worldsteel ASSOCIATION

# LIFE CYCLE INVENTORY STUDY

May 2018

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## ACRONYMS

| | |
|---|---|
| AP | Acidification potential |
| BF | Blast furnace |
| BF Gas | Process gas produced in the blast furnace |
| BOF | Basic Oxygen Furnace |
| BOF Gas | Process gas produced in the basic oxygen furnace |
| CO Gas | Process gas produced in the coke ovens |
| EAF | Electric arc furnace |
| ECCS | Electrolytic Chrome Coated Steel (tin-free steel) |
| EP | Eutrophication potential |
| GWP | Global warming potential |
| HDG | Hot-dip galvanized steel |
| HRC | Hot rolled coil |
| ISSF | International Stainless Steel Forum |
| LCA | Life cycle assessment |
| LCI | Life cycle inventory |
| LCIA | Life cycle impact assessment |
| NCV | Net calorific value |
| PED | Primary energy demand |
| POCP | Photochemical oxidant creation potential |
| worldsteel | World Steel Association |

# 1. Project context

This report presents a summary of the 4th global World Steel Association (worldsteel) Life Cycle Inventory (LCI) Study. It provides an explanation of the implementation of the methodology, results and interpretation of the LCI data for steel products. The study was originally carried out for 1994/1995 steel production data. The first update was then undertaken for 1999/2000 data, then 2005/2006[1] and as part of worldsteel's ongoing commitment to improving data quality, has now been updated for 2012-2015 data.

The main goal of the study is to update the LCI data for steel products on a global and regional basis. Currently regional data is available for Europe, Asia and Latin America for certain products. It is believed that other datasets on steel have been derived with limited accuracy or representation and/or contain out of date information.

The data collection and methodology development have been subject to a great amount of quality control in order to provide a sophisticated database of steel product LCIs for use both internally and externally to the global steel industry.

Previous worldsteel LCI studies were reported as one main document. The decision was taken to separate this document into two parts, the methodology report which remains the same for all subsequent LCI studies that will be conducted and a study report which gives the details that ascertain to the particular study that has been conducted for each annual data release. Therefore, this report aims to describe the details of the LCI study 2017 and the methodology followed can be found in the World Steel Association LCI methodology report 2017[2]. Further details on the steel industry production processes are available from other publications (available via the worldsteel website www.worldsteel.org and steeluniversity.org).

This study report conforms to the World Steel Association LCI methodology report 2017. Throughout the study report, reference is made to the methodology report, but not all aspects covered in the methodology report are repeated here for readability purposes. However, all of the requirements documented in the methodology report still apply for the study presented here.

Although this report features a comprehensive level of detail, it is intended to serve as a basis of dialogue between steel industry representatives and third parties using the data. Recommendations for improvement concerning both the documentation and the LCI data are highly welcomed. They will be considered as the worldsteel LCI database is improved in the future.

Data can be requested from www.wordsteel.org.

The worldsteel LCI study has been undertaken in accordance with ISO14040: 2006[3] and 14044: 2006[4], and has been critically reviewed by an independent critical review specialist. The reviewer has already reviewed the separate 2017 worldsteel LCI methodology report which had previously been reviewed three times by a panel of specialists, but on this occasion only one specialist was selected as the methodology has not changed significantly since the previous reviews. This approach has improved the integrity of the study and helps to establish transparency. The final critical review report of this study report is included in Appendix 12.

# 2. Goal of the study

This 2017 release of steel industry data is the 3$^{rd}$ update of worldsteel LCI data, first released in 1995. The industry has regularly collected data and released updates to ensure that the data remains representative of the current steelmaking technologies and their associated emissions and impacts.

The LCI results alone shall not be used for comparisons intended to be used in comparative assertions intended to be disclosed to the public. The LCI data can be used as part of an LCA for comparative studies disclosed to the public if this is stated in the goals and scope of the LCA study, is done based on a proper functional unit and is subject to a study specific critical review by an external panel of experts.

The target audience of the study includes the World Steel Association and its members. Furthermore, aggregated and averaged data will be made available for many different external applications of the data, for technical and non-technical use, including customers of the steel industry, policy makers, LCA practitioners and academia. The data will also be made available in public and proprietary databases.

The goals of the project are to:

- Produce worldwide LCI data for steel industry products. The LCIs are both cradle-to-gate data and cradle-to-gate data including end-of-life recycling (end-of-life credits are separately reported).
- Provide data to support communication with industry stakeholders.
- Assist industry benchmarking and environmental improvement programmes.

The changes that have been made to the model and methodology have been made to improve the quality and representativeness of the data compared to previous versions of the model that have been used to generate the results. Where appropriate, a conservative approach has been taken.

# 3. Scope of the study

## 3.1 System description overview

The scope of the LCA study is defined in ISO 14044: 2006 section 4.2.3.1, and among other things outlines the function, functional unit, system boundary and cut-off criteria of the study. These are outlined in the following sections.
Sixteen steel products (**Error! Reference source not found.**) were included in the study. These products were chosen as they cover the vast majority of steel products (> 95%). Additional products which have not been included at this stage are generally processed from one of the products listed below. The detailed specifications of each steel product, such as size range, gauge and coating thickness, vary from site to site and are a function of the technology, equipment and product ranges at the sites involved and are detailed in Appendix 1. The range of specifications within a product category will to some extent influence the regional and global LCI results.

| Product category | Manufacturing route | List of products |
|---|---|---|
| Long products | Blast furnace route<br>and<br>Electric arc furnace route | Sections<br>Rebar<br>Wire rod<br>Engineering steels |
| Flat products | Blast furnace route and<br>Electric arc furnace route | Plate<br>Hot rolled coil<br>Cold rolled coil<br>Pickled hot rolled coil<br>Finished cold rolled coil<br>Electrogalvanized steel<br>Hot-dip galvanized steel<br>Tin-free steel (ECCS)<br>Tinplated products<br>Organic coated steel<br>Welded pipes<br>UO pipes |

*Table 1: List of products covered by the study*

The study focused on carbon and low alloy steels (with alloy content lower than 2 %). The upstream impact of all alloys has been included in the study, as detailed in Appendix 5.

Notably stainless steels (with at least 12% chromium) were outside the study scope, but form the basis of another study via EUROFER and ISSF[5].

## 3.2 Functional unit

Within the scope of this study, the functional unit is the production of 1kg of a steel product at the factory gate, i.e. cradle-to-gate data. Where the data is intended to be supplied as cradle-to-gate including end-of-life recycling, the function includes the upstream burdens of the scrap used in the steelmaking process and the credits associated with the end-of-life recycling of the steel product. Further functions relating to the generation of co-products from the steel production system have been considered using the allocation procedure recommended in ISO 14040: 2006 as documented in the 2017 worldsteel LCI methodology report, section 3.6.

## 3.3 System boundaries

The study is a cradle-to-gate LCI study with and without the end-of-life recycling of the steel as defined in the 2017 worldsteel LCI methodology report, Figures 1 and 2. That is, it covers all of the production steps from raw materials in the earth (i.e. the cradle) to finished products ready to be shipped from the steelworks (i.e. the gate). The cradle-to-gate LCI study, with end-of-life recycling, includes net credits (these are the end-of-life scrap value minus any scrap consumed in the production of the product) associated with recycling the steel from the final products at the end-of-life (end-of-life scrap). It does not include the manufacture of the downstream final products or their use. If the user of steel uses steel datasets including the end-of-life credits on the material level, it has to be checked that no double-counting occurs when the user models the end-of-life of the downstream product.

A full description of the system boundaries and cut-off criteria is given in the 2017 worldsteel LCI methodology report, section 3.3.

For this study, primary data were collected for 23 separate steelmaking process steps (Table 2 shows the break down and the number of sites contributing to this study), plus boilers, compressors, water intake, effluents, stockpile emissions and transport. A representation of one of these processes, the basic oxygen furnace module is given in Appendix 2. Data were also collected regarding the use of steel industry co-products such as process gases and slags.

| Process stage | Number of sites | Process stage | Number of sites |
|---|---|---|---|
| Coke making | 40 | Electrogalvanizing | 12 |
| Sinter making | 37 | Hot-dip galvanizing | 34 |
| Pellet plant | 6 | Tin-free mill (ECCS) | 4 |
| Blast furnace | 44 | Tinplate mill | 15 |
| Direct reduced iron | 7 | Organic coating line | 13 |
| Basic oxygen furnace | 44 | Section mill | 22 |
| Electric arc furnace | 38 | Heavy plate mill | 18 |
| Hot strip mill | 41 | Rebar | 23 |
| Pickling plant | 38 | UO pipe | 5 |
| Cold rolling mill | 38 | Welded pipe | 9 |
| Annealing & tempering mill | 37 | Wire rod | 22 |
| | | Engineering Steels | 7 |
| Total processes | | | 554 |

*Table 2: Number of process stages represented in the study*

The steel product manufacturing flow diagrams via the blast furnace route and the electric arc furnace route are shown in the 2017 worldsteel LCI methodology report, Appendix 1.

### 3.3.1 Technology coverage

Steel is produced predominantly by two process routes; the blast furnace route and the electric arc furnace route (the BOF and EAF routes respectively). Typical steel manufacturing flow diagrams are shown in the 2017 worldsteel methodology report, Appendix 1.
Both routes are represented in this data update and the number of sites contributing data for each process is specified in Table 2.

### 3.3.2 Geographic coverage

The companies participating in the study produce over 25% of global steel production and the contributing sites (which cover 15% of global steel production) are among the largest of the principal producer countries. The highest represented region is Europe: the sites participating represent over 38% of European steel production. The list of participating companies is shown in Appendix 3.

109 sites located in 28 countries participated in the study. The major steel producing countries and regions are included. These are listed below in Table 3.

| | | |
|---|---|---|
| Argentina | France | Saudi Arabia |
| Australia | Germany | Spain |
| Austria | India | Sweden |
| Belgium | Italy | Taiwan |
| Bosnia | Japan | Thailand |
| Brazil | Luxembourg | Turkey |
| Canada | Mexico | UK |
| China | Morocco | USA |
| Czech Republic | Netherlands | |
| Finland | Poland | |

*Table 3: Countries participating in the worldsteel study*

### 3.3.3 Time coverage

The data collection is related to one-year operation and the year of the data is indicated by the data provider in the questionnaire for each data point. The primary data collected from the steel companies in this study relate to one year's production in the period from 2012 to 2015 and is believed to be representative of global steel production during this time frame due to minimal changes in technologies employed during this period Although improvements are continually being sought for the steelmaking processes, this is more of a gradual process than any major global change.

Secondary data was sourced from the GaBi database and relates to datasets dated from 2013 to 2017, with the exceptions of cement from 2006 (which will be updated in the next annual update) and nitrogen and oxygen production from 2007. These gas processes have limited data inputs but as they are linked directly to the most up-to-date country specific grid electricity production from 2013, the datasets are therefore representative for this study. The source of each secondary dataset is listed in Appendix 5.

## 3.4 Application of LCIA categories

The LCI study set out to include as many inputs and outputs from the steel production route as possible so that any future studies could consider a range of impact categories. The methodological aspects for key data categories are discussed in section 3.5.

The goal of the study is to provide the LCI profiles for a number of different steel products and not to analyse the impact categories as they are not included in an LCI profile. In addition, normalisation, grouping and weighting are not applied to the worldsteel LCI data. worldsteel does not routinely provide impact category information with the LCI profiles, except for the following CML impacts, which are given for information purposes only: global warming potential, acidification potential, eutrophication potential and photochemical ozone creation potential. Therefore, the same selection of LCIA results have been included in this report for illustrative purposes only and is included in further detail in Section 6. The impact assessment is based on the methods and data compiled by the Centre of Environmental Science at Leiden University, CML 2001 – Jan. 2016[6].

The following LCIA categories, which have been chosen as examples, will be applied to the LCI data:

- Global warming potential (GWP 100 years): an impact assessment level with global effect; GWP is mainly caused from $CO_2$ and methane emissions which account for over 98% of GHG emissions from the steel industry.
- Acidification potential (AP): an impact assessment level with local effect; within the steel industry, AP is mainly caused by $SO_2$ and $NO_x$.
- Eutrophication potential (EP): an impact assessment level with local effect; within the steel industry, EP is mainly caused from $NO_x$ emissions.
- Photochemical oxidant creation potential (POCP): an impact assessment level with local effect; within the steel industry, POCP, also known as summer smog, is mainly caused from carbon monoxide emissions.

## 3.5 Data collection

The LCI data for this study has been collected according to the principles set out in ISO 14040: 2006 and ISO 14044: 2006. Further clarification to data collection principles can be found in the 2017 worldsteel LCI methodology report, section 3.5.

The worldsteel LCI model used to create the LCIs used GaBi 7.3 which was based on the previous steel industry model for the 2011 data collection. The initial model was created by a team of experts including worldsteel, thinkstep and the worldsteel members and represents the steel production and manufacturing processes. Site data were collected using the internet-based GaBi Web Questionnaire, known as SoFi. The LCA software system GaBi 7.3 communicates with the web-based questionnaire platform via a specific interface. The questionnaires are uploaded to the web-platform and each company has individual password protected access to their specific questionnaires. A separate questionnaire was available for each of the process stages for each site (a full list of questionnaires is shown in Appendix 10), an example of which is shown in Appendix 4, as well as for ancillary utilities such as boilers/power plants, compressors, alternators etc. Each of the questionnaires contained a list of input and output flows which fall into the following categories: material and energy inputs, air and water emissions, wastes, products and co-products, and recovered material that can be processed internally to displace raw material inputs. Transport data for the raw materials and internal transportation fuel used was also provided in the questionnaires. The central allocation of access rights by an administrator ensures the confidentiality of all collected data.

Details of the upstream inputs to the steelmaking process are detailed in Appendix 5 and energy grid mixes for each country in Appendix 6.

A training manual is available to assist those in providing the data via the GaBi Web Questionnaire. A number of features are available in the questionnaire in order to facilitate data collection:

- The GaBi Web Questionnaire has an export function which allows data to be collected in excel and imported into the relevant questionnaire
- In each questionnaire, the amount of each flow per unit product for that process is shown. This gives an easy way to check that the value of the flow was in the correct range and order of magnitude and helps to avoid errors with units.
- Iron, carbon and mass balances can be seen at the process and site level to enable verification of data submission.

The data were collected by worldsteel member companies, i.e. the steel producing companies, on a site-by-site and process-by-process basis, ensuring a high-quality dataset. The data represents normal or abnormal operation, but excludes accidents, spills and similar events.

### 3.5.1 Exceptions

In 2014, 99.5% of crude steel production was produced either via the BOF or EAF route. Open hearth production and ingot cast steel production, accounting for approximately 0.4% of global steel production, was not included. No other exceptions to the scope of this study on carbon steel products are given.

## 3.6 Methodological details

### 3.6.1 Co-products

With any multi-product system, rules are defined to relate the system inputs and outputs to each of the products. This is particularly important in the case of the BOF route, which generates important quantities of valuable co-products, but also applies equally to co-products produced in the EAF route, such as slag.

The allocation methods applied in this study are detailed in the 2017 worldsteel LCI methodology report, section 3.6.1.

Significant material co-products such as slags, which are sold to known destinations, replace functionally similar products. This information is collected from the steel companies participating in the data collection.  For example, BF slags can be used in cement manufacture (in cement making and as a replacement for cement), for road construction or aggregate, or as a fertiliser. On average for this study, 0.28 kg of BF slag is generated per kg of hot metal. The generation rate, which depends on the quality of the raw materials used, can be as high as 0.53 kg in some cases. On the sample of participating sites, 99% of the total amount of BF slag produced is recovered of which 78% is used for cement making. Some slag is used for such things as on-site construction. Details on the use of slags, for the data collected, is provided in Table 4. Care should be taken in studies where both concrete (using slag) and steel are used in order to avoid double counting the credits of the slags.

| Slag type | Total % recovered | Percentage use of material recovered | | |
|---|---|---|---|---|
| | | Cement | Roadstone | Fertiliser |
| BF slag | >99% | 78% | 21% | <1% |
| BOF slag | >69% | 16% | 81% | <3% |
| EAF slag | >82% | 16% | 84% | 0% |

*Table 4: Slag recovery rates and usages*

System expansion is used to deal with the slags. This method allows discriminating between alternative recovery routes of steel co-products from an environmental perspective as different "credits" are given for recovery based on the end use of the co-product. This reinforces the environmental value of using co-products in the industry. Allocation by mass scenarios do not integrate the actual use of co-products. For example, allocation applied to BF slags only considers the mass of slag recovered and does not differentiate between the environmental benefits of replacing cement or replacing aggregates.

System expansion is also used to account for dusts, scales, oils etc. that are produced in the steelmaking processes and then recovered. Details of the assumptions made for all recovered material are included in Appendix 8.

With further analysis, the processes linked with the system expansion retain their initial (actual) inventories of the process (e.g. cement or fertiliser production) and the expanded system processes are also reported separately. When combined, the result is the overall LCI of the product at the route (cradle-to-gate) level.

### 3.6.2 Steel scrap

Methods for dealing with steel scrap are outlined in the 2017 worldsteel LCI methodology report, section 3.6.2 and have been followed in this study.

## 3.7 Interpretation

The results of the LCI/LCIA are interpreted according to the Goal and Scope of the study. The interpretation addresses the following topics:

- Identification of significant findings such as the main contributors to the overall results or certain impact categories, see Section 6.
- Evaluation of completeness and sensitivity to justify the inclusion or exclusion of data from the system boundary or methodological choices, see Section 6.2.2.
- Conclusions, limitations and recommendations, see Section 7.

## 3.8 Critical review

In order to ensure that this study report correctly follows the methodology for LCA according to ISO 14044: 2006 and the 2017 worldsteel LCI methodology report, a critical review according to ISO TS 14071 (2014) was conducted by an external expert, Prof. Dr. Matthias Finkbeiner.

The critical review statement is included in Appendix 12.

# 4. Data quality

### 4.1.1 Data quality requirements

To ensure that worldsteel can provide the most accurate and representative data for steel industry products, the quality of the data used in the models needs to be high.
Data Quality requirements from the 2017 worldsteel LCI methodology report, section 3.5.7 were followed.
The data that have been used for this study can be classified in three ways:

- Primary data collected from worldsteel member companies, gate-to-gate data.
- Primary data for some upstream inputs, e.g. aluminium and zinc from industry associations or producers, cradle-to-gate data.
- Cradle-to-gate data, plus background system from the GaBi 7.3 Professional database for upstream inputs e.g. electricity, iron ore, coal etc.

Due to the extensive checks made of the data provided by each site, the overall quality of the data is considered to be high and is representative of the systems described in terms of technological coverage. The primary steel data are collected directly from the steel producers themselves, enabling a thorough analysis and exchange with these producers. The steel industry is striving to continually improve the quality of its own data and upstream data that are used in the model.

The data collection was managed in the following way. The project was led by the worldsteel LCA manager, reporting to the Head of Product Sustainability. Data was provided individually by the worldsteel member companies and they were supported by worldsteel LCA expert group members, thinkstep and worldsteel LCA fellows. The data was reviewed by the worldsteel LCA expert group members, thinkstep for GaBi supplied datasets and external critical review.

<u>Gate-to-gate data</u>
All data on steel production and processing were collected on a site-by-site basis utilising the GaBi Web Questionnaire. All data submitted were checked as detailed in section 4.2. Companies were provided with a data collection user guide and was given training on how to use the GaBi Web Questionnaire. worldsteel was available for web meetings or calls to answer specific questions relating to the data collection exercise.

<u>Cradle-to-gate data from industry associations</u>
For industry supplied datasets such as aluminium or zinc, the datasets were checked to ensure they were consistent with the goals and scope of the worldsteel study. Expert judgement was used to select the appropriate datasets and documentation relating to these datasets is given within the dataset or can be obtained directly from the supplying industry associations.

<u>Upstream GaBi data</u>
All data from the GaBi Professional database were created with consistent system boundaries and upstream data by thinkstep. Expert judgement and advice was used in selecting appropriate datasets to model the materials and energy for this study. Detailed database documentation for GaBi datasets can be accessed at http://documentation.gabi-software.com/.

## 4.2 Data quality check

The GaBi Web Questionnaires were based on the worldsteel LCA model that had been set up by worldsteel and thinkstep. In this way, all relevant flows, processes and interconnections between the processes were included in the model. The data collector was able to specify the data in their preferred units within the data collection system to avoid human error when entering the data, for the conversion from one unit to another. For example, natural gas could be entered as kg, MJ, GJ, $Nm^3$, kWh etc.

This data was then extracted by worldsteel for analysis. In addition to the worldsteel LCA Manager and worldsteel LCA fellows, the worldsteel LCA Expert Group ‘verified’ the process data and LCI results to ensure its validity. This was carried out by examining the individual processes for all sites and comparing the inputs and outputs. The experts applied their knowledge of the steelmaking processes to ensure the data was consistent with known steelmaking practices.

### 4.2.1 Raw data

All completed GaBi Web Questionnaires submitted by the sites were checked individually and systematically by worldsteel.

The questionnaires were imported directly into the GaBi software on a site by site basis. No manual import was necessary which therefore avoided errors in conversion or typing mistakes.

### 4.2.2 Process, site and route data.

Data checks were done at the process, site (gate-to-gate) and route level and at each stage, benchmarking analysis was carried out to ensure that the data provided were accurate. Data checks included:

- Carbon and iron balance per kg of product for each process
- Energy consumption per process, including the boilers
- Emissions to air and water
- Yields between different process steps and scrap produced / consumed
- Route comparison against 2 standard deviations of data for a range of impact assessments
- Slag balance across the whole site
- Process gas balance across the whole site
- Water balance
- LCIA level checks

The product LCIs were calculated in GaBi, by averaging the available site-specific routes (by setting up individual plans) for each product included in the study. The steel product LCI average datasets were calculated using a vertical aggregation approach (see **Error! Reference source not found.**.), i.e. calculating the LCI for product A from site X and averaging with product A from site Y, based on the weighted average of the production volume of product A.

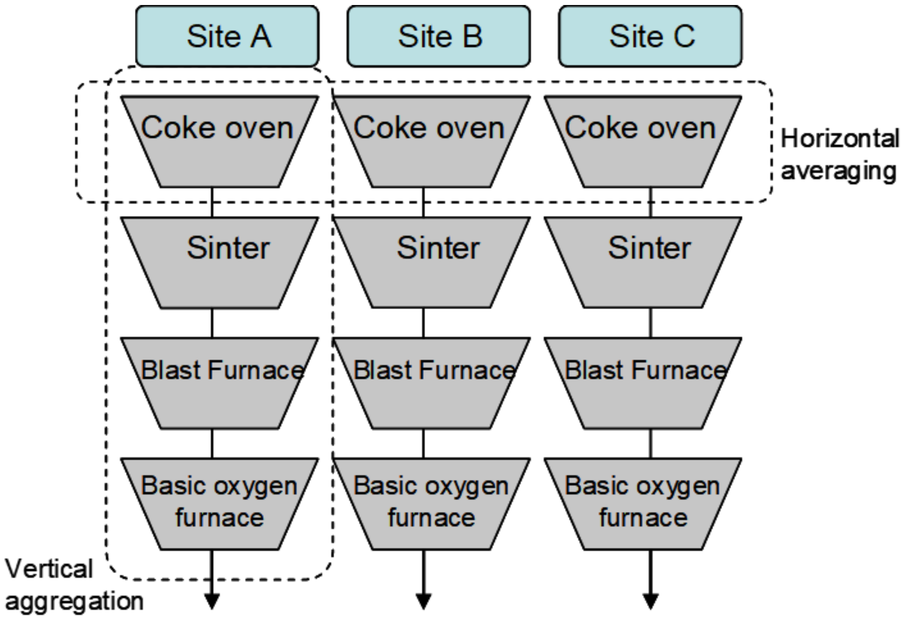



*Figure 1: Horizontal averaging and vertical aggregation*

The final product tonnage LCI results were then distributed to the worldsteel LCA experts in order to check them for accuracy to ensure that the final LCI results were accurate and robust.

### 4.2.3 Water emissions

Due to the uncertainty in conducting a water balance that accounts for all water inputs and outputs across a site boundary which includes evaporation losses and unmeasured water inputs such as rainfall, there is a variability of data regarding water usage and water emissions. Better metering and monitoring will help to reduce this in future. For some sites located downstream of urban and industrial areas, the outflow water is purer than the intake, due to discharge regulations, and this could therefore contribute positively to the overall water quality. However, there are gaps for this category of data for which it is not possible to calculate an estimate. Therefore, the values of waterborne emissions are potentially overestimated in terms of net emissions.

## 4.3 Data gaps

Where there were gaps in the data, the data collector was contacted in order to provide any missing data. Where this was not possible, the average value, based on data collected from other steel production sites, was incorporated into the dataset where it was missing. For all accounted air and water emissions, this average approach was taken. This is detailed in the 2017 worldsteel LCI methodology report, section 3.5.4.

# 5. LCA results and analysis

It is not the intention to provide an impact assessment of the steel products considered in this study but they are considered here as a plausibility check and for illustrative purposes only.

Life cycle inventory data are available for 16 steel products and is freely available from worldsteel, upon request via www.worldsteel.org. The data are provided using the GaBi Envision tool, which enables the data to be easily generated directly from the GaBi 7.3 software thus reducing the likelihood of errors in generating datasets. The data provided are LCI data and are provided as cradle-to-gate data as well as cradle-to-gate including end-of-life recycling. A description of the data provided can be found in Appendix 7.

Table 6 shows typical impacts for three main steel industry products: steel sections, hot rolled coil and hot-dip galvanized steel, which cover a wide range of use of steel products. Steel sections are produced both in the EAF and in the BOF route and are rolled on a hot rolling mill. These include I-beams, H-beams, wide flange beams and sheet piling and are often found on the market for direct use. Hot rolled coil is one of the first products being produced from the BOF route and EAF route. The hot rolled coil is generally further processed into finished products by the manufacturers and can be used in transport, construction, ship-building, pressure vessels, pipelines etc. Hot-dip galvanized steel is generally hot rolled coil that has been further processed (e.g. rolling, annealing, tempering, coating) and has a thin layer of zinc to provide corrosion resistance and can be used in a number of applications for automotive, construction, domestic appliances etc.

The data are based on global average datasets and include:

- Cradle-to-gate
- Cradle-to-gate including recycling, with a typical end-of-life recycling rate (RR) of 85%

This end-of-life recycling rate means that 85% of the steel within the final product will be recycled when the product reaches the end of its useful life. The end-of-life recycling rate of steel depends on the type of final product and its use. Typical rates for the automotive sector are above 95%, for construction around 85% and for packaging around 70%. These values are based on expert judgement amongst the worldsteel LCA experts and are meant as guidance only and they are believed to be conservative values as recycling of products will improve in the future. When a request for data is received by worldsteel which requests a different end-of-life recycling rate, this specified value can be used.

## 5.1 LCI value of steel scrap

The methodology for determining the LCI for steel scrap has been described in the 2017 worldsteel LCI methodology report, section 3.6.2 and further discussed in the 2017 worldsteel LCI methodology report, Appendix 2. A credit is given for the net scrap that is produced at the end of a final products life. The net amount of scrap that is used is determined as follows:

**Net scrap = Amount of steel recycled at end-of-life – Scrap input**

The results provided in section 5 include this net credit for scrap recycling. The impact of recycling 1kg steel scrap is shown in Table 5; this has been calculated using the methodology in the 2017 worldsteel LCI methodology report, section 3.6.2. based on data collected from the sites for this study. The results are illustrative only.

| Impact category | LCIA for 1kg steel scrap |
|---|---|
| Primary energy demand, MJ | 14.3 |
| Global warming potential (100 years) kg $CO_2$-e | 1.63 |
| Acidification potential, kg $SO_2$-e | 0.0032 |
| Eutrophication potential, kg Phosphate-e | 2.35E-04 |
| Photochemical ozone creation potential, kg Ethene -e | 0.00075 |

*Table 5: Example impact categories and primary energy demand for 1 kg steel scrap*

Thus, for every 1kg scrap consumed in the steelmaking process, and every 1kg of steel recycled from a final product at the end of its life, the LCIA displayed in Table 5 can be applied. The burden for scrap consumption would result in adding the steel scrap LCI. The credit for steel recycling at the end of the final products' life would result in subtracting the steel scrap LCI from the product LCI.

## 5.2 Energy demand and environmental impact categories

For the purpose of this study report, the impact assessment is based on the methods and data compiled by the Centre of Environmental Science at Leiden University as detailed in Section 3.4. Primary energy demand is also included as an indicator of overall energy demand for the production of the steel products. These data are illustrative and should not be used for specific studies. The data provided is not the LCI data. For the most up-to-date regional LCI data for all steel products, visit www.worldsteel.org.

The data for the steel sections comes from both the EAF and the BOF route. Based on the latest worldsteel LCI data and the sites that have submitted data to generate these averages (production split: BOF 46%, EAF 54%), the net scrap content is around 0.65 tonnes per tonne steel section. Hot rolled coil and hot-dip galvanized steel are also produced in the EAF and BOF route, though typically with a higher proportion of BOF route so the amount of net scrap consumption is generally a lot lower. Based on the sites providing data for this study (production split, BOF 98%, EAF 2% for both), around 0.07 tonnes of scrap per tonne of hot-dipped galvanized steel and 0.12 tonnes of scrap per tonne of hot rolled coil were used.

| | | PED MJ | GWP kg $CO_{2-e}$ | AP kg $SO_{2-e}$ | EP kg Phosphate-e | POCP kg ethene-e |
|---|---|---|---|---|---|---|
| Sections, 1kg | Cradle-to-gate | 18.3 | 1.5 | 0.0042 | 0.00032 | 0.00064 |
| | Net Recycling benefit | -2.8 | -0.3 | -0.0006 | -0.00005 | -0.00015 |
| | Cradle-to-gate including recycling | 15.5 | 1.2 | 0.0036 | 0.00027 | 0.00049 |
| Hot rolled coil, 1kg | Cradle-to-gate | 23.3 | 2.2 | 0.0054 | 0.00046 | 0.00091 |
| | Net Recycling benefit | -10.1 | -1.2 | -0.0023 | -0.00017 | -0.00054 |
| | Cradle-to-gate including recycling | 13.2 | 1.0 | 0.0031 | 0.00029 | 0.00036 |
| Hot-dip galvanized steel, 1kg | Cradle-to-gate | 29.5 | 2.7 | 0.0065 | 0.00059 | 0.00101 |
| | Net Recycling benefit | -10.7 | -1.3 | -0.0025 | -0.00018 | -0.00058 |
| | Cradle-to-gate including recycling | 18.8 | 1.4 | 0.0040 | 0.00041 | 0.00043 |

*Table 6: Life cycle impact assessment results of steel products*

The recycling credit that can be seen in Table 6 and the following charts varies depending on the net recycling credit level. For sections where the input level of scrap is relatively high, then the net overall scrap credit at end-of-life is low since the credits are based on recycling rate minus scrap input. For the products that are mainly produced via the BOF route, then the scrap inputs to the process are low and therefore the net scrap end-of-life credit is much higher.

### 5.2.1 Primary energy demand, PED

The primary energy demand for the three products described above is shown in Figure 2.

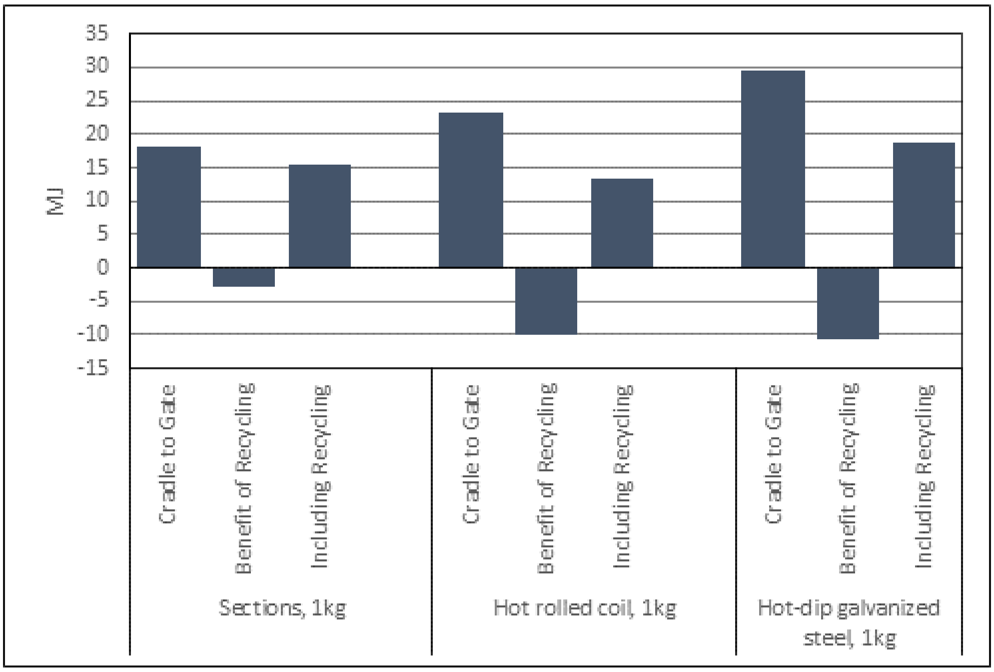



*Figure 2: Primary energy demand (MJ) of steel products*

This PED is made up of both renewable and non-renewable resources. For the cradle-to-gate data for each of the three products shown above, between 90% and 97% of the demand is from non-renewable resources, with the majority being attributable to hard coal consumption, see Figure 3. The consumption of uranium is only associated with the upstream profiles of electricity consumption.

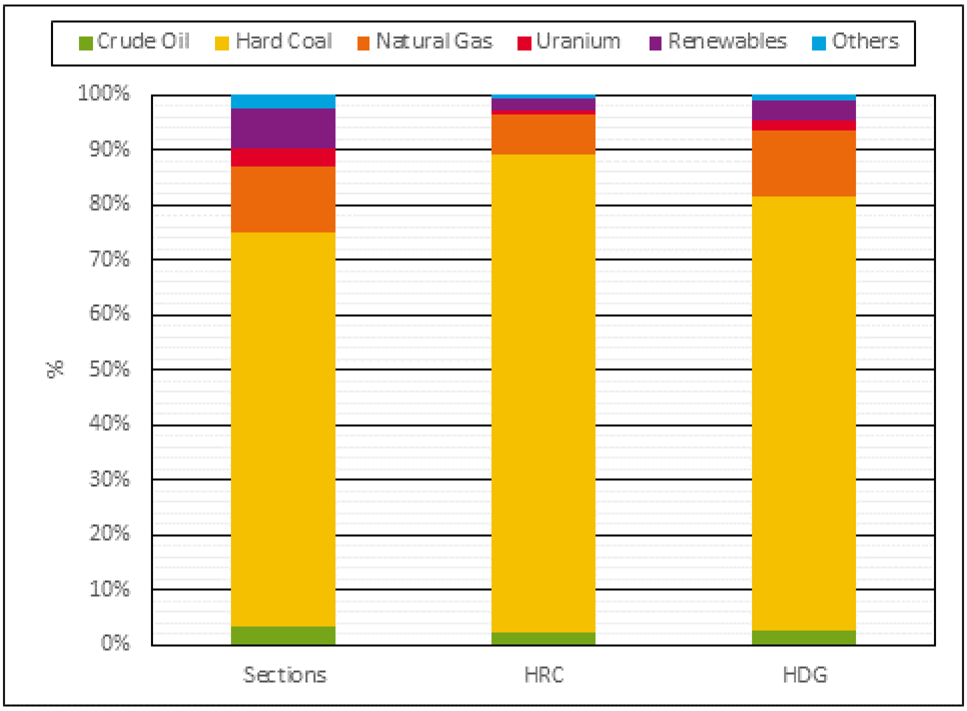



*Figure 3: Contributions to primary energy demand of steel products*

### 5.2.2 Global warming potential, GWP

The GWP for the three products described above is shown in Figure 4.

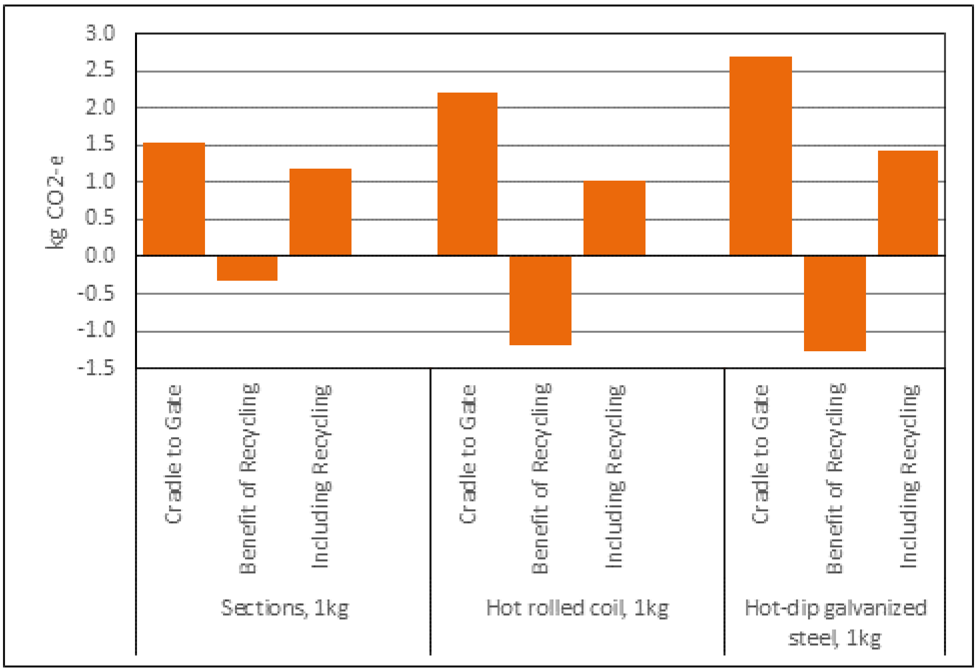



*Figure 4: Global warming potential ($CO_2$-e) of steel products*

The GWP for steel products is dominated by $CO_2$ and methane emissions, which account for over 98% of all GHG emissions for the steel industry. Methane emissions come predominantly from the upstream emissions of coal that is used within the process and for coke making. Figure 5 shows the contributions to the GWP, with the categories 'renewable resources' including biomass credits and 'others' including nitrous oxide, sulphur hexafluoride, NMVOCs, and hydrocarbons.

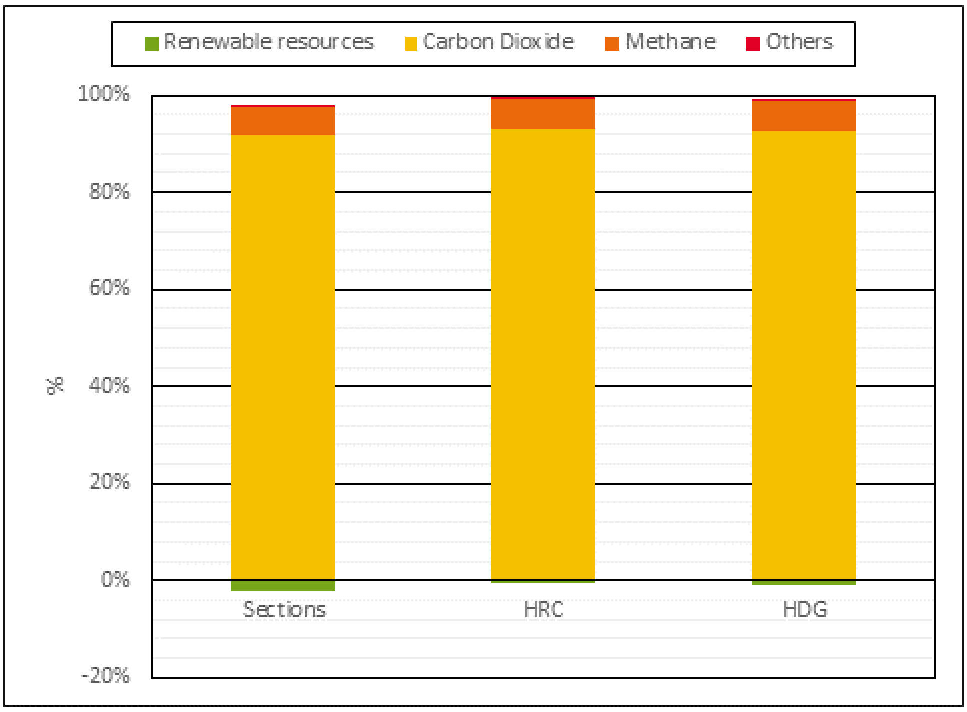



*Figure 5: Contributions to global warming potential of steel products*

### 5.2.3 Acidification potential, AP

The acidification potential for the three products described above is shown in Figure 6.

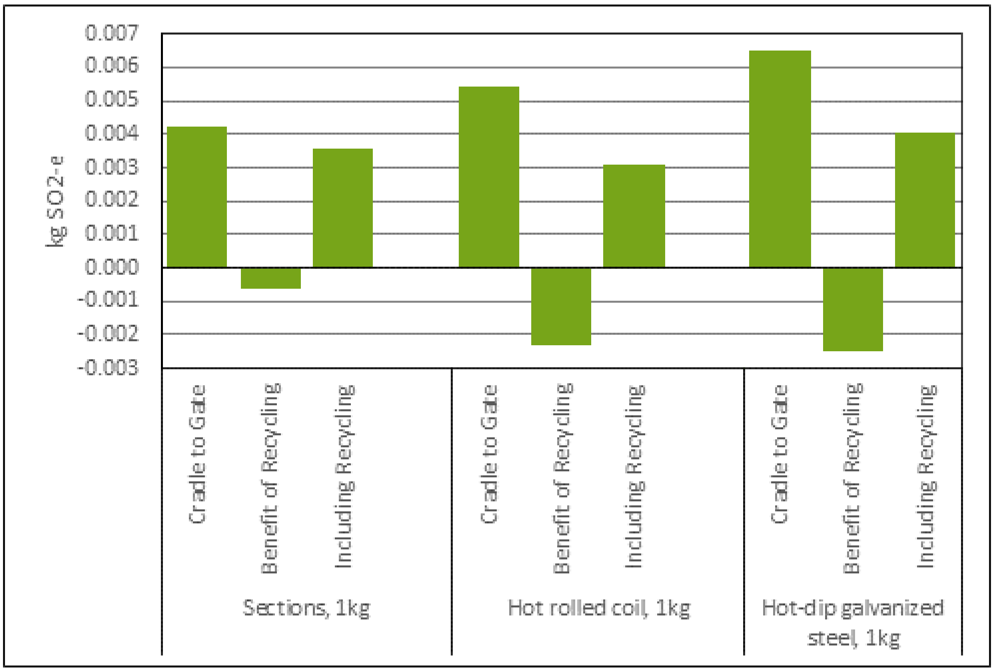



*Figure 6: Acidification potential ($SO_2$-e) of steel products*

The acidification potential for steel products is dominated by$SO_2$ and $NO_x$ emissions to air, which contribute over 97% to this impact as shown in Figure 7.

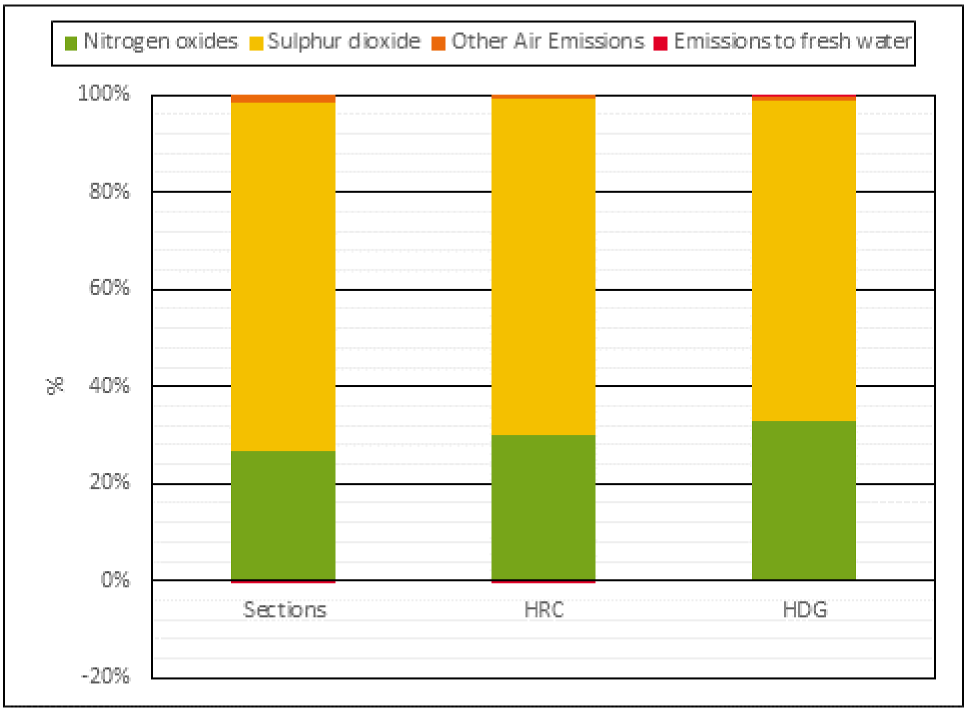



*Figure 7: Contributions to acidification potential of steel products*

### 5.2.4 Eutrophication potential, EP

The eutrophication potential for the three products described above is shown in Figure 8.

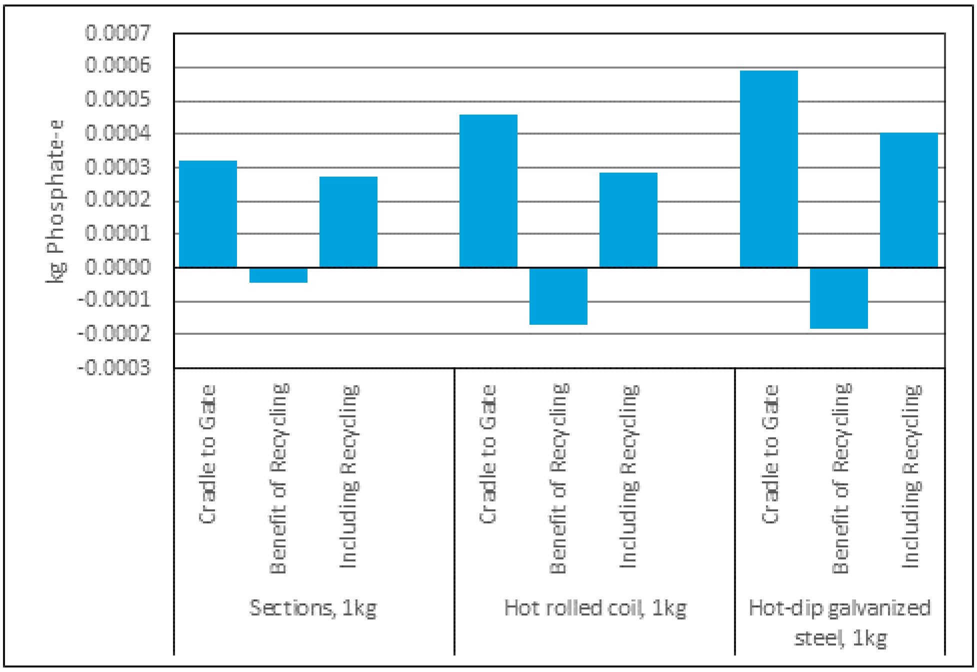



*Figure 8: Eutrophication potential ($PO_4^{3-}$-e) of steel products*

The eutrophication potential for steel products is dominated by emissions to air, which contribute over 92% to this impact. The main contributor is nitrogen oxides. Emissions to water that contribute to this impact are from nitrogen containing substances, e.g. nitrate, ammonia etc. Contributions are shown in Figure 9.

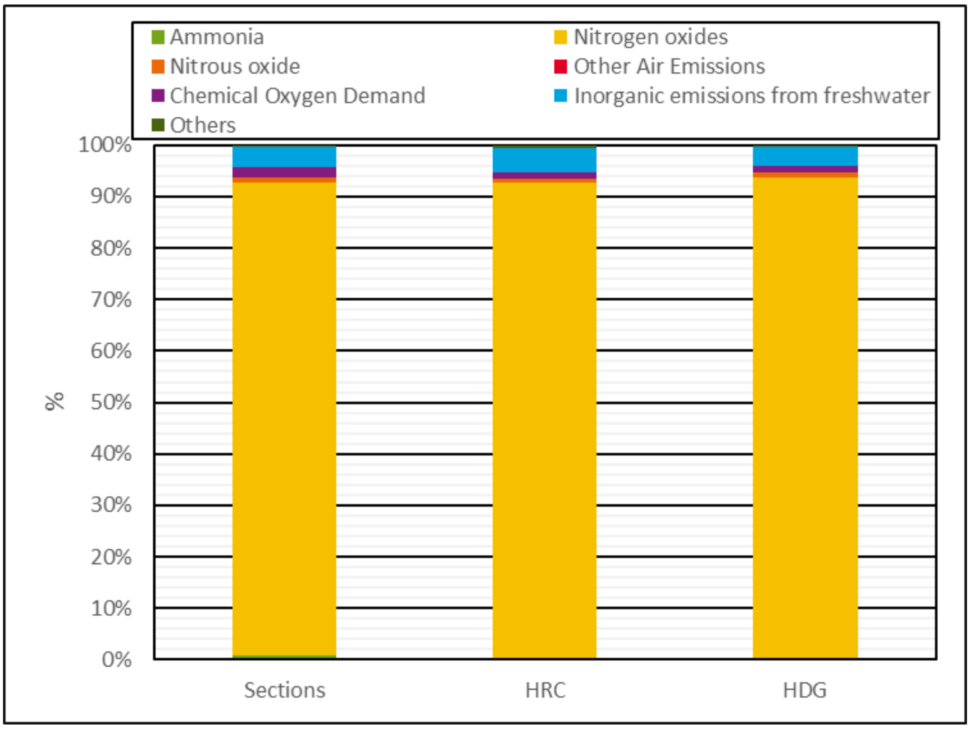



*Figure 9: Contributions to eutrophication potential of steel products*

### 5.2.5 Photochemical ozone creation potential, POCP

The POCP for the three products described above is shown in Figure 10.

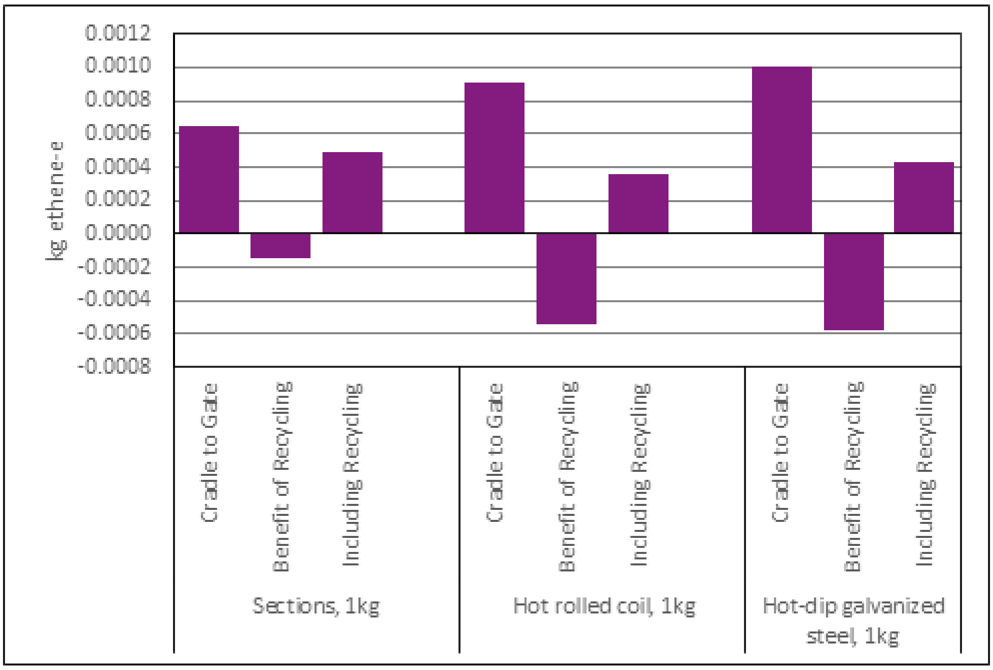



*Figure 10: Photochemical ozone creation potential ($C_2H_4$-e) of steel products*

The photochemical ozone creation potential for steel products is dominated by carbon monoxide, which accounts for over 63% of the contribution to this impact. All other major substances contributing to the POCP are shown in Figure 11.

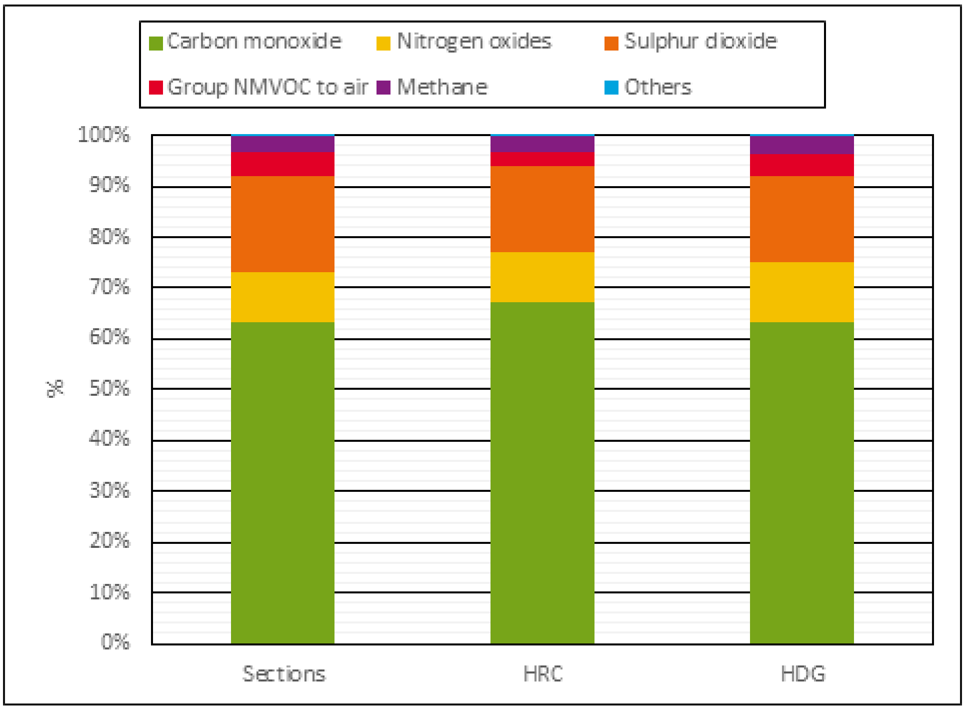



*Figure 11: Contributions to POCP of steel products*

# 6. Life cycle interpretation

This section of the report summarises the key contributors to the life cycle study in terms of the life cycle inventory data developed, the impact assessment categories and each of the life cycle stages included in the data.

This includes the main energy sources which contribute to the cradle-to-gate values for the primary energy demand and the main emissions that contribute to the four impact categories: GWP, AP, EP, and POCP.

## 6.1 Identification of significant issues

Figure 12 to Figure 14 show the life cycle contributions to the PED and the four impact categories discussed above, for global steel sections. The cradle-to-gate data is the 100% reference data. This is made up from the gate-to-gate data (as defined in section 3.3 of the 2017 worldsteel LCI methodology report and shown within the methodology report Figure 1), the contribution from the upstream inputs (see Appendix 5) to the steelmaking process, and the contribution from the avoided burden of co-products. Following this, the end-of-life recycling credits are shown, followed by the overall value which is the cradle-to-gate including end-of-life recycling. For this report, an example of 85% has been used as the amount of steel that will be recycled at the end-of-life of the steel product. PED, AP and EP are dominated by the upstream contribution, whereas the GWP and POCP impacts have a greater influence from the on-site, gate-to-gate, activities.

Credits for avoiding co-product allocation (by system expansion) and end-of-life recycling generally reduce the overall impact of the products as shown. For GWP this however is not the case as the co-product element of the impact is a burden rather than a credit. This is because the combustion of process gases from the steel works has a higher carbon impact than the credit of the fuel that is being replaced. Therefore, the utilisation of system expansion for the processes gas exports from the steel industry actually increases the GWP. If the end-of-life recycling rate is less than the amount of scrap input to the product, this will result in a net increase in the final results.

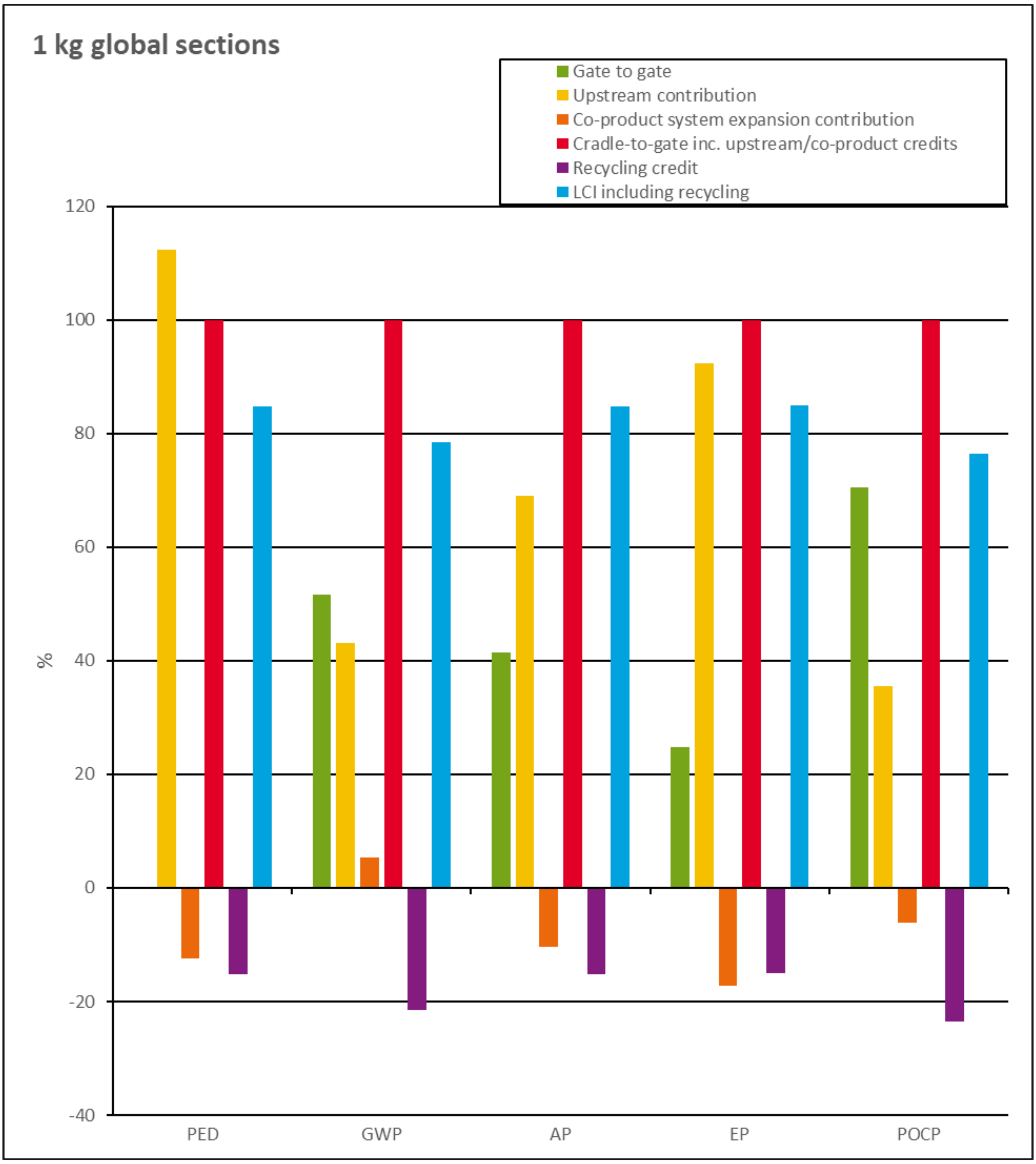



*Figure 12: Life cycle contributions to PED and Impact categories for sections*

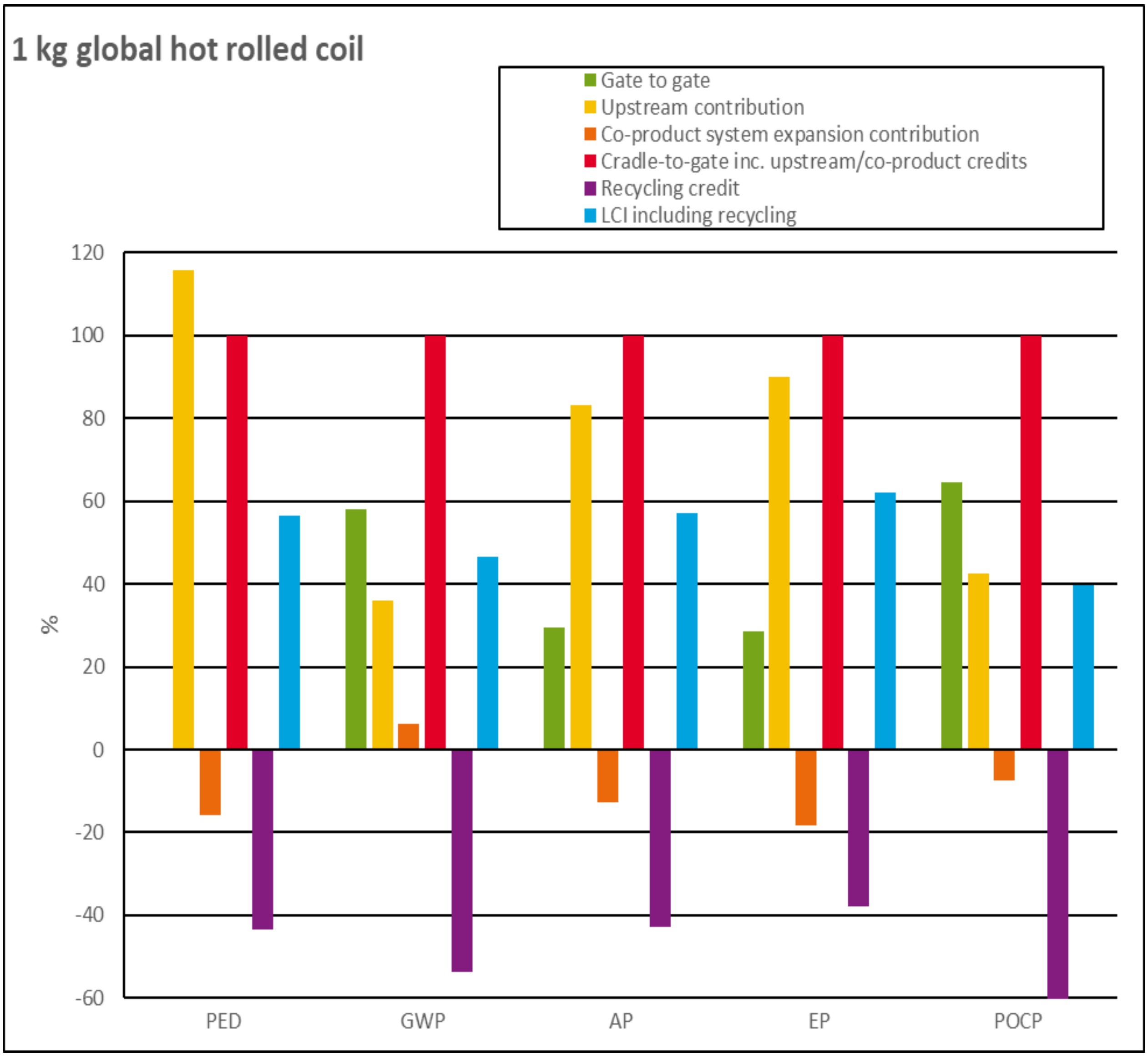



*Figure 13: Life cycle contributions to PED and impact categories for HRC*

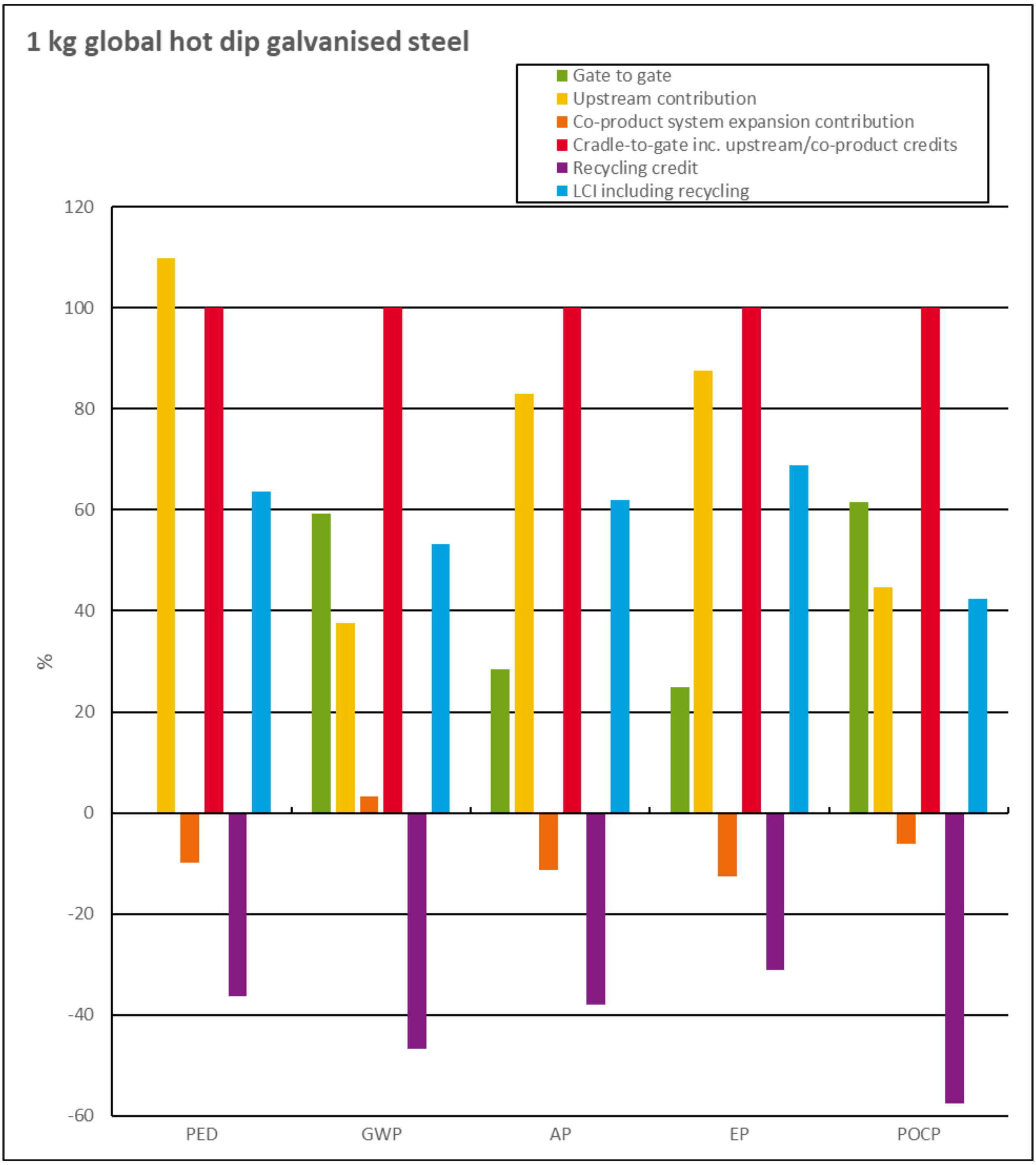


*Figure 14: Life cycle contributions to PED and impact categories for HDG*

Table 7 summarises the main contributors to each of the impact categories and PED. Steel production is an energy intensive industry and therefore the consumption of energy and electricity are one of the main contributors to the environmental impact of the steelmaking process. The influence that this has on the LCIA of the product is therefore very much dependent on the geographical location of the steel works, which determines the source of electricity and energy consumption.

| Impact category | Main input/output | Main phase | Main processes |
|---|---|---|---|
| Primary energy demand | Hard coal (71 – 86%)<br>Natural gas (7 – 12%) | Upstream (~ 100%) | |
| Global warming potential (100 years) | Carbon dioxide (93%)<br>Methane (~ 6%) | Gate-to-gate (> 50%)<br>Upstream (35 – 43%) | |
| Acidification potential | Sulphur dioxide (66 – 72%)<br>Nitrogen oxides (27 – 33%)<br>Others ( ~1%) | Gate-to-gate (28 – 41%)<br>Upstream (68 – 83%) | Upstream energy: electricity and fuels |
| Eutrophication potential | Nitrogen oxides (>91%)<br>Nitrous oxide (~ 1%)<br>Chemical Oxygen Demand (~ 1%)<br>Inorganic emissions to fresh water (4-5%) | Gate-to-gate (24 - 28%)<br>Upstream (~ 90%) | Gate-to-gate: steel production processes up to slab production |
| Photochemical ozone creation potential | Carbon monoxide (63 – 67%)<br>Sulphur dioxide (16 – 19 %)<br>Nitrogen oxides (9-11%)<br>NMVOCs (3 - 5%)<br>Methane (~3%) | Gate-to-gate (> 61%)<br>Upstream (~ 40%) | |

*Table 7: Life cycle significant flows, phases and processes (excluding end-of-life phase)*

Including the end-of-life recyclability of the steel products within the LCI gives the overall impact of a steel-containing product or service excluding the use, reuse, maintenance and dismantling phases.

## 6.2 Completeness, sensitivity and consistency checks

### 6.2.1 Completeness

Within the worldsteel LCA model, completeness checks were carried out at the gate-to-gate level in order to analyse:

- The completeness of data provided for each of the steelmaking processes
- The coverage of relevant energy and material inputs for each steel product
- The coverage of significant outputs (accounted emissions), co-products and wastes

Following these checks, cradle-to-gate completeness checks were then made to ensure coverage of all significant upstream data. There were no data gaps identified that were not already covered by the cut-off criteria defined in the 2017 worldsteel LCI methodology report.

### 6.2.2 Sensitivity

In any LCA methodology, certain assumptions and methodological choices have to be made. For the worldsteel methodology, a sensitivity analysis of three of these such decisions has been carried out in the past and is described below. The three aspects which have been chosen are:

- system expansion: the treatment of co-products is one of the key methodological issues, particularly as the steel industry co-products are valuable and widely used
- internal transportation: only fuel consumption (e.g. diesel, propane etc) is included
- packaging: packaging materials are excluded from the study except steel strap.

The recycling of steel scrap at the end of a product's life is another key aspect of the worldsteel methodology. This has not been included as part of the sensitivity analysis but the impact of including end-of-life recycling can be seen in the graphs in Section 5 and Section 6. In addition, the recycling methodology has been discussed in detail in the 2017 worldsteel LCI methodology report, Appendix 10.

For this analysis, three products have been selected, to cover a wide range of steel products.

### 6.2.2.1 Sensitivity analysis on system expansion

The relevance of applying system expansion to the co-products from the steelmaking process was analysed. The reasoning behind using system expansion has been described in section 3.6.

| | Cradle-to-gate data | GWP | PED |
|---|---|---|---|
| | | Kg $CO_2$-e | MJ |
| **Sections, 1kg** | **Excluding system expansion** | 1.4 | 20.5 |
| | **Including system expansion** | 1.5 | 18.3 |
| | **% Difference** | 5.6% | -11.0% |
| **Hot rolled coil, 1kg** | **Excluding system expansion** | 2.1 | 27.0 |
| | **Including system expansion** | 2.2 | 23.3 |
| | **% Difference** | 6.6% | -13.7% |
| **Hot-dip galvanized steel, 1kg** | **Excluding system expansion** | 2.6 | 32.4 |
| | **Including system expansion** | 2.7 | 29.5 |
| | **% Difference** | 3.4% | -9.0% |

*Table 8: Sensitivity analysis of system expansion*

Table 8 shows the influence that system expansion has on the worldsteel LCI data. This also demonstrates that the steel industry co-products are valuable, whether in the form of replacing raw materials for cement, road-stone, fertiliser etc., or as a replacement for energy sources both within or external to the steelmaking site, or for export for electricity generation.

The contribution of system expansion to the GWP is 3 to 7%. Steel sections are made from both the EAF and BOF route; the EAF route does not produce (but might use if co-located on a BOF route site) process gases which are used to replace other forms of energy supply, either on site or replacing energy and electricity off-site.
Due to the relatively high carbon intensity of the process gases, when they are used to replace other energy sources with a lower carbon intensity, this will result in an additional burden being applied on the steel LCI and not a credit.

The contribution of system expansion to the PED ranges between -9 and -14%. This is due to the recovery of the co-products from the carbon intensive processes (coke oven, BF and BOF) that can then be reused on site or exported off-site. The data already represents the energy consumption describing the production of steel as the main product and the process gases as co-products.

These process gases have good calorific value and can thus be recovered very effectively. The steel sections see a lower benefit to PED as the product is made in both the BOF and the EAF, where there are no process gases being generated and thus recovered. The more complex product HDG has a lower percentage difference because the more complex processing steps consumes the process gases internally.

The exemplary results presented for PED and GWP represent important aspects to be considered for steelmaking due to the energy intensity and carbon intensity of the steel industry. Other typical impact categories that are often considered in LCA studies include AP, POCP and EP which are described further in Section 5.

### 6.2.2.2 Sensitivity analysis on internal transport

The environmental burden of internal transportation is very small, as a study on a sample of sites in the original study showed an average of 0.00004 litres of diesel per kg crude steel was used, corresponding to about 0.0014MJ fuel energy/kg of steel product. However, the combustion of the internal transport fuels such as diesel, for on-site vehicles has not been included.

#### 6.2.2.3 Sensitivity analysis on packaging

In the previous LCI data collection studies, it was shown that the impacts of packaging materials were negligible (<1% of all impacts studied)[7]. In this study, the packaging of materials supplied to the steelworks is therefore also not included. However, steel strap, which is used to hold a coil together, has been requested and supplied, when available, in the questionnaires, as this material is a steel product and data are often readily available. An upstream burden for hot rolled coil is assigned to the steel strap. The contribution of the steel strap is around 0.1% for the impacts studied.

### 6.2.3 Consistency checks

Details of the consistency checks are covered in Section 4.

A check of the previous data compared to the new data for three products, sections, hot rolled coil and hot-dip-galvanized steel is given in Appendix 9.

Differences in results can be explained by two main changes.

- the companies submitting data between the two data collections are different and therefore the location of the sites and the country specific impacts and the sites tonnage weighted impacts are different between the two studies and will result in differences in results.
- All upstream data utilised has been updated a number of times between the two studies to the most up-to-date data in GaBi. All upstream data and their sources are listed in Appendix 5 and Appendix 6.

As the primary data quality is high and data gaps were dealt with as detailed in Section 4, there is only a small number of inconsistencies that have been identified in the study. These are detailed below:

- As already detailed in Section 3.3.3, a small number of secondary datasets were older than the target time frame of 2013 – 2017. This, however was found not to be critical to the overall result and in fact gives a more accurate reflection of country specific impacts in relation to the process gases consumed.
- A list of all of the upstream processes utilised within the worldsteel model is given in Appendix 5. Within this list is the geographic location of where the dataset has been derived from. A number of these datasets are confined to a specific country (e.g. Germany) as these datasets were seen to have a higher data quality than the other limited datasets available.

# 7. Conclusions, limitations and recommendations

A critical review has been carried out to ensure that the changes made to the methodology (Appendix 9) are conform to ISO 14040: 2006 and ISO 14044: 2006, in line with the goal and scope of this study.

This study is representative of over 99% of steel technologies worldwide and covers over 25% of the steel production by company on a global basis.

The completeness and accuracy of the data have been vigorously checked to ensure that the data provided are of the highest quality for the global steel industry.

### 7.1.1 Conclusions

This study provides LCI data for 16 steel industry products on a global level, of which a number of products are also represented on a regional level (EU, Asia and Latin America, see **Error! Reference source not found.**). The addition of new sites is an ongoing process in order to increase the geographical spread and representativeness of the data. These will be added in due course.

In an LCA study, end-of-life scenarios should always be considered. The worldsteel methodology considers the end-of-life recycling of steel products and recommends this method to be used in LCA studies.

### 7.1.2 Limitations

The data provided by the steel producers currently ranges from 2012 to 2015. With continuing measures to improve the environmental performance of these companies, it should be noted that some minor improvements will occur over the coming years and these will need to be incorporated into the steel product LCI data.

In addition, there are a number of companies and regions not fully represented in this study. Nevertheless, efforts are continually ongoing to incorporate these sites within the worldsteel LCI data collection project.

The data and methodology is therefore appropriate for the products that have been listed in the report and for the steelmaking processes via the BOF steelmaking route and the EAF steelmaking route. It is not appropriate for other approaches such as open-hearth furnace steelmaking. The data should not be used for stainless steel products.

### 7.1.3 Recommendations to uses of the data

When an LCA study is to be conducted including steel LCI data, it is preferable that the practitioner contacts the worldsteel LCA Manager to ensure that the appropriate steel product is used and that the methodological conditions are understood, in particular with respect to the end-of-life recycling of steel products.

A detailed description of the products available from worldsteel is provided in Appendix 1 and a matrix of possible uses for each product is provided in Appendix 11. As steel is a globally traded commodity, using global average data is appropriate for many studies. Regional data is also provided where a preference for regional production is made.

The results from the study reflect global steel production from 2012 to 2015 and new sites are continually joining the worldsteel data collection project. It will therefore be necessary to update the worldsteel steel LCI datasets on a timely basis, which will contribute changes to the data. The latest LCI data is available via worldsteel.org.

The World Steel Association endeavours to provide the datasets to LCA software tools and databases in order that they can be used as easily as possible. Care should be taken to ensure that the correct steel product is selected and the methodology fully understood.

# 8. Appendices

APPENDIX 1: DESCRIPTION OF STEEL PRODUCTS COVERED BY THE STUDY

APPENDIX 2: REPRESENTATION OF THE BOF PROCESS

APPENDIX 3: LIST OF PARTICIPATING COMPANIES

APPENDIX 4: EXAMPLE DATA COLLECTION QUESTIONNAIRE

APPENDIX 5: LIST OF UPSTREAM INPUTS AND THEIR SOURCES

APPENDIX 6: ELECTRICITY GRID MIX INFORMATION

APPENDIX 7: STEEL LCI DATA EXPLANATION

APPENDIX 8: SYSTEM EXPANSION ASSUMPTIONS

APPENDIX 9: UPDATES FROM THE STUDY OUTLINDED IN THE 2010 METHODOLOGY REPORT

APPENDIX 10: LIST OF ALL AVAILABLE QUESTIONNAIRES

APPENDIX 11: MATRIX OF USES OF STEEL PRODUCTS

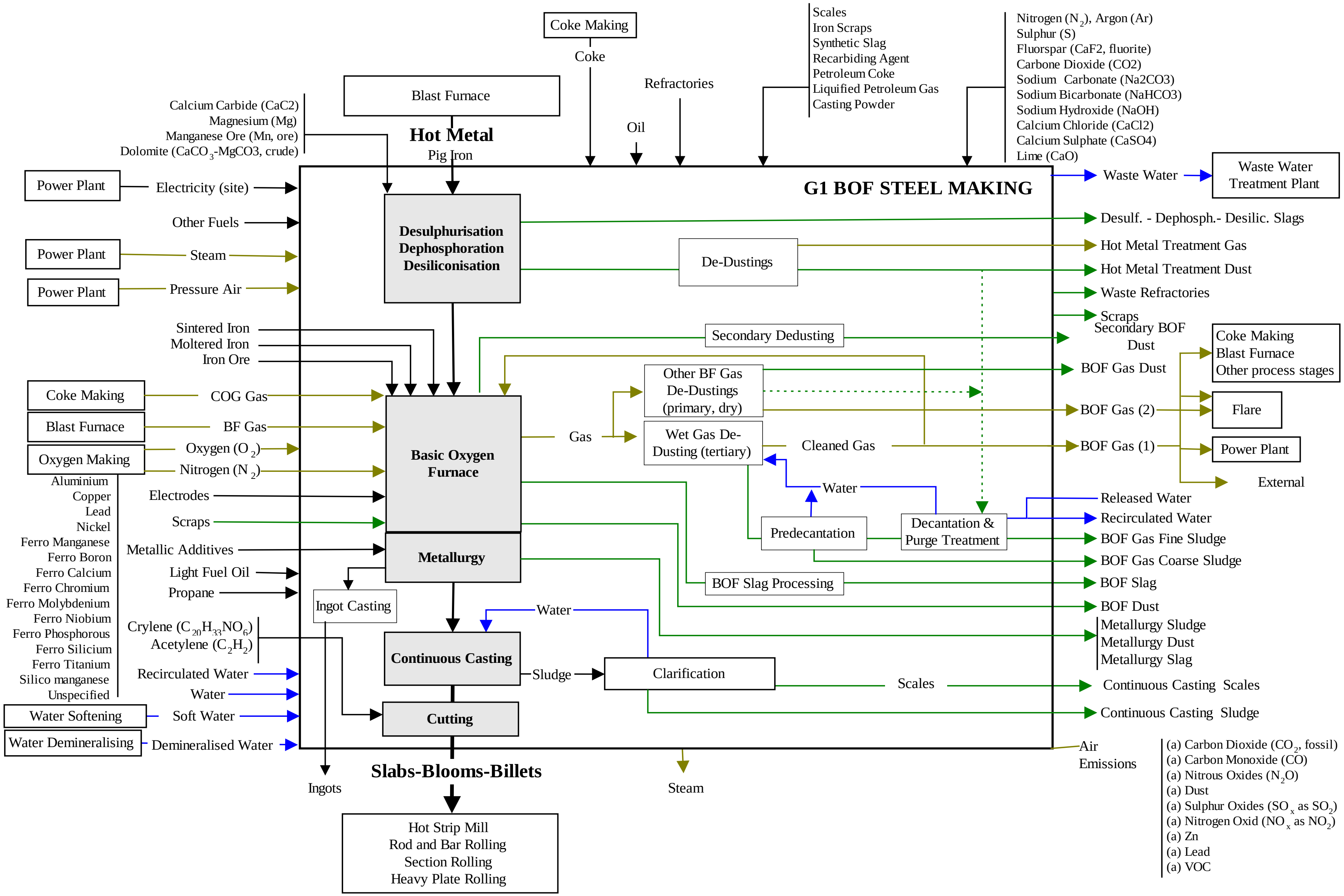
APPENDIX 12: CRITICAL REVIEW: WORLD STEEL ASSOCIATION LIFE CYCLE INVENTORY STUDY FOR STEEL PRODUCTS

## APPENDIX 1: DESCRIPTION OF STEEL PRODUCTS COVERED BY THE STUDY

| Product | Product Description |
|---|---|
| Plate | A flat steel sheet rolled on a hot rolling mill; can be further processed. Includes use in the following sectors: structural steels, shipbuilding, pipes, pressure vessels, boilers, heavy metal structures, offshore structures etc. Typical thickness between 2 to 20 mm. The maximum width is 1860 mm. |
| Hot rolled coil | Steel coil rolled on a hot-strip mill; can be further processed. Applications in virtually all sectors of industry: transport, construction, shipbuilding, gas containers, pressure vessels, energy pipelines, etc. Typical thickness between 2 - 7 mm. Typical width between 600 - 2100 mm |
| Pickled hot rolled coil | Hot rolled steel from which the iron oxides present at the surface have been removed in a pickling process; can be further processed. Applications in virtually all sectors of industry: transport, construction, shipbuilding, gas containers, pressure vessels, energy pipelines, etc. Typical thickness between 2 - 7 mm. Typical width between 600 - 2100 mm |
| Cold rolled coil | Obtained by a further thickness reduction of a pickled hot rolled coil. This step is achieved at low temperature in a cold-reduction mill; can be further processed. Used as primary material for finished cold rolled coils and coated coils. Typical thickness between 0.15 - 3 mm. Typical width between 600 - 2100 mm |
| Finished cold rolled coil | Obtained by heat treatment (annealing) and strain-hardening of cold rolled steel in a way to achieve final mechanical properties making the steel suitable for further uses (forming and bending); can be further processed. Classified into the following: formable steels, high strength formable steels, weathering structural steels, structural steels, hardenable steels. They have excellent forming properties, electromagnetic properties, paintability, weldability, and are suitable for fabrication by forming, pressing and bending. Applications include domestic applications, automotive applications, lighting fixtures, electrical components (stators, rotors) and various kinds of sections roofing applications, profiled sheets, wall elements, etc. Typical thickness between 0.3 - 3 mm. Typical width between 600 - 2100 mm. |
| Hot-dip galvanized steel | Obtained by passing cold rolled coil through a molten zinc bath, in order to coat the steel with a thin layer of zinc to provide corrosion resistance; can be further processed. They have excellent forming properties, paintability, weldability, and are suitable for fabrication by forming, pressing and bending. Applications include domestic applications, building applications (e.g. wall elements, roofing applications), automotive applications (e.g. body in white for vehicles underbody auto parts), lighting fixtures, drums and various kinds of sections applications, profiled sheets, etc. Typical thickness between 0.3 - 3 mm. Typical width between 600 - 2100 mm. |
| Electrogalvanized steel | Obtained by electro plating finished cold rolled steel with a thin layer of zinc or zinc-nickel to provide corrosion resistance; can be further processed. They have excellent forming properties, paintability, weldability, and are suitable for fabrication by forming, pressing and bending. Applications include domestic applications, building applications (e.g. wall elements, roofing applications), automotive applications (e.g. body in white for vehicles underbody auto parts), lighting fixtures, drums and various kinds of sections applications, profiled sheets, etc. Typical thickness between 0.3 - 3 mm. Typical width between 600 - 2100 mm. |
| Rebar | A steel reinforcing bar is rolled on a hot rolling mill; can be further processed. This product is used to strengthen concrete in highway and building construction also as primary product for the wire rod process. |
| Engineering steel (Tool steel) | Engineering Steel is rolled on a Hot Rolling mill. It can be found on the market and is further processed into finished products by the manufacturers This steel is used in the manufacture of tools, dies, components for engines, drives, equipment, transmissions, etc. |
| Sections | A steel section rolled on a hot rolling mill. Steel Sections include I-beams, H-beams, wide-flange beams, and sheet piling. This product is used in construction, multi-story buildings, industrial buildings, bridge trusses, vertical highway supports, and riverbank reinforcement. |

| | |
|---|---|
| UO pipe | UO pipe is usually large in diameter and produced one piece at a time by forming plates. The plate is first pressed into a U shape by the U-press, and then into an O shape by the O-press.<br>Because relatively thick material is used for making UO pipes, submerged arc welding is used for joining. UO pipe is mainly used as line pipe for transporting petroleum and natural gas in large quantity over long distances. |
| Welded pipe | A flat plate steel coil that is bended and welded into a tube. It can be found on the market for final use.<br>A heavy-wall pipe is technically used to transport fluids (e.g. oil, gases, water, chemicals) |
| Wire rod | Wire rod is a rolled steel product, produced from a semi and having a round, rectangular or other cross-section. Particularly fine cross-sections may be achieved by subsequent cold forming (drawing). Wire rod is wound into coils and transported in this form. |
| Tinplate | Obtained by electro plating a thin finished cold rolled coil with a thin layer of tin. It can be found on the market in coil or in sheets and is further processed into finished products by the manufacturers.<br>Tin plated steel is used primarily in food cans, industrial packaging (e.g. small drums)<br>Typical thickness between 0.13 - 0.49 mm. Typical width between 600 - 1100 mm. |
| Tin-free (ECCS) | Also known as Electrolytic Chrome Coated Steel (ECCS).<br>Obtained by electro plating a thin finished cold rolled coil with a thin layer of chrome. It can be found on the market in coil or in sheets and is further processed into finished products by the manufacturers.<br>ECCS is used primarily in food cans, industrial packaging (e.g. small drums).<br>Typical thickness between 0.13 - 0.49 mm. Typical width between 600 - 1100 mm |
| Organic coated | Obtained by coating a steel substrate with organic layers such as paint or laminated film. The substrate is mainly hot-dip galvanized coil but may also be electrogalvanized coil, finished cold rolled coil or tin-free steel. It can be found on the market in coil or in sheets and is further processed into finished products by the manufacturers.<br>Used in all activity sectors e.g. construction (roof, wall and ceiling claddings, lighting, radiators etc.), general industry (e.g. office furniture, heating, ventilating, air conditioning), domestic appliances (refrigerators, washing machines, small kitchen appliances, computer casings & DVD casings, etc.) and packaging.<br>Typical thickness between 0.15 - 1.5 mm. Typical width between 600 - 1300 mm |

# APPENDIX 2: REPRESENTATION OF THE BOF PROCESS



# APPENDIX 3: LIST OF PARTICIPATING COMPANIES

The companies that contributed to the data released in September 2017 are listed below:

| | |
|---|---|
| Acciaierie Bertoli Safau | Nisshin Steel |
| Aichi Steel | Nippon Steel & Sumitomo Metal Corporation (NSSMC) |
| ArcelorMittal | Osaka Steel (part of NSSMC) |
| Baosteel now part of China Baowu Steel Group | Salzgitter |
| BlueScope | Sanyo Special Steel |
| British Steel | Shimizu Steel Tomakomai |
| China Steel Corporation | SSAB |
| Daido Steel | Sahaviriya Steel Industries (SSI) |
| Erdemir | Tata Steel Europe |
| Sidenor | Tata Steel India |
| Godo Steel | Tenaris |
| Hadeed | Ternium |
| HBIS | thyssenkrupp Steel Europe |
| Isdemir (part of Erdemir Group) | Tokyo Kohtetsu |
| Itoh Ironworks Corp | Tokyotekko |
| JFE Steel | Topy Industries |
| Kobe Steel | voestalpine |
| Kyoei Steel | |

# APPENDIX 4: EXAMPLE DATA COLLECTION QUESTIONNAIRE

| | | | | | |
|---|---|---|---|---|---|
| **Fiscal period** | 2017 | | | | |
| **Site** | Example BF, 2017 | | | | |
| **Questionnaire** | (H) Hot Strip Mill (new) | | | | |
| **Tab** | Input | | | | |
| **Name** | **Unit** | **Value** | **Quality of data** | **Source** | **Year** |
| Flows | - | - | - | - | - |
| Production residues in life cycle | - | - | - | - | - |
| Waste for recovery | - | - | - | - | - |
| Scarfing dust | kg | | n.a. | Factory | |
| Used oil | kg | | n.a. | Factory | |
| Waste water treatment sludge | kg | | n.a. | Factory | |
| Resources | - | - | - | - | - |
| Material resources | - | - | - | - | - |
| Renewable resources | - | - | - | - | - |
| Water | - | - | - | - | - |
| Fresh water | kg | | n.a. | Factory | |
| Sea water | kg | | n.a. | Factory | |
| Water (softened, deionized) | kg | | n.a. | Factory | |
| Water Cooling fresh | kg | | n.a. | Factory | |
| Water Cooling sea | kg | | n.a. | Factory | |
| Valuable substances | - | - | - | - | - |
| Energy carrier | - | - | - | - | - |
| Electric power | - | - | - | - | - |
| Electricity | MJ | | n.a. | Factory | |
| Fuels | - | - | - | - | - |
| Crude oil products | - | - | - | - | - |
| Heavy fuel oil | kg | | n.a. | Factory | |
| Liquefied petroleum gas | kg | | n.a. | Factory | |
| Refinery products | - | - | - | - | - |
| Light fuel oil | kg | | n.a. | Factory | |
| Natural gas products | - | - | - | - | - |
| Natural gas, at production | - | - | - | - | - |
| Natural gas | kg | | n.a. | Factory | |
| Other fuels | - | - | - | - | - |
| Basic Oxygen Furnace Gas (MJ) (Copy) | MJ | | n.a. | Factory | |
| Blast furnace gas (MJ) | MJ | | n.a. | Factory | |
| Coke oven gas (MJ) (Copy) | MJ | | n.a. | Factory | |
| Mechanical energy | - | - | - | - | - |
| Compressed air for process | $m^3$ | | n.a. | Factory | |
| Thermal energy | - | - | - | - | - |
| Hot water (MJ) | MJ | | n.a. | Factory | |
| steam | - | - | - | - | - |
| Steam (MJ) | MJ | | n.a. | Factory | |
| Materials | - | - | - | - | - |
| Intermediate products | - | - | - | - | - |
| Inorganic intermediate products | - | - | - | - | - |
| Ferric chloride | kg | | n.a. | Factory | |
| Nitrogen gaseous | kg | | n.a. | Factory | |
| Oxygen gaseous | kg | | n.a. | Factory | |
| Sodium hydroxide (100%; caustic | kg | | n.a. | Factory | |
| Sulphuric acid (100%) | kg | | n.a. | Factory | |
| Organic intermediate products | - | - | - | - | - |
| Lubricant | kg | | n.a. | Factory | |
| Propane | kg | | n.a. | Factory | |
| Metals | - | - | - | - | - |
| Cold rolled coil (from DSP) | kg | | n.a. | Factory | |
| Slab (from BOF) | kg | | n.a. | Factory | |
| Slab (from EAF) | kg | | n.a. | Factory | |
| Slab (from external supply) | kg | | n.a. | Factory | |
| Steel strap | kg | | n.a. | Factory | |
| Minerals | - | - | - | - | - |
| Lime quicklime (lumpy) | kg | | n.a. | Factory | |
| Refractories (magnesia, alumina, | kg | | n.a. | Factory | |
| Refractories (silica, alumina) | kg | | n.a. | Factory | |
| Operating materials | - | - | - | - | - |
| Grease | kg | | n.a. | Factory | |
| Water for industrial use | kg | | n.a. | Factory | |

| | | | | | |
|---|---|---|---|---|---|
| **Date** | 2018-02-20T07:46:45 | | | | |
| **Fiscal period** | 2017 | | | | |
| **Site** | Example BF, 2017 | | | | |
| **Questionnaire** | (H) Hot Strip Mill (new) | | | | |
| **Tab** | Output | | | | |
| **Name** | **Unit** | **Value** | **Quality of data** | **Source** | **Year** |
| Flows | - | - | - | - | - |
| Emissions to air | - | - | - | - | - |
| Heavy metals to air | - | - | - | - | - |
| Arsenic (+V) | kg | | n.a. | Factory | |
| Copper | kg | | n.a. | Factory | |
| Iron | kg | | n.a. | Factory | |
| Zinc | kg | | n.a. | Factory | |
| Inorganic emissions to air | - | - | - | - | - |
| Ammonia | kg | | n.a. | Factory | |
| Carbon dioxide | kg | | n.a. | Factory | |
| Carbon monoxide | kg | | n.a. | Factory | |
| Nitrogen oxides | kg | | n.a. | Factory | |
| Sulphur oxides (as SO2) | kg | | n.a. | Factory | |
| Organic emissions to air (group VOC) | - | - | - | - | - |
| Group NMVOC to air | - | - | - | - | - |
| Group PAH to air | - | - | - | - | - |
| Polycyclic aromatic hydrocarbons | kg | | n.a. | Factory | |
| Halogenated organic emissions to air | - | - | - | - | - |
| Dioxins (unspec.) | kg | | n.a. | Factory | |
| Methane | kg | | n.a. | Factory | |
| VOC (unspecified) | kg | | n.a. | Factory | |
| Particles to air | - | - | - | - | - |
| Dust (PM10) | kg | | n.a. | Factory | |
| Dust (unspecified) | kg | | n.a. | Factory | |
| Emissions to fresh water | - | - | - | - | - |
| Analytical measures to fresh water | - | - | - | - | - |
| Biological oxygen demand (BOD) | kg | | n.a. | Factory | |
| Heavy metals to fresh water | - | - | - | - | - |
| Arsenic (+V) | kg | | n.a. | Factory | |
| Cadmium | kg | | n.a. | Factory | |
| Iron | kg | | n.a. | Factory | |
| Tin | kg | | n.a. | Factory | |
| Zinc | kg | | n.a. | Factory | |
| Inorganic emissions to fresh water | - | - | - | - | - |
| Acid (calculated as H+) | kg | | n.a. | Factory | |
| Aluminium | kg | | n.a. | Factory | |
| Ammonia (NH4+, NH3, as N) | kg | | n.a. | Factory | |
| Barium | kg | | n.a. | Factory | |
| Nitrogen dioxide | kg | | n.a. | Factory | |
| Organic emissions to fresh water | - | - | - | - | - |
| Carbon, organically bound | kg | | n.a. | Factory | |
| Hydrocarbons to fresh water | - | - | - | - | - |
| Oil (unspecified) | kg | | n.a. | Factory | |
| Phenol (hydroxy benzene) | kg | | n.a. | Factory | |
| Thiocyanates (CNS-) | kg | | n.a. | Factory | |
| Other emissions to fresh water | - | - | - | - | - |
| Waste water | kg | | n.a. | Factory | |
| Particles to fresh water | - | - | - | - | - |
| Solids (suspended) | kg | | n.a. | Factory | |
| Emissions to sea water | - | - | - | - | - |
| Analytical measures to sea water | - | - | - | - | - |
| Biological oxygen demand (BOD) | kg | | n.a. | Factory | |
| Chemical oxygen demand (COD) | kg | | n.a. | Factory | |
| Heavy metals to sea water | - | - | - | - | - |
| Copper | kg | | n.a. | Factory | |
| Iron | kg | | n.a. | Factory | |
| Manganese | kg | | n.a. | Factory | |
| Zinc | kg | | n.a. | Factory | |
| Production residues in life cycle | - | - | - | - | - |
| Hazardous waste for disposal | - | - | - | - | - |
| Hazardous non organic waste for | - | - | - | - | - |
| Hazardous Waste | kg | | n.a. | Factory | |
| Hot Rolling Sludge | kg | | n.a. | Factory | |
| Refractories (silica, alumina) | kg | | n.a. | Factory | |
| Scale internal | kg | | n.a. | Factory | |
| Waste from steel works | kg | | n.a. | Factory | |
| Hazardous organic waste for disposal | - | - | - | - | - |
| Waste water treatment sludge | kg | | n.a. | Factory | |
| Waste for disposal | - | - | - | - | - |
| Non hazardous non organic waste for | - | - | - | - | - |
| Hot Rolling Sludge | kg | | n.a. | Factory | |
| Scale internal | kg | | n.a. | Factory | |
| Waste from steel works | kg | | n.a. | Factory | |
| Non hazardous organic waste for | - | - | - | - | - |
| Waste water treatment sludge | kg | | n.a. | Factory | |
| Waste for recovery | - | - | - | - | - |
| Refractories | kg | | n.a. | Factory | |
| Scales internal (Copy) | kg | | n.a. | Factory | |
| Steel scrap (external supply) | kg | | n.a. | Factory | |
| Steel scrap (Home scrap) | kg | | n.a. | Factory | |
| Used oil | kg | | n.a. | Factory | |
| Waste water treatment sludge | kg | | n.a. | Factory | |
| Resources | - | - | - | - | - |
| Material resources | - | - | - | - | - |
| Renewable resources | - | - | - | - | - |
| Water | - | - | - | - | - |
| Fresh water | kg | | n.a. | Factory | |
| Sea water | kg | | n.a. | Factory | |
| Valuable substances | - | - | - | - | - |
| Energy carrier | - | - | - | - | - |
| Thermal energy | - | - | - | - | - |
| Hot water from process stages (MJ) | MJ | | n.a. | Factory | |
| Steam (from process stages, in MJ) | MJ | | n.a. | Factory | |
| Materials | - | - | - | - | - |
| Metals | - | - | - | - | - |
| Steel hot rolled coil | kg | | n.a. | Factory | |
| Operating materials | - | - | - | - | - |
| Water for industrial use | kg | | n.a. | Factory | |

# APPENDIX 5: LIST OF UPSTREAM INPUTS AND THEIR DATA SOURCES

| Item | Process Information | Country | Year | Source |
|---|---|---|---|---|
| Acetylene | Ethine (acetylene), SACHSSE-BARTHOLOME process | DE | 2016 | thinkstep |
| Activated carbon | Activated carbon is the collective name for a group of porous carbons. They all have small amounts of chemically bonded oxygen and hydrogen and contain up to 20 % mineral matter | DE | 2016 | thinkstep |
| Aluminium | Cradle-to-gate, Aluminium ingot production based on data from the International Aluminium Institute (IAI). | GLO | 2013 | IAI |
| Aluminium chloride | Aluminium chloride hexahydrate | DE | 2016 | thinkstep |
| Aluminium foil | Data is primarily from 2005 sources with energy mixes and ingot imports from 2009. The foil production process itself is based on European production and corresponds to a foil thickness of 5-200 micrometers. | EU-28 | 2016 | thinkstep |
| Aluminium sulphate | Aluminium sulphate | DE | 2016 | thinkstep |
| Ammonia | Ammonia is produced almost exclusively by the well-known HABER-BOSCH process. | EU-28 | 2016 | thinkstep |
| Ammonium sulphate | Ammonium sulphate mix (by-product) | DE | 2016 | thinkstep |
| Anthracite | Country specific data, based on hard coal mix for each country | Country specific | 2013 | thinkstep |
| Argon | Gaseous, LINDE process | DE | 2016 | thinkstep |
| Bauxite | Opencast and underground mining | EU-28 | 2016 | thinkstep |
| Benzene | technology mix, from pyrolysis gasoline, reformate and toluene dealkylation | EU-28 | 2016 | thinkstep |
| BOF slab | 1kg global slab, weighted average | GLO | 2017 | worldsteel |
| Calcium chloride | (from epichlorohydrine synthesis) | DE | 2016 | thinkstep |
| Carbon dioxide | From HABER-BOSCH process (ammonia synthesis, NH3/CO2) | DE | 2016 | thinkstep |
| Catalyst | Ethylene glycol | EU-28 | 2016 | thinkstep |
| Cement | Portland cement (CEM I) | EU-28 | 2006 | CEMBUREAU |
| Charcoal | Site data for production | GLO | 2015 | worldsteel |
| Coal | Country specific data, based on hard coal mix for each country | Country specific | 2013 | thinkstep |
| Coal for coke making | Coking coal global consumption mix including transport to border of country of production | GLO | 2013 | thinkstep |
| Coal for injection | Country specific data, based on hard coal mix for each country | Country specific | 2013 | thinkstep |
| Coke | 1kg global coke, weighted average | GLO | 2017 | worldsteel |
| Copper | Global copper mix: electrolyte copper 99,99%. Outokumpu was modelled for Chile, ISA smelt for Australia and the Mitsubishi process for Indonesia. | GLO | 2016 | thinkstep |

| Item | Process Information | Country | Year | Source |
|---|---|---|---|---|
| Corrugated board | EU-27: Corrugated board including paper production, average composition 2015 thinkstep/FEFCO | EU-27 | 2014 | thinkstep |
| Diesel | Country/region specific | Country/region specific | 2013 | thinkstep |
| Diesel (high Sulphur) | Country/region specific | Country/region specific | 2013 | thinkstep |
| Diesel (low Sulphur) | Country/region specific | Country/region specific | 2013 | thinkstep |
| Direct Reduced Iron | 1kg global DRI, weighted average | GLO | 2017 | worldsteel |
| Dolomite | Decarboxylation process by burning mined dolomite | EU-27 | 2016 | thinkstep |
| Dolomite (crude) | Dolomite extraction | DE | 2016 | thinkstep |
| Electricity | See Appendix 6 – country specific | Country specific | 2013 | thinkstep |
| Electrode | baking petrol coke, pitch and hard coal tar | ZA | 2016 | thinkstep |
| Ferric chloride | Ferric (III) chloride (hexahydrate) | DE | 2016 | thinkstep |
| Ferro chrome | Ferro Chromium (high carbon) | GLO | 2016 | thinkstep |
| Ferro manganese | Production of ferro-manganese (77% Mn) with high carbon content.<br>The direct process chain includes the mining and the beneficiation of the ore (South African specific and mining and beneficiation are at the same operation site), a sinter and melting process (electric furnace), the transportation to the port of transhipment (Rotterdam) and the subsequent 300 km transportation to the German trade market. | ZA | 2016 | thinkstep |
| Ferro molybdenum | Ferro molybdenum (67% Mo) | GLO | 2016 | thinkstep |
| Ferro nickel | Ferro nickel (29% Ni) | GLO | 2016 | thinkstep |
| Ferro silicum | Ferro silicon mix (91%) | GLO | 2016 | thinkstep |
| Ferro vanadium | Ferro vanadium (FeV 80%) | ZA | 2016 | thinkstep |
| Ferrous sulphate | Ferrous (II) sulphate | EU-28 | 2016 | thinkstep |
| Gasket (seal) | EPDM gaskets for aluminium profile (EN15804 A1-A3) | DE | 2016 | thinkstep |
| Gasoline | From crude oil | EU-28 | 2013 | thinkstep |
| Glass wool | For glass wool production, the pure mineral primary glass is melted in a melting vat at approx. 1400°C | EU-28 | 2016 | thinkstep |
| Glue | Mixer of Methylenediphenyl diisocyanate ( (p)MDI) and Aromatic Polyester Polyols (APP) production mix | EU-27 | 2014 | thinkstep |
| Heavy fuel oil | Country/region specific | Country/region specific | 2013 | thinkstep |
| Hot metal | 1kg global hot metal, weighted average | GLO | 2017 | worldsteel |
| Hydrochloric acid | 100% hydrochloric acid mix. The 'mix' process considers the technologies involved in the production of hydrochloric acid, based on the technology distribution of the respective technology for the country. | DE | 2016 | thinkstep |

| Item | Process Information | Country | Year | Source |
|---|---|---|---|---|
| Hydrogen | Steam reforming - natural gas | EU-28 | 2016 | thinkstep |
| Hydrogen peroxide | 50% $H_2O_2$. Anthraquinone process | DE | 2016 | thinkstep |
| Iron Ore | worldsteel production mix of 4 thinkstep datasets | GLO | 2016 | thinkstep |
| Kerosene | From crude oil | EU-28 | 2013 | thinkstep |
| Lead | Lead (99.995%), primary lead produced on the traditional process route. Does not include lead and zinc recovery. | RNA | 2016 | thinkstep |
| Light fuel oil | Country/region specific | Country/region specific | 2013 | thinkstep |
| Lime | Calcination of limestone | DE | 2016 | thinkstep |
| Limestone | Mining and beneficiation | DE | 2016 | thinkstep |
| Liquefied petroleum | Liquefied gas (LPG; 70% Propane; 30% Butane), refining process | DE | 2013 | thinkstep |
| Lubricants | The data set covers the entire supply chain of the refinery products. | EU-28 | 2013 | thinkstep |
| Magnesium | Magnesium Pidgeon process | CN | 2016 | thinkstep |
| Manganese | South Africa and Australia cover 90% of the world manganese production (International Manganese Institute). 80% of the mining takes place underground and 20% in open cast operations. The beneficiation is done at the mining site. The manganese ore is crushed and processed. The concentrate is then reduced by intense heating in a calcination process. Manganese metal is produced during electrolysis by addition of ammonia and sulphuric acid. The end product is manganese 99%. | ZA | 2016 | thinkstep |
| MDI (Isocyanate) | Phosgenation of methylenedianiline | DE | 2016 | thinkstep |
| Mineral rock wool | Rock wool flat roof plate (120 mm) | DE | 2016 | thinkstep |
| Natural gas | Country specific data, based on natural gas mix for each country | Country specific | 2013 | thinkstep |
| Nickel | Global Nickel mix. The data set represents the global situation, focusing on the main technologies, the region specific characteristics and / or import statistics. The data set is a mix of South Africa, Canada, Norway, Australia and Russia. | GLO | 2016 | thinkstep |
| Nitric acid | 98%. Two-step oxidation of ammonia to nitrogen monoxide and further to nitrogen dioxide and the absorption of the latter in water. | DE | 2016 | thinkstep |
| Nitrogen | Air and power to produce gaseous nitrogen | NA | 2007 | thinkstep |

| Item | Process Information | Country | Year | Source |
|---|---|---|---|---|
| Olivine | Silica sand (Excavation and processing) | DE | 2016 | thinkstep |
| Oxygen | Air, cooling water and power to produce gaseous oxygen | NA | 2007 | thinkstep |
| Paint (epoxy, melamine) | Mix of three powder coating upstreams, red, black and white | DE | 2016 | thinkstep |
| Paint (epoxy, phenolic) | Mix of three powder coating upstreams, red, black and white | DE | 2016 | thinkstep |
| Paint (polyester, melamine) | Mix of three powder coating upstreams, red, black and white | DE | 2016 | thinkstep |
| Paint (polyurethane) | Mix of water and solvent based primer | DE | 2016 | thinkstep |
| Paint (polyvinyl chloride) | Underbody protection PVC | DE | 2016 | thinkstep |
| Paint (silicon modified polyester) | Mix of Coating water-based red, black and white | DE | 2016 | thinkstep |
| Paint (PVDF, acrylic) | Mix of Coating solvent-based red, black and white | DE | 2016 | thinkstep |
| Pellet | 1kg global pellet, weighted average | GLO | 2017 | worldsteel |
| Pentane | Estimated via Butane | EU-28 | 2016 | thinkstep |
| Petroleum coke | Country / region specific data, based on hard coal mix for each country | Country / region specific | 2013 | thinkstep |
| Phosphoric acid | 100%, wet process | DE | 2016 | thinkstep |
| PMDI | Methylenediphenyl diisocyanate ( (p)MDI) | EU-27 | 2010 | thinkstep |
| Polyethylene | Polyethylene low density granulate (PE-LD) | EU-28 | 2016 | thinkstep |
| Polyol | Aromatic Polyester Polyols (APP) production mix | EU-27 | 2014 | PU Europe |
| Polyvinyl Chloride | PVC is produced by polymerization of vinyl chloride monomer to polyvinyl chloride PVC | DE | 2016 | thinkstep |
| Propane | Regional specific | Region specific | 2013 | thinkstep |
| Protection Foil (PE-LD) | Polyethylene Film (PE-LD) without additives | EU-27 | 2016 | thinkstep |
| Quartz sand | Silica sand is mined together with kaolin and feldspar using bucket excavators or bucket chain dredgers. The material is elutriated and the sand sieved in a multi-step process. | DE | 2016 | thinkstep |
| Refractories (all) | Sand-lime insulation brick | EU-28 | 2016 | thinkstep |
| Sand | Silica sand is mined together with kaolin and feldspar using bucket excavators or bucket chain dredgers. The material is elutriated and the sand sieved in a multi-step process. | DE | 2016 | thinkstep |
| Serpentine | Mined, as kaolin, normally together with silica sand and feldspar using bucket excavators or bucket chain dredgers. | DE | 2016 | thinkstep |
| Silicon mix | Purified, electric arc furnace process, from quartz sand | GLO | 2016 | thinkstep |
| Sinter | 1kg global sinter, weighted average | GLO | 2017 | worldsteel |
| Sinter/pellet fines | 1kg global sinter, weighted average | GLO | 2017 | worldsteel |

| Item | Process Information | Country | Year | Source |
|---|---|---|---|---|
| Sodium carbonate | Soda (Na2CO3), produced by the Solvay process | DE | 2016 | thinkstep |
| Sodium chloride | Rock salt is obtained from salt mines by use of machines or leaching techniques. | EU-28 | 2016 | thinkstep |
| Sodium hydroxide | 100% caustic soda from brine extraction, electrolysis and purification | EU-28 | 2016 | thinkstep |
| Sodium hypochlorite | 50% solution | DE | 2016 | thinkstep |
| Sodium sulphate | Sodium sulfate is a by-product in the production of boric acid. | GLO | 2016 | thinkstep |
| Steam | Process steam from natural gas 85% | EU-28 | 2013 | thinkstep |
| Steel scrap | See section 3.6.2. | GLO | 2017 | worldsteel |
| Steel scrap processing | Steel allocation of shredder process inputs and wastes | GLO | 2009 | worldsteel |
| Steel strap | 1 kg global hot rolled coil, weighted average | GLO | 2017 | worldsteel |
| Sulphur | From Crude Oil | EU-28 | 2013 | thinkstep |
| Sulphur dioxide | Sulphur dioxide estimation from oxygen and sulphur production | GLO | 2013 | thinkstep |
| Sulphuric acid | Oxidation of sulphur over sulphur dioxide to sulphur trioxide (contact procedure in several reactors with different catalysts), loosened in concentrated sulphuric acid in several columns and forms thereby a still higher concentrated sulphuric acid. | EU-28 | 2016 | thinkstep |
| Surface cleaning agent | Non-ionic surfactant (fatty acid derivative) | GLO | 2016 | thinkstep |
| Synthetic gas | Synthesis gas ($H_2$:CO = 3:1). Produced from water (steam) and methane (natural gas). The latter can be replaced with other hydrocarbons and mixtures thereof, e.g. naphtha or fuel oils. | DE | 2016 | thinkstep |
| Tar | Based on hydro-skimming and more complex refineries including hydro treatment, conversion (e.g. cracking) and refining processes | EU-28 | 2013 | thinkstep |
| Thermal energy | Mix of thermal energy from peat and biomass | FI | 2013 | thinkstep |
| Timber | Timber pine (12% moisture; 10.7% $H_2O$ content) (EN15804 A1-A3) | DE | 2016 | thinkstep |
| Tin | The dataset represents the 6 largest tin producing countries: Indonesia, Peru, Malaysia, Brazil, China, Belgium and Thailand focusing on the main technologies, the region-specific characteristics and / or import statistics. | GLO | 2016 | thinkstep |
| Titanium dioxide | Chloride process | EU-28 | 2016 | thinkstep |
| Zinc | Global zinc mix | GLO | 2012 | IZA |

# APPENDIX 6: ELECTRICITY GRID MIX INFORMATION

The power grid mix that is used for each site is relevant to the location of each steelmaking site, by country. All data has been taken from the GaBi 7.3 software and is listed in more detail below. The data is a cradle-to-gate inventory and is in conformity with ISO 14040: 2006 and 14044: 2006.

| Country | Age | Grid |
|---|---|---|
| Argentina | 2013 | 54.33% Natural gas, 22.49% Hydro,14.23% Heavy fuel oil, 4.47% Nuclear, 1.92% Hard coal, 1.77% Biomass, 0.44% Coal gases, 0.34% Wind, 0.01% Photovoltaic, |
| Australia | 2013 | 46.35% Hard coal, 21.32% Natural gas, 18.25% Lignite, 7.34% Hydro, 2.94% Wind, 1.53% Photovoltaic, 1.37% Heavy fuel oil, 0.44% Biogas, 0.34% Biomass, 0.13% Coal gases |
| Austria | 2013 | 66.98% Hydro, 9.75% Natural gas, 6.15% Hard coal, 5.51% Biomass, 4.61% Wind, 2.77% Coal gases, 1.43% Waste, 1.01% Heavy fuel oil, 0.92% Biogas, 0.85% Photovoltaic. |
| Belgium | 2013 | 51.29% Nuclear, 25.16% Natural gas, 4.37% Wind, 4.04% Biomass, 3.62% Hard coal, 3.18% Photovoltaic, 2.59% Coal gases, 2.42% Waste, 2.07% Hydro, 1.08% Biogas, 0.19% Heavy fuel oil |
| Bosnia and Herzegovina | 2013 | 41.46% Hydro, 33.9% Hard coal, 24.14% Lignite, 0.24% Heavy fuel oil, 0.22% Natural gas |
| Brazil | 2013 | 68.60% Hydro, 12.11% Natural gas, 7.02% Biomass, 4.66% Heavy fuel oil, 2.57% Nuclear, 1.56% Lignite, 1.22% Coal gases, 1.15% Wind, 1.04% Hard coal, 0.08% Biogas |
| Canada | 2013 | 60.11% Hydro, 15.77% Nuclear, 10.30% Natural gas, 8.36% Lignite, 1.78% Wind, 1.64% Hard coal, 1.15% Heavy fuel oil, 0.67% Biomass, 0.14% Biogas, 0.06% Photovoltaic, 0.04% Waste |
| China | 2013 | 74.23% Hard coal, 16.90% Hydro, 2.59% Wind, 2.05% Nuclear, 1.66% Natural gas, 1.24% Coal gases, 0.70% Biomass, 0.28% Photovoltaic, 0.23% Waste, 0.12% Heavy fuel oil |
| Czech Republic | 2013 | 41.86% Lignite, 35.31% Nuclear, 6.04% Hard coal, 4.18% Hydro, 4.16% Natural gas, 2.63% Biogas, 2.34% Photovoltaic, 1.93% Biomass, 0.77% Coal gases, 0.55% Wind, 0.17% Waste, 0.05% Heavy fuel oil |
| Finland | 2013 | 33.27% Nuclear, 18.1% Hydro, 16.15% Biomass, 15.07% Hard coal, 9.57% Natural gas, 4.46% Peat, 1.09% Wind, 1.04% Waste, 0.72% Coal gases, 0.33% Heavy fuel oil, 0.20% Biogas, 0.01% Photovoltaic |
| France | 2013 | 74.09% Nuclear, 13.30% Hydro, 3.84% Hard coal, 3.00% Natural gas, 2.80% Wind, 0.82% Photovoltaic, 0.67% Waste, 0.50% Coal gases, 0.43% Heavy fuel oil, 0.28% Biomass, 0.26% Biogas |
| Germany | 2013 | 25.49% Lignite, 19.28% Hard coal, 15.41% Nuclear, 10.89% Natural gas, 8.19% Wind, 4.91% Photovoltaic, 4.67% Biogas, 4.56% Hydro, 1.90% Waste, 1.84% Biomass, 1.71% Coal gases, 1.14% Heavy fuel oil, 0.01% Geothermal |
| India | 2013 | 58.42% Hard coal, 14.27% Lignite, 11.87% Hydro, 5.45% Natural gas, 2.87% Nuclear, 2.81% Wind, 1.94% Heavy fuel oil, 1.75% Biomass, 0.29% Photovoltaic, 0.13% Coal gases, 0.11% Waste, 0.08% Biogas |
| Italy | 2013 | 37.67% Natural gas, 18.91% Hydro, 15.26% Hard coal, 7.47% Photovoltaic, 5.36% Heavy fuel oil, 5.15% Wind, 3.88% Biogas, 1.96% Geothermal. 1.56% Waste, 1.27% Biomass, 1.17% Coal gases, 0.34% Lignite |
| Japan | 2013 | 38.43% Natural gas, 28.53% Hard coal, 14.34% Heavy fuel oil, 8.12% Hydro, 3.69% Coal gases, 3.07% Biomass, 1.37% Photovoltaic, 0.89% Nuclear, 0.82% Waste, 0.50% Wind, 0.25% Geothermal |

| | | |
|---|---|---|
| Luxembourg | 2013 | 49.19% Natural gas, 40.10% Hydro, 3.29% Waste, 2.87% Wind, 2.56% Photovoltaic, 1.94% Biogas, 0.07% Biomass |
| Mexico | 2013 | 55.79% Natural gas, 16.12% Heavy fuel oil, 10.32% Hard coal, 9.43% Hydro, 3.97% Nuclear, 2.04% Geothermal, 1.41% Wind, 0.34% Biomass, 0.33% Lignite, 0.11% Coal gases, 0.05% Biogas, 0.05% Waste |
| Morocco | 2013 | 42.76% Hard coal, 20.70% Natural gas, 20.65% Heavy fuel oil, 10.63% Hydro, 5.26% Wind |
| Netherlands | 2013 | 54.75% Natural gas, 24.43% Hard coal, 5.59% Wind, 3.75% Waste, 2.90% Coal gases, 2.88% Biomass, 2.87% Nuclear, 1.24% Heavy fuel oil, 0.97% Biogas, 0.51% Photovoltaic, 0.11% Hydro |
| Poland | 2013 | 49.60% Hard coal, 34.15% Lignite, 4.82% Biomass, 3.65% Wind, 3.19% Natural gas, 1.82% Hydro, 1.24% Coal gases, 1.08% Heavy fuel oil, 0.42% Biogas, 0.03% Waste |
| Saudi Arabia | 2013 | 52.75% Natural gas, 47.25% Heavy fuel oil |
| Spain | 2013 | 20.13% Natural gas, 20.01 Nuclear, 19.01% Wind, 14.48% Hydro, 13.60% Hard coal, 4.85% Heavy fuel oil, 2.93% Photovoltaic, 1.55% Solar thermal, 1.34% Biomass, 0.87% Lignite, 0.49% Coal gases, 0.42% Waste, 0.32% Biogas |
| Sweden | 2013 | 43.39% Nuclear, 40.15% Hydro, 6.43% Wind, 6.27% Biomass, 1.96% Waste, 0.55% Natural gas, 0.43% Hard coal, 0.27% Heavy fuel oil, 0.24% Coal gases, 0.21% Peat, 0.09 Biogas, 0.02% Photovoltaic |
| Taiwan | 2013 | 39.49% Hard coal, 26.18% Natural gas, 16.52% Nuclear, 8.03% Lignite, 3.42% Hydro, 2.98% Heavy fuel oil, 1.33% Coal gases, 1.28% Waste, 0.53% Wind, 0.13% Photovoltaic, 0.11% Biomass, 0.01% Biogas |
| Turkey | 2013 | 43.81% Natural gas, 24.76% Hydro, 12.92% Lignite, 12.89% Hard coal, 3.15% Wind, 0.78% Coal gases, 0.72% Heavy fuel oil, 0.57% Geothermal, 0.35% Biogas, 0.04% Waste, 0.01% Biomass |
| United Kingdom | 2013 | 36.41% Hard coal, 26.62% Natural gas, 19.66% Nuclear, 7.92% Wind, 2.94% Biomass, 2.12% Hydro, 1.65% Biogas, 1.19% Waste, 0.60% Heavy fuel oil, 0.57% Photovoltaic, 0.32% Coal gases |
| United States of America | 2013 | 37.57% Hard coal, 26.93% Natural gas, 19.11% Nuclear, 6.74% Hydro, 3.95% Wind, 2.14% Lignite, 1.06% Biomass, 0.86% Heavy fuel oil, 0.46% Waste, 0.43% Geothermal, 0.34% Photovoltaic, 0.30% Biogas, 0.10% Coal gases, 0.02% Solar thermal |

Full documentation for GaBi 7.3 can be found at:
http://www.gabi-software.com/support/gabi/gabi-6-lci-documentation

# APPENDIX 7: STEEL LCI DATA EXPLANATION

The function of this section is to explain some of the main features of the datasets and clarify potential ambiguities. LCI datasets have been produced for all products both globally and regionally, whenever more than three sites contributed. This is necessary to maintain confidentiality between companies and to ensure a minimum level of representativeness.

The datasets are provided as a static report created in the basis of an Envision report which has been generated using the GaBi 7.3 software, and are distributed from a web based platform via rtf format to enable ease of use of the data. The data is also available in the GaBi software or in Excel.

Cradle-to-gate data is given as standard. Data can also be provided including the credits and burdens of steel recycling. This means that a burden is given for the steel scrap that is used in the steelmaking process and a credit for the steel that will be recycled from the final product when it reaches the end of its life. In this case the net recycling credits are also provided separately. The scrap LCI is also given.

## A7.1 LCI flows

Only major flows are provided in the data sheets, namely the major raw materials and the "accounted" emissions (see the 2017 worldsteel LCI methodology report, section 3.5.4). Information on other flows is also available on request. Where end-of-life recycling has been taken into consideration, the material resource list does not add up to 1 tonne of resources per tonne of steel product due to the credits applied for end-of-life recycling.

The following sections provide more information on some of the flows provided in the data sheets.

### A7.1.1 Iron (ore)

The mass of iron ore in ground is reported in kg of iron oxides (mainly FeO, $Fe_3O_4$, $Fe_2O_3$) and excludes the mass of overburden.

### A7.1.2 Ferrous scrap (net)

The net ferrous scrap takes into account imports and exports from the system. It includes both steel and iron scrap (although iron scrap generation and usage is generally small). When the recycling credits and burdens are included, the scrap input is not listed as the associated upstream burden has been included instead.

Ferrous scrap includes:

- Scrap input to the steelmaking process – this is the net scrap consumed in the steelmaking process and does not include internally generated scrap.
- Home scrap is considered when the scrap comes from a process which occurs on the steelmaking site, but does not contribute to any of the production stages of the product.

### A7.1.3 Water consumption

The net fresh water consumption per kg of steel product is listed in the datasets. In addition to the water used directly on site, the water used in the upstream processes is also included. Fresh water used by the steel plants has several origins: namely surface water (river and lake), deep water (e.g. mine water) or "technosphere" sources (other industrial plants, waste water treatment plants, etc.).

The quantity of salt water used by the steel plants is recorded. It is mainly used for indirect cooling and therefore it is not contaminated with pollutants coming from the processes.

The full list of water flows is available on request.

### A7.1.4 Carbon dioxide emissions

This flow indicates both fossil and mineral sources of $CO_2$ (e.g. combustion of natural gas, oil, lime calcinations, and the oxidation of coal). In addition to providing $CO_2$ data, the environmental indicator for global warming potential is also provided, for information only, as this is one of the most common indicators currently being requested.

### A7.1.5 Particulate emissions to air

This flow includes all types of airborne particulate emissions, including PM 10 and PM 2.5. In the extended list of flows, the emission of particles to air is split into a number of sources including PM 10, PM 2.5, fugitive emissions etc. However, as the data are not always reported in the same format, this split is not always complete.

### A7.1.6 Waste

During the steelmaking process, there are a number of materials and gases that are produced that have a useful role either within or external to the steelmaking site. These materials that are recovered are referred to as recovered material or co-products and are listed in Appendix 8. Due to the demand in these markets, it may arise that these materials are no longer recovered but sent to landfill, incinerated, flared etc. In these circumstances, the material is classified as waste. In order to comply with ILCD[viii], any wastes or recovered materials where the final process step is unknown, have been modelled as connected to a landfill process and the associated impacts included in the overall LCI.

### A7.1.7 Primary Energy Demand

Certain material inputs, (e.g. coal, oil etc.) constitute energy as well as mass inputs, which can be calculated based on calorific value. Within the LCI data sheets, the total primary energy demand (including renewable and non-renewable resources) is provided, based on the net (low) calorific value. This information is provided for information only and should not be used in addition to the data provided in the material inputs section of the datasheet.

Total primary energy is the sum of all energy sources which are drawn directly from the earth, such as natural gas, oil, coal, biomass or hydropower energy, and includes non-renewable and renewable energy. Non-renewable energy includes all fossil and mineral primary energy sources, such as natural gas, oil, coal and nuclear energy. Renewable energy includes all other primary energy sources, such as hydropower and biomass.

A full breakdown of energy is available on request.

### A7.1.8 Life cycle impacts

Four Life Cycle Impact Assessment Indicators are reported for informational purposes only, based on CML 2001 – Dec 07. These are: global warming potential, acidification potential, eutrophication potential and photochemical ozone creation potential.

### A7.1.9 Other articles not reported

Within the data sheets, only the major raw materials are shown for simplification reasons. Concerning the air and water emissions, all ‘accounted’ emissions (see Section 4.3.) are reported in the data sheets.

The full list of flows is available on request. Depending on the product, a wide variety of other alloy metals such as copper, manganese and molybdenum can also be used but always in low quantity. These are included in the full list of flows. Lead can be incorporated in higher quantity in some special products called “free cutting” steels which were not included in the study due to lack of data. Other natural resources used for the production of crude steel are abundant materials such as sand, sodium chloride and clay.

# APPENDIX 8: SYSTEM EXPANSION ASSUMPTIONS

| Steel co-product | Co-product function | Avoided production | Data Source |
|---|---|---|---|
| Blast furnace slag, basic oxygen furnace slag, electric arc furnace slag | Cement or clinker production | 0.9 tonne per tonne of cement. Portland cement (CEM I) | GaBi 7.3 (RER) |
| | Aggregate or roadstone | Gravel production | GaBi 7.3 (DE) |
| | Fertiliser | Lime production | GaBi 7.3 (DE) |
| Process gas (coke oven, blast furnace, basic oxygen furnace, off gas) | Heat production for internal or external use | Coal, heavy fuel oil, light fuel oil or natural gas | GaBi 7.3 (Country specific) |
| | Electricity production | 1MJ gas = 0.365 MJ electricity | GaBi 7.3 (Country specific) |
| Electric arc furnace dust | Zinc production | 1 kg dust = 0.5 kg Zinc | GaBi 7.3 (Global) |
| Electricity from energy recovery | Electricity production | Electricity production | GaBi 7.3 (Country specific) |
| Steam from energy recovery | Heat generation | Steam production from natural gas 85% efficiency | GaBi 7.3 (EU-28) |
| Hot water from energy recovery | Heat generation | Steam production from natural gas 85% efficiency | GaBi 7.3 (EU-28) |
| Ammonia | Any ammonia application | Ammonia production | GaBi 7.3 (EU-28) |
| Ammonium sulphate | Any ammonium sulphate application | Ammonium sulphate production | GaBi 7.3 (DE) |
| Benzene | Any benzene application | Benzene production based on different technologies | GaBi 7.3 (EU-28) |
| BTX | Any BTX application | Benzene production based on different technologies | GaBi 7.3 (EU-28) |
| Scales | Metallurgical input to steelmaking | Iron ore extraction | worldsteel |
| Sulphuric acid | Any sulphuric acid application | Sulphuric acid production | GaBi 7.3 (EU-28) |
| Tar | Any tar application | Bitumen production | GaBi 7.3 (EU-28) |
| Used oil | Heat generation | Coal, heavy fuel oil, light fuel oil or natural gas | GaBi 7.3 (Country specific) |
| Zinc | Any zinc application | Zinc production | GaBi 7.3 (GLO) |
| Zinc dust | Any zinc application | Zinc production | GaBi 7.3 (GLO) |
| Electrode | Electrode making | Electrode mix | GaBi 7.3 (ZA) |

# APPENDIX 9: UPDATES FROM THE LCI STUDY OUTLINDED IN THE 2010 METHODOLOGY REPORT

This study report covers an update of the global steel industry LCI data and follows the 2017 LCI methodology report. During this update, a number of changes and updates have been made (compared to the 2010 study), and for ease of comparison, these differences are summarised here. Further information can be found in relevant sections of the report.

- The modelling software used for this update is GaBi 7.3 SP33. All upstream data which have not been collected by worldsteel from industry associations are based on GaBi 7.3 upstream data. The previous study used an earlier version of GaBi 4.
- For some energy related inputs, more country specific data has been implemented.
- Scrap processing is now included as an input to the boundary of the steel works. This impact is based on the shredding process, which is likely to be a conservative estimate of other steel scrap processing (such as baling and shearing)
- New upstream processes have been included, including charcoal production and new paint formulations for organic coated steels.
- Due to naming issues of some emission flows in GaBi 4, they were not picked up by impact assessments. These have been corrected to ensure all emission flows are correctly named. Currently this is done through a manual process using a flow name modification plan.
- To ensure the data is ILCD compliant, recovered material and wastes that had no final fate have now been modelled to be landfilled which will result in impacts that are higher than reality but is a conservative approach.
- Global iron ore upstream data is calculated using a 4-region-specific mix of iron ore production for 2014.

Below is a summary table which compares the 2017 data release with the previous 2010 release for steel sections, hot rolled coil and hot-dip galvanized steel.

The changes in the results can be explained by the changes that have been implemented above as well as the fact that the two data collection periods contain different companies and sites providing data. These different data points affect the results as shown below. While for some impacts the results have increased, for others there has been a decrease, demonstrating that looking at a range of impacts is important to understand the overall impact of a product LCI.

| Cradle to Gate Impacts | | PED MJ | GWP kg CO2-e | AP kg SO2-e | EP kg Phosphate-e | POCP kg ethene-e |
|---|---|---|---|---|---|---|
| Sections, 1kg | 2010 | 19.6 | 1.6 | 0.0045 | 0.00036 | 0.0008 |
| | 2017 | 18.3 | 1.5 | 0.0042 | 0.00032 | 0.00064 |
| Hot rolled coil, 1kg | 2010 | 21.6 | 2 | 0.0052 | 0.00035 | 0.00094 |
| | 2017 | 23.3 | 2.2 | 0.0054 | 0.00046 | 0.00091 |
| Hot-dip galvanized steel, 1kg | 2010 | 27.5 | 2.5 | 0.0074 | 0.00048 | 0.0012 |
| | 2017 | 29.5 | 2.7 | 0.0065 | 0.00059 | 0.00101 |

# APPENDIX 10: LIST OF ALL AVAILABLE QUESTIONNAIRES FOR DATA COLLECTION

- Coke oven
- Sinter plant
- Blast furnace
- Alternative iron making
- Basic oxygen furnace
- Electric arc furnace
- Direct sheet plant
- Plate mill
- Hot strip mill
- Pickling plant
- Cold rolling mill
- Annealing and tempering
- Section rolling
- Rebar
- Engineering steel
- Wire rod
- Seamless pipe making
- UO pipe making
- Welded pipe making and tube making
- Electrogalvanizing
- Hot-dip galvanizing
- Electrolytic chrome coating (ECCS or tin-free steel)
- Tinplating
- Organic coating
- Softening / deionising water
- Application of co-products (slags and used oil)
- Boilers (power plants)
- External power supply
- Destination of process gases (coke oven, blast furnace, basic oxygen furnace, off gas)
- Flaring of process gases (coke oven, blast furnace, basic oxygen furnace)
- Fresh water supply
- Sea water supply
- Isolated blast air compressor
- Isolated compressed air compressor
- Isolated turbo alternator
- Stockpile emissions
- Additional information
- Transport

# APPENDIX 11: MATRIX OF USES OF STEEL PRODUCTS

| Application | 1 = preferable 2 = possible | Plate | Pipe | Hot Rolled Coil | Pickled Hot Rolled Coil | Cold Rolled Coil | Finished Cold Rolled Coil | Electro-Galvanized | Hot-Dip Galvanized | Organic Coated | Tin Plate | Electrolytic Chromed Coated Steel | Section Rolling | Rebar | Engineering Steel | Wire Rod |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frame-Work | Profiles | | | 1 | 1 | 2 | | 2 | 1 | | | | 1 | | | |
| | Framing | | | | | | | | 1 | | | | | | | |
| Automotives | Body in white | | | | 2 | | 1 | 1 | 1 | 2 | | | | | | |
| | Structural parts | | | | 1 | | 1 | 1 | 1 | 2 | | | | | | |
| | Engine | | | | | | | | | | | | | | 1 | |
| | drives equipements | | | | | | | | | | | | | | 1 | |
| | transmissions | | | | | | | | | | | | | | 1 | |
| | wheels | | | | 1 | | | | | | | | | | | |
| | tyres | | | | | | | | | | | | | | | 1 |
| Construction | Structural parts | 1 | 1 | 1 | | | | | 2 | 1 | | | 1 | | | |
| | walls elements | | | | | | | 1 | 1 | 1 | | | | | | |
| | Basement | | | | | | | | | | | | 1 | 1 | | |
| | Concreete reinforcement | | | | | | | | | | | | | 1 | | |
| | Cladding | | | 2 | | | | 1 | 1 | 1 | | | | | | |
| | Roofing | | | | | | | | 1 | 1 | | | | | | |
| | Farm building walls | | | | | | | | 2 | 1 | | | | | | |
| | Gutter system (ducts) | | | | | | | | 1 | 1 | | | | | | |
| | Chimney ducts | | | 2 | | | | | | | | | | | | |
| | construstion components | | | 2 | 2 | | | 1 | 1 | 1 | | | | | | |
| | Farm building components | | | | | | | | 2 | 1 | | | | | | |
| | Doors and garages | | | | | | | | 2 | 1 | | | | | | |
| | Fences | | | | | | | | 2 | | | | | | | |
| | Stairs | | | 1 | | | | | 2 | | | | | | | |
| | Tiles | | | | | | | | 2 | 1 | | | | | | |
| | Ceilings components | | | | | | | 1 | 1 | 1 | | | | | | |
| | Floor components | | | 1 | | | | 2 | 1 | | | | | | | |
| | Inside decoration panels | | | | | | | | | 1 | | | | | | |
| | partition walls | | | | | | | 2 | 1 | 1 | | | | | | |
| | inside panels food industry | | | | | | | | | 1 | | | | | | |
| | security rails on roads | | | | | | | | 1 | | | | | | | |
| Home appliances | furnnitures | | | | | | 2 | 1 | | 1 | | | | | | |
| | white goods | | | | | | 1 | 1 | 1 | 1 | | | | | | |
| | heating, ventilation and air conditioni | | | | | | 1 | 1 | 1 | 1 | | | | | | |
| Packaging | Steel Food & General Line Cans | | | | | | | | | 1 | 1 | 1 | | | | |
| | Pails | | | | | | | | | | | 1 | | | | |
| | Beverage cans | | | | | | | | | 1 | 1 | 1 | | | | |
| | Drums | | | | | | 1 | 1 | | | | | | | | |
| Machinery | Rail | | | | | | | | | | | | 1 | | | |
| | Machines | 2 | | | | | 1 | | | | | | | | 1 | |
| | Pipes | | 1 | | | | | | | | | | | | | |
| Others | tubes | | | 1 | 2 | | 1 | | | | | | | | | |
| | pools | | | | | | | | 2 | 2 | | | | | | |
| | water tanks | | | | | | | | 1 | | | | | | | |
| | greennhouses | | | | | | | | 2 | 2 | | | | | | |
| | signs | | | | | | | | 2 | | | | | | | |
| | tools | | | | | | | | | | | | | | 1 | |
| | dies | | | | | | | | | | | | | | 1 | |
| | wires | | | | | | | | | | | | | 1 | | 1 |

# APPENDIX 12: CRITICAL REVIEW STATEMENT

Commissioned by: World Steel Association (worldsteel), Brussels, Belgium

Reviewer: Prof. Dr. Matthias Finkbeiner, Berlin, Germany

References:

- ISO 14040 (2006): Environmental Management - Life Cycle Assessment - Principles and Framework
- ISO 14044 (2006): Environmental Management - Life Cycle Assessment – Requirements and Guidelines
- ISO/TS 14071 (2014): Environmental management -Life cycle assessment - Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006

## Scope of the Critical Review

The reviewer had the task to assess whether:

- the methods used to carry out the LCA are consistent with the international standards ISO 14040 and ISO 14044
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study,
- the technological coverage of the steel industry in the prevalent LCA study is representative of current practice,
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

The review was performed at the end of the study according to paragraph 6.2 of ISO 14044, because the study as such is not intended to be used for comparative assertions intended to be disclosed to the public. This does not preclude that the data may be used in studies where comparative assertions are made, provided a separate panel review of that study is carried out. This review statement is only valid for this specific report in its final version dated May 2018 received on 30.05.2018.

The analysis of LCI models or the verification of individual datasets are outside the scope of this review.

## Review process

The review process was coordinated between worldsteel and the reviewer. The first draft of the study report was submitted to the reviewer on 26.04.2018. The reviewer provided 36 comments of general, technical and editorial nature to the commissioner by 7th of May 2018. After personal and email communication to clarify some of the comments, worldsteel provided the final version of the study report addressing all comments on 30.05.2018. The feedback provided and the agreements on the treatment of the review comments were properly adopted in this version of the report. All critical issues and the majority of recommendations of the reviewer were addressed in a comprehensive manner.

The reviewer acknowledges the unrestricted access to all requested information as well as the open and constructive dialogue during the critical review process.

## General evaluation

This study report is the result of a cooperative effort of the leading steel producers in the world organized by its global industry association, worldsteel. The current study report is the third update of the previous publications from 1995/96, 2000/01 and 2011. As a result, the methodology and its application has reached a high level of maturity. This study report conforms to the World Steel Association LCI methodology report from 2017, which is available as a separate document and has undergone a separate critical review.

The outstanding feature of this study is the large amount of primary data collected to reach representative results for global steel production. Primary data were collected for 23 separate steelmaking process steps at a total of 109 sites operated by 28 companies. The companies participating in the study produce over 25% of global steel production and the contributing sites (which cover 15% of global steel production) are among the largest of the principal producer countries.

Because the focus of the study is the production of a material that can be used in a variety of products with very different use profiles, the chosen cradle-to-gate-approach is appropriate. Several assumptions as well as the differences to the previous report were addressed and checked by sensitivity respectively consistency analyses. As a result, the report is deemed to be representative for the global production of steel. The defined and achieved scope for this LCI study was found to be appropriate to achieve the stated goals.

## Conclusion

The study has been carried out in conformity with ISO 14040 and ISO 14044. The reviewer found the overall quality of the methodology to be mature and of a high standard for the intended application. The methodology documentation in the study and methodology reports is comprehensive including a transparent description of its scope and methodological choices.

Matthias Finkbeiner

31st May 2018

# References

[1] World Steel Association Life cycle assessment methodology report, Brussels, 2011
[1] World Steel Association Life Cycle Inventory Methodology Report, 2017
[1] ISO 14040: 2006 – Environmental management – Life cycle assessment- Principles and framework
[1] ISO 14044: 2006 – Environmental management – Life cycle assessment – Requirements and guidelines
[1] ISSF LCI data for stainless steel products, www.worldstainless.org
[1] The Centre of Environmental Science at Leiden University, CML 2001 – Dec 07
[1] International Iron and Steel Institute, Worldwide LCI Database for Steel Industry Products, Technical Report 1, Brussels, 1998
[1] The International Reference Life Cycle Data System – Compliance rules and entry-level requirements, EU JRC, 2012

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