pr} + (RRY)X_{re} + (RRY)^2 X_{re} + ... + (RRY)^{n-1} X_{re}}{1 + RRY + (RRY)^2 + ... + (RRY)^{n-1}} \qquad (6)$$

With the use of the following geometric progression

$$1 + RRY + (RRY)^2 + ... + (RRY)^{n-1} = \frac{(RRY)^n - 1}{RRY - 1} \qquad (7)$$

Rearranging equation (6) and substituting in equation (7) the whole life LCI value can be expressed as follows:

$$\text{LCI for the whole system} \quad X = \frac{X_{pr} - X_{re} + [X_{re}((RRY)^n - 1)/(RRY - 1)]}{((RRY)^n - 1)/(RRY - 1)}$$

$$= (X_{pr} - X_{re})\left[\frac{(1 - RRY)}{(1 - (RRY)^n)}\right] + X_{re} \qquad (8)$$

As the recycling equation is shown in (8) the overall environmental burden is dependent on the number of life cycle stages *n*, the recycling efficiency, and the total environmental burden of the primary route (X_{pr}) and recycling/reuse routes (X_{re}). Since $X_{re}<X_{pr}$ the LCI for the whole system is always more efficient than the primary route but never converges to the value of the recycling route.

Relationship to the closed material loop methodology

When materials can be recycled indefinitely with losses limited to efficiency of material recovery and yield of the process, infinite loop recycling or reuse can be applied and the mathematical equation (8) simplifies as follows.

For a system where a material is continually recycled:

$$\begin{aligned} &n \longrightarrow \infty \\ &(RRY)^n \longrightarrow 0 \qquad (9) \\ &(1 - (RRY)^n) \longrightarrow 1 \end{aligned}$$

Substituting (9) into (8)

LCI for the whole system $X = (X_{pr} - X_{re})(1 - RRY) + X_{re}$ (10)

$$X = X_{pr} + RRY(X_{re} - X_{pr}) \tag{11}$$

Equation (11) can also be rearranged to explicitly demonstrate the benefit of recycling and reuse

$$X = \overset{\text{Burden of primary production}}{X_{pr}} - RRY\overbrace{(X_{pr} - X_{re})}^{\text{Benefit of recycling/reuse}}$$

For infinite loop recycling the result turns out the same as in equation (3) demonstrating that the closed material loop methodology also accounts for the ability of steel to by recycled many times.

Summary

The multiple life method is a useful forecasting tool for evaluating the benefits of recycling because it allows environmental burdens to be calculated for any particular life (*n*). This enables designers to evaluate where the largest environmental savings can be made in multi-life product systems. However, to be an effective LCA methodology, it requires an unrealistically large amount of data on many product lives. Commonly LCA practitioners only look at once through product systems and do not set the boundary beyond one phase of manufacture, use and end-of-life. For this reason the IISI have adopted the closed material loop method as a method of incorporating the benefits of steel recycling into LCI data for steel products

For the LCA studies that examine end of life scenarios for reuse similar methodologies can be applied to those illustrated for multiple recycling.

17.4.5. IISI LCI data including recycling scenarios

The IISI LCI database of steel products has been updated, to present LCI data for products in an aggregated format, which includes end-of-life recycling scenarios and production data. The methodology for carrying out this LCI calculation is based upon the principles of the closed material loop methodology.

System boundary

The methodology takes account of steel recycling in LCI data for steel products by integrating recycling into 'cradle to gate' manufacturing data. The highlighted area in the systems diagram below shows the extent of aggregation. LCI information on final processing and use of the product are excluded.

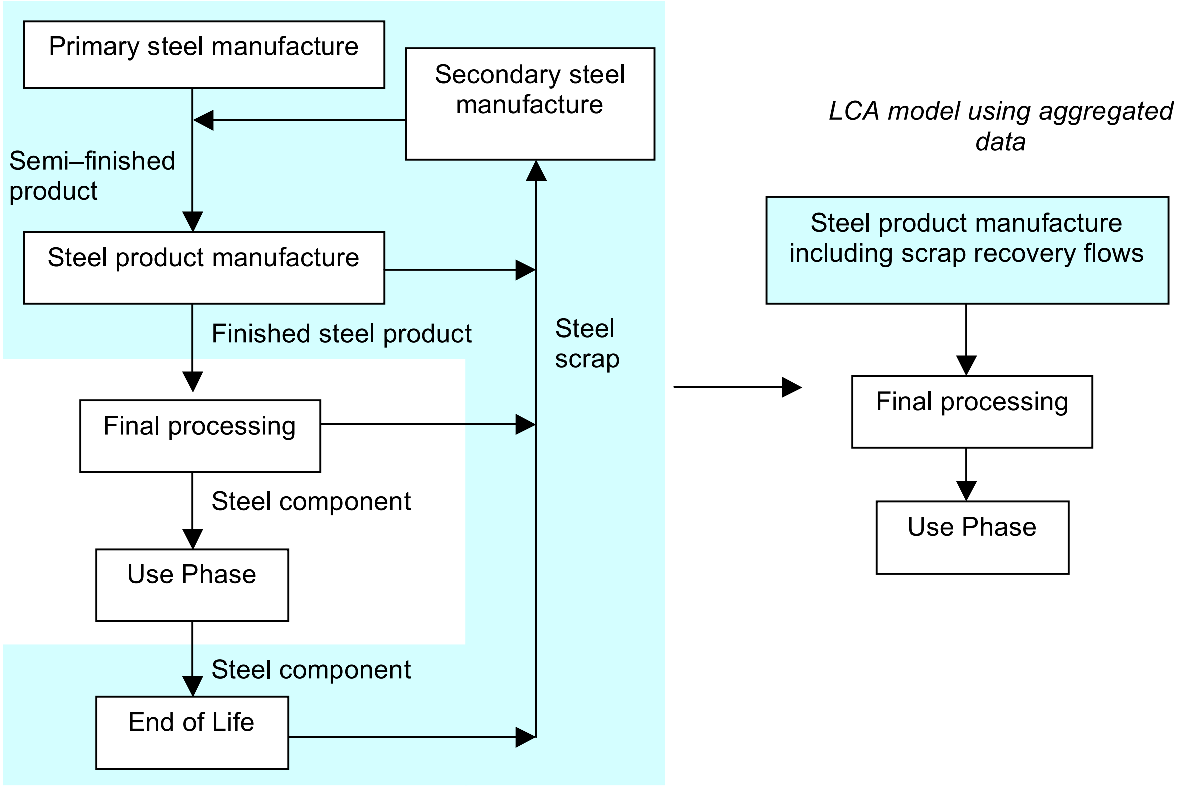


Figure 60: Simplification of the LCA process by aggregating manufacturing and end of life information on scrap.

The methodology excludes end of life information on non-recovered steel, as the destination of non-recovered steel from product systems is usually project/product specific. For example, non-recovered steel from a building could either be reused for a new project, sent to landfill or even remain in the existing infrastructure.

Information on scrap processing has been excluded from the study due to lack of comprehensive data. The LCA system boundary for steel manufacture from 'cradle to gate' can be found in the main body of the IISI LCA methodology report.

Allocation procedure and scrap usage in BF/BOF route

The scrap allocation procedure is based on the assumption that manufacture of secondary steel from scrap saves the production of primary steel from iron ore. The common point at which this saving applies is at the first steel product, which is usually a semi-finished product (Figure 60). In order to apply this procedure it is first necessary to calculate LCI data for both 100% primary steel production and 100% secondary steel production.

a) LCI data for 100% secondary steel production

The IISI have LCI data for a semi-finished product produced via the EAF route. Almost exclusively the EAF sites that were included in the study produced steel from scrap and therefore the LCI data for secondary steel production was calculated as a straight average of these sites.

b) LCI data for 100% primary steel production

The majority of IISI LCI data for products produced via the BF/BOF route have some element of external scrap consumption. To calculate data for a 100% primary route to steel it was necessary to allocate for the burdens associated with secondary steel production (Figure 61). By extending the system boundary to include secondary steel production via the EAF route, LCI data for 100% primary steel production was obtained.

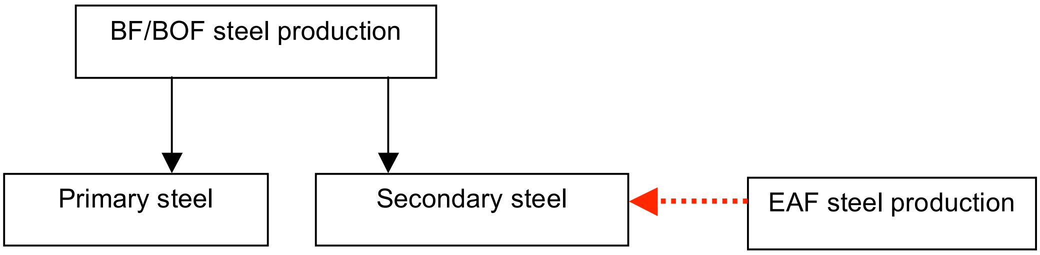


Figure 61: Allocation for scrap consumption in the BF/BOF process

Based on the LCI data for secondary and primary steel production routes it is possible to calculate the savings associated with recycling scrap. If X_{re} is the LCI for the recycling route and X_{pr} is the LCI for the primary route then the LCI associated with scrap can be expressed as follows:

$$\text{LCI saving for scrap recycling} = Y(X_{pr}-X_{re}) \qquad (12)$$

Since the recycling process is not 100% efficient, the data was adjusted for the metallic yield (Y) of the process. In the IISI study it was found that, on average, 1.05 kg of scrap was required to produce 1 kg of secondary steel. The LCI saving associated with recycling scrap provides a mechanism to credit and debit systems, which produce and consume scrap respectively.

Applying the methodology to steel product systems

So far the discussion has been restricted to the savings associated with recycling scrap. To apply the methodology to finished steel products, which make up the IISI LCI database, some further analysis is required. This requires the definition of two further parameters:

Finished steel product LCI (X')

The finished steel product LCI (X') represents the LCI for a steel product at the factory gate as it appears in the IISI database (eg hot rolled coil, sections etc...) without an allocation for recycling.

Scrap input (S)

The scrap input refers to the amount of scrap that is used to make the finished steel product.

Steel products manufactured via the BF/BOF, in general, will have a lower scrap input than products manufactured via the EAF route. Scrap appears as an input in the finished steel product LCI (X').

To broaden the boundary to the full life cycle of a steel product application it is necessary to allocate an LCI value to both scrap inputs and outputs as described in Section 17.4.3. For the recycling methodology it is necessary to evaluate the net amount of scrap produced or consumed through the life cycle (

Figure 62). Almost all steel product systems will contain some scrap steel (or recycled content) and similarly at end of life will produce scrap. The scrap input (S) will depend on the particular process route and the end of life scrap will depend on the recovery rate (RR) of the product.

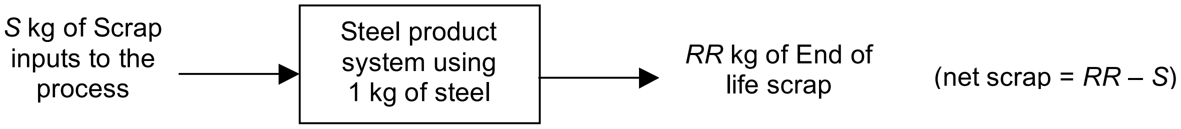


Figure 62: Net scrap consumption/production across the life cycle

Based on the net scrap consumption/production the debit or credit can be expressed as follows

$$\text{LCI credit/debit} = (RR - S) \times Y(X_{pr}\text{-}X_{re}) \tag{13}$$

If the LCI associated with the manufacture of the finished steel product is X' then the LCI for the product accounting for end of life recycling can be expressed as:

$$\text{Product LCI} = X' - [(RR - S) \times Y(X_{pr}\text{-}X_{re})] \tag{14}$$

If the product is a semi finished product made from 100% primary material equation (14) can be simplified since scrap input is zero ($S = 0$) and $X'=X_{pr}$

$$\text{Semi Finished Product LCI} = X_{pr} - RRY(X_{pr}\text{-}X_{re}) \tag{15}$$

Equation (14) has been used by the IISI to generate product LCIs including recycling as shown in the following example of a steel section.

Applying the methodology to IISI data: An example for steel sections

This example for a steel section demonstrates how the IISI have applied the methodology to LCI data, to account for end of life recycling. Figure 63 shows a life-cycle system for a steel section, which is used in a building. In this instance the steel section is manufactured via the BF/BOF route and the process uses a small amount of scrap. At the end of the buildings useful life it is demolished and the scrap that is recovered (89.6%) is sent for recycling. The amount of scrap recovered represents an average figure for steel recovery across all sectors (Table 39).

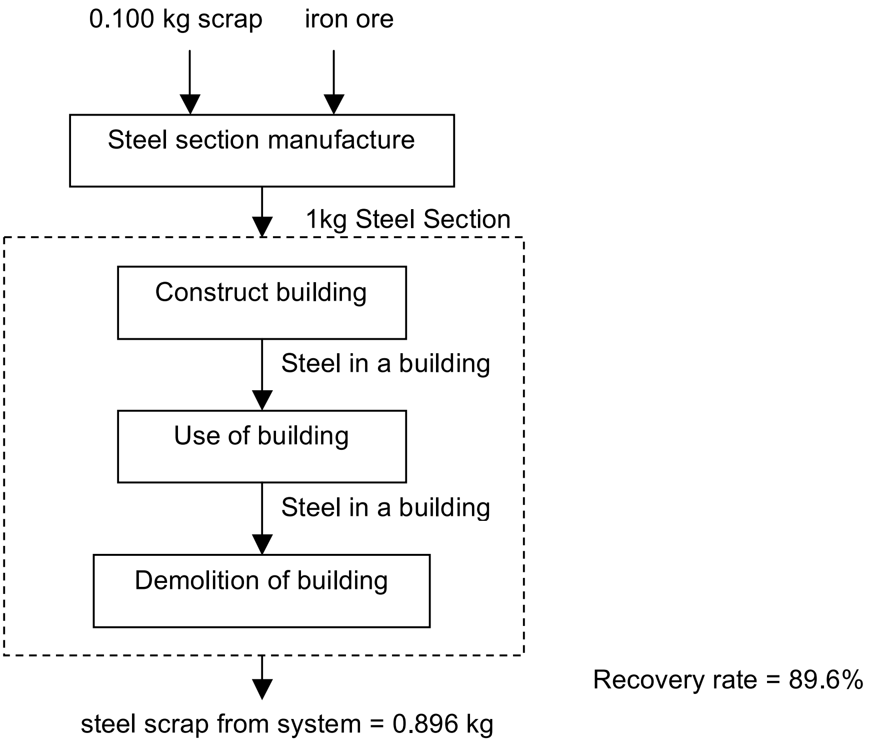


Figure 63: An LCA systems diagram for 1 kg of steel sections, which are used in the structure of a building.

To calculate the LCI data for the steel section including end of life recycling it is necessary to determine the net amount of scrap produced by the life cycle system.

net scrap produced for 1 kg of steel section = 0.896 – 0.100 = 0.796 kg Steel

By applying the scrap credit developed in equation (1) to the steel product system results in the LCI

$$\text{Product LCI} = X' - 0.796 \times Y(X_{pr}\text{-}X_{re})$$

Where X' is the LCI for the product produced via the BOF/BF route excluding recycling

An example of how this procedure works for some specific LCI flows is shown in Table 40.

Examples of LCI flow	LCI for manufacture of 1 kg of sections via BF/BOF route without allocation for recycling (X')	net saving as a result of recycling 0.796 x $Y(X_{pr}\text{-}X_{re})$	Final product LCI for the manufacture of 1 kg of sections (X) Including recycling
Iron ore /kg	1.79	1.52	0.27
Carbon dioxide /kg	2447	1434	1012
Total Primary energy /MJ	29.0	12.9	16.1

Table 40: An example of how the recycling methodology can be applied to LCI data for the production of 1 kg of steel sections via the BF/BOF route. (Note: metallic yield Y = 0.953)

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