Life cycle inventories of steel and iron processes

Client

Bundesamt für Umwelt BAFU
3003 Bern
Frank Hayer

Authors

Mischa Zschokke, Philipp Bolt and Stefanie Conrad, Carbotech AG

Validation

Frank Werner

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Carbotech AG

www.carbotech.ch

Büro Basel
St. Alban-Vorstadt 19, 4052 Basel
T +41 61 206 95 25

Büro Zürich
Gasometerstrasse 9, 8005 Zürich
T +41 44 444 20 10

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Abbreviations

BAT *Best available techniques*
BF *Blast furnace*
BFG *Blast furnace gas*
BOF *Basic oxygen furnace*

C_nH_{2n+2} *Hydrocarbons*
CO *Carbon monoxide*
COG *Coke oven gas*

DETEC *Federal Department of the Environment, Transport, Energy and Communications*

EAF *Electric arc furnace*
ESP *Electrostatic precipitators*
EU *European Union*

HCl *Hydrogen chloride*
HF *Hydrogen fluoride*
HM *Hot metal*

IPCC *Intergovernmental Panel on Climate Change*

NO_x *Nitrogen oxides*

PAH *Polycyclic aromatic hydrocarbons*
PCB *Polychlorinated biphenyls*
PCDD/F *Polychlorinated dibenzo-p-dioxins (PCDD), dibenzofurans (PCDF)*

SO_x *Sulphur oxides*

UVEK *Eidgenössische Departement für Umwelt, Verkehr, Energie und Kommunikation*

1 Introduction

Life cycle assessment (LCA) has been an important tool to assess the environmental performance of products, materials or entrepreneurial activities for decades. LCAs are based on knowledge of, among other things, material propoperties and physical or chemical processes which have been curated by the LCA community in large background databases. To keep these databases up-to-date, reviewing existing processes is an important undertaking, especially for processes that feed into many product systems. Steel and iron processes are among the most relevant in the LCA ecosystem.

1.1 Goal and Scope

The goal of this project was to update and expand the data on steel and iron LCA processes to the reference year 2020, with a focus on background data on iron and steel processes in the ecoinvent and DETEC (UVEK:2018). Naturally, this was not possible for all processes, either because of lack of new data or budget limitations. This report provides an overview of the updates and additions to the data involved. Thus, the reader should have a full overview about the data sets as they are now provided for the DETEC database.

In general, subchapters about process steps that are assessed as relevant in the final LCIA results (Ecological Scarcity 2013) have been retained or updated. The documentation focuses on aspects which are relevant for the updated life cycle inventories (LCI) presented in this report. Where no more updated data were found, the existing data remains, even if it is dated (in line with the motto "outdated rather than no data").

The following processes were updated or newly created for this report:

- iron scrap, at plant, CH (new)
- pellets, iron, at plant, RER (updated)
- pig iron, blast furnace, at plant, RER (updated)
- reinforcing steel, at plant, CH (new)
- reinforcing steel, at regional storage, CH (new)
- reinforcing steel, at plant, RER (updated)
- sinter, iron, at plant, RER (updated)
- steel, converter, unalloyed, EU (updated)
- steel, electric, alloyed, 23MnCrSiMoF66, CH (new)
- steel, electric, alloyed, 44FMn28, CH (new)
- steel, electric, alloyed, 42CrMoS4, CH (new)
- steel, electric, low-alloyed, CH (new)
- steel, electric, unalloyed, CH (new)
- steel, electric, un- and low-alloyed, at plant, RER (updated)
- steel, electric, low-alloyed, at plant, RER (new)
- steel, electric, low-alloyed, at plant, best planst (min. values), RER (new)
- steel, electric, low-alloyed, at plant, worst planst (max. values), RER (new)
- basic oxygen furnace gas, burned in power plant, RER (new)
- blast furnace gas, burned in power plant, RER (new)
- blast furnace slag, at plant, RER (updated)
- electric arc furnace slag, at plant, RER (new)

- electric arc furnace slag, at plant, CH (new)
- disposal, basic oxygen furnace wastes, 0% water, to residual landfill, CH (updated)
- disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill, CH (updated)
- disposal, slag, unalloyed EAF steel, 0% water, to residual material landfill, CH (updated)
- disposal, sludge from steel rolling, 20%, to residual material landfill, CH (updated)

1.2 Validation process

All inventories were validated by the external reviewer Frank Werner (Dr. Werner Umwelt & Entwicklung) according to the ecoinvent v2.0 methodology (Frischknecht et al., 2007). The following criteria were reviewed:

- Completeness of the documentation. All investigated datasets should be described in the report, and all necessary meta information and flow data should be available for each dataset.
- Consistency with the quality guidelines. It is checked whether the unit processes have been modelled according to the ecoinvent quality guidelines (Frischknecht et al., 2007). The quality guidelines cover for example the estimation of transport distances or the calculation of energy demands in the inventory.
- Plausibility check of the life cycle inventory data. Selected input and output flows are controlled for plausibility.
- Completeness of inputs and outputs. The completeness of flows is based on the environmental and technical knowledge of the reviewing person. Reviewers are not necessarily technical experts of the processes reviewed. If necessary, they were supported by the person responsible for the report.
- Mathematical correctness of calculations. Selected inputs and outputs are controlled in view of mathematical correctness.

This review procedure is not comparable to the peer review specified in the ISO standards. The validation report is attached in the annex.

1.3 Comments on this report

This report builds on of the text in Life Cycle Inventories of Metals, version v2.1, Part II Iron and Steel (Classen et al., 2009). The steel production in Europe is modelled primarily based on data from the description of the current situation in the “Best Available Techniques Reference Document on the Production of Iron and Steel” Remus (2013). Some text passages are based on text content from these two above mentioned reports.
Data for newly modelled Swiss inventories were collected from the two steelworks in Switzerland, Swiss Steel AG and Stahl Gerlafingen.

2 General Information

2.1 Steel production in Europe and Switzerland

Steel is one of the world's most important engineering and construction materials. It is used in many aspects of our lives. There exist thousands of different grades and types of steel, which make steel a versatile industrial material.

Steel production can take place at integrated facilities where steel is made from iron ore or at secondary facilities where steel is mainly produced from recycled scrap. An integrated facility comprises a blast furnace (BF) and a basic oxygen furnace (BOF). The BF produces the pig iron, a semi-finished product, whereas the BOF produces the raw steel. Secondary steel making is mainly done in electric arc furnaces (EAF) (EEA, 2019).

Steel production in Europe is based on the Blast Furnace-Basic Oxygen Furnace route (BF-BOF) and the Electric Arc Furnace route. Blast furnaces produce iron from iron ore. In a second step a basic oxygen converter turns iron, with some additions of scrap, into steel. Electric arc furnaces produce steel mostly from scrap collected from recycling.

The production of crude steel via the BF-BOF route in the EU in 2019 was 92 million tons (58.6%) and 65 million tons (41.4%) were produced via EAF route (Eurofer, 2020). The majority of ferrous scrap is recycled in EAF. The EAF is the only steel production process applied within Switzerland (Kägi & Hellweg, 2018).

Worldwide crude steel production in 1950 was 189 million tons, 850 million tons in 2000 and 1'808 million tons in 2018. The crude steel production has seen a continuous increase since the beginning of the 50ies and has increased by 9 times since then (World Steel Association, 2019).

3 Characterization of the materials

This part is mainly based on Classen et al. (2009) and Remus (2013).

3.1 Iron ore

Iron ore is mainly mined in China, India, Brazil and Australia (World Steel Association, 2019). Iron ore is a mixture of different minerals and contains different iron oxides. Therefore, the iron content of the iron ore varies. In the DETEC data base (and in ecoinvent) an average iron content of 46% is used. At the mine, iron ore is being enriched and reaches an iron content of 65% in world average. About 13% of the enriched ore are big lumps that can be fed directly to the BF. The rest is fine grade ore, which is agglomerated to sinter and pellets and then fed to the BF (see Figure 1) (Classen et al., 2009).

Use and application of iron ore

Iron ore is mostly mined and then used directly for iron and steel production or agglomerated to sinter and pellets for iron and steel production (Classen et al., 2009).

3.2 Sinter and pellets

The burden that is fed to the BF contains lump ore, sinter and pellets. The main difference between sinter and pellets is the type of raw materials used for their production and their agglomeration process (Mourão et al., 2020).

Sinter is produced from a pre-designed mixture containing fine iron ore, coke breeze and residues from various recycled iron bearing materials from downstream iron and steel making processes (e.g. dust from blast furnace gas cleaning). When the fuel in the sinter mix is fired, it generates high temperatures and the fine particles fuse together and form a porous clinker material. Sinter clinker is then crushed and sized after cooling to room temperature. Sintering plants are usually located at the ironworks, since sinter is not stable enough to be transported over long distances.

Pellets are produced from fine ore (< 0.1 mm) or concentrate, usually at the mine and are then transported in this form to ironworks. The mixture of fine iron ore and finely ground fluxes is added to a rotating drum or disc. Through the right combination of moisture and temperature and through the addition of a binder such as bentonite, small green balls are formed (9-16 mm). The green balls are fired in an induration furnace. The high temperatures harden the green pellets and turn them into fired pellets. Due to their physical resistance, compared to sinter, pellets can be transported long distances and are therefore usually produced at the mine and later transported to the ironworks (Mourão et al., 2020).

Use and application of sinter and pellets

Sinter and pellets are used for iron and steel production in blast furnaces.

3.3 Pig iron / Hot metal

Pig iron is iron produced from the BF. Liquid pig iron is often referred to as hot metal. Pig iron contains 94% iron and a minimum of 2% carbon (Classen et al., 2009). The production of pig iron in the BF is still by far the most commonly process for the production of hot metal. This technique is likely also to dominate hot metal (HM) production in the medium term (Remus, 2013).

Use and application of pig iron / hot metal:

Most of the pig iron / hot metal from BF is used for steel production before it solidifies. A smaller part is cast into ingots, which are later used for the production of cast iron.

3.4 Cast iron

Cast iron is carbon casting material with a carbon content of more than 2%. Iron alloys with lower carbon content are known as steel. Chemically, the carbon is not bound to the iron, but is present in elementary form. Cast iron can have different properties depending on added elements such as nickel, chromium, manganese, copper and silicon, which change the metallic structure and therefore the irons properties (Classen et al., 2009).

Use and application of cast iron

Applications of cast iron include mechanical engineering, the building industry (e.g., radiators, boilers, sanitary ware and pipes), chemical plant, ship-building, and mining gear, machine parts etc. (Classen et al., 2009).

3.5 Steel

Steels are iron alloys with a carbon content of less than 2%. Steel is produced via different routes with different iron bearing materials as inputs. Hot metal from BF is used for the production of steel by BOF. Steel that is produced via the BF-BOF route is classified as converter steel. Scrap and pig iron (from BF) are used for melting steel in EAF. Steel produced in the EAF is classified as electric steel (Classen et al., 2009).

The yearly world steel production in 2019 was 1'870 million tonnes. The share of the worldwide steel production in Europe was 16% (298 million tonnes) in 2019. The number one steel producer in 2019 was China with a worldwide share of 53.3% (Eurofer, 2020).

3.5.1 Unalloyed steel

In accordance with DIN 10 020, the proportion of alloying elements in unalloyed steels must be below specific limits given in

Table 1. Unalloyed steel is primarily defined as having a carbon content of between 0.40 – 1.40 %. Heat treatment of unalloyed steel results in high surface hardness, high wear resistance and good cutting ability, characterized by a tough core (pure, surface-hardening steel (National Material, 2020).

Table 1: Limiting concentration of elements in unalloyed steel according to EN 10 020 from Classen et al. (2009)

Element	Al	B	Bi	Co	Cr[1]	Cu[1]	La	Mn	Mo[1]	Nb[2]
Max. concentration	0.10	0.0008	0.10	0.10	0.30	0.40	0.05	1.65[3]	0.08	0.06
Element	Ni[1]	Pb	Se	Sl	Te	Ti[2]	V[2]	W	Zr[2]	Others[4]
Max. concentration	0.30	0.40	0.10	0.50	0.10	0.05	0.10	0.10	0.05	0.05

[1] If two, three or four of these elements are present in concentrations less than the maximum permitted, their total concentration must not exceed 70% of the sum of the maximum

[2] The same rule applies to these elements

[3] If the manganese content is quoted as minimum, this value applies

[4] Except C, N, O and S

Use and application of unalloyed steel

Unalloyed steel is primarily used in the building industry as reinforcing steel. Nevertheless, unalloyed steels are also used in many other applications in the industry. They are well suited for easy-to-use tools that are subject to low stress. Unalloyed tool steels can be subjected to working temperatures of up to 200 degrees Celsius (National Material, 2020).

3.5.2 Alloyed steel

Alloyed steel contains at least one alloying element with a content above the specific limits in accordance with DIN 10 020 shown in

Table 1. There are thousands of different types of alloys, which are responsible for the characteristics of the steel and its application (National Material, 2020). A steel is called low-alloyed if it contains more than the minimum given in

Table 1 of at least one of the elements but the share of alloying elements in total is less than 5% (Classen et al., 2009).

Use and application of alloyed steel

Alloyed steels are the most widely used steels. They are produced to make machine parts, dies and tools. These alloy steels are made of iron, carbon and other elements such as vanadium, silicon, nickel, manganese, copper and chromium (Classen et al., 2009).

3.5.3 Stainless steel

Stainless steel is the standard name for steel that is resistant to corrosion. Chromium is the key element in all stainless steels and is present in all stainless steels with a minimum share of 15 %. Of all stainless steels, the 304 steel (18/8 stainless, 18% chromium and 8% nickel) is most commonly used (Remus, 2013).

Use and application of stainless steel

Stainless steel is often used in the food and chemical industry due to its resistance to corrosion but it is also used in many other applications (Classen et al., 2009).

4 Process overview

The process chain of the ferrous metal end-products was analysed to identify the hotspots of environmental impact. A rough overview of the process flow of reinforcing steel as the end-product and steel production processes are given in Figure 1.

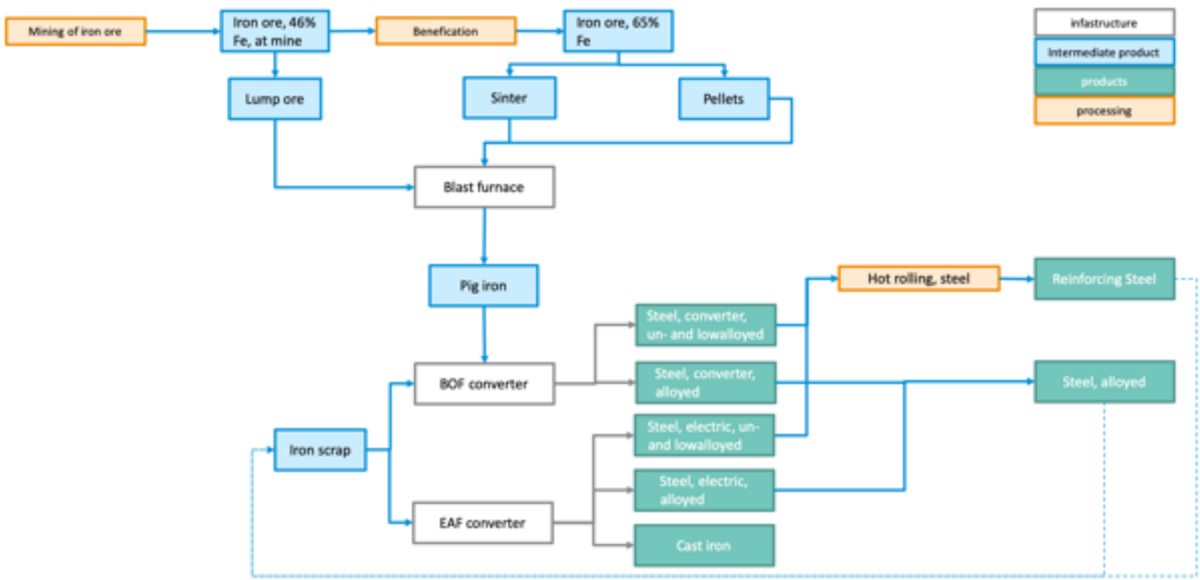

Figure 1: Ferrous metals: Process flow (adapted from Classen (2009))

4.1 Steel production in Switzerland

The electric arc furnace (EAF) route is the only steel production process that is applied within Switzerland. Therefore, only recycling steel is produced. As part of this project, EAF steel production processes as well as relevant steel disposal processes have been updated for the geographical region of Switzerland.

There are two EAF plants in operation in Switzerland. The plant of Swiss Steel AG is located in Emmen and produces steel for the mechancial and electrical engineering industries. The plant of Stahl Gerlafingen AG in Gerlafingen produces steel for the construction industry. Both EAFs are operated with iron scrap collected within Switzerland (66%) and imported from Europe (33%), mainly Germany, France, Italy and Austria (oral expert statement, personal communication).

New inventory data for Swiss electric steel was obtained from both plants in Switzerland, enabling the creation of five new processes: unalloyed electric steel, low-alloyed electric steel and three processes for electric steel with specific alloys. Also, whereas in the past the EAF slag was landfilled, today it increasingly replaces gravel in road construction work. This reuse of by-products was considered when creating theses processes and an economical allocation of the slag was conducted.

The data used for this update of the electric steel processes was collected from the respective plants. All data is provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation.
For each investigated process, two types of tables (X-Process and X-Exchange) are provided in this report. Metadata are presented in an X-process table and and raw process data are presented in X-Echange tables.

4.2 Steel production in Europe

In Europe, steel is produced in both EAF (41.4%) and in BF-BOF (58.6%) (Eurofer, 2020). New data was published by the European Commission in 2013 with the Best Available Techniques (BAT) for Iron and Steel Production (Remus, 2013). This publication served as basis for the update of the following processes: the production of sinter and pellets, the production of pig iron, converter steel, blast furnace gas and basic oxygen gas (burned in power plant), electric steel and reinforcing steel.
This BAT reference document for the iron and steel production forms part of a series presenting the results of an exchange of information between EU Member States, the steel industries, non-governmental organisations promoting environmental protection and the Commission, to draw up, review, and where necessary, update BAT reference documents as required by Article 13(1) of the Directive (Directive 2010/75/EU of the European Parliament and the Council on industrial emissions (integrated pollution prevention and control). The document was published by the European Commission in 2013.

The information in the BAT reference document has been collated and assessed by the European IPCC Bureau (of the Commission's Joint Research Centre) who led the work on determining BAT, guided by the principles of technical expertise, transparency and neutrality (Remus, 2013). The roprt is the result of collected data from various steel production plants in the EU showing partially a very high range of variation.
For most processes the data is reported as minimum/best values and maximum/worst values, and for some processes, an average value of inputs and outputs of the respective process is given. The wide ranges of the presented values may be explained by different inputs (esp. the energy mix), variations in emission limit values and environmental protection equipment, different plant characteristics and plant productivity.

In this update of the iron and steel processes for the DETEC database the arithmetic mean of the minimum and the maximum value was used. Only for the update of the production of European electric steels, three inventories have been created presenting best values (minimum values), mean values (arithmetic mean) and worst values (maximum values).
All data is provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation.

For each investigated process, two types of tables (X-Process and X-Exchange) are provided in this report. Metadata are presented in an X-process table and and raw process data are presented in X-Echange tables.

4.3 Allocation of by-products

In addition to iron and steel products, by-products such as slags and gases are also produced during steel production. Some of these by-products are reused, others are landfilled and gases can be returned to the process itself as an energy input.

If there is a market for a by-product, in this case usually slags, the by-products is economically allocated.

The allocation factor, results from the current market value and mass share of the by-product. Specific allocation factors for allocated by-products are stated in the respective chapters. In the specific case of economic allocation of slags, the average price for blast furnace slag was assumed in interest of simplification also for EAF slag.

5 Ferrous metal processes

5.1 Iron ore

The two processes available in the DETEC database “Iron ore 46% Fe, at mine/GLO U” and “Iron ore 65% Fe, at beneficiation/GLO U” have not been updated.

5.2 Sinter

This part is mainly based on Remus (2013).

5.2.1 Production process and infrastructure

Blast furnaces achieve their best performance through prior physical and metallurgical preparation of the burden. This preparation includes agglomeration of the furnace charge by either sintering or pelletizing (see chapter 3.2), which improves the permeability and reducibility for further processes. The burden of a sintering process consists of a mixture of fine ores, additives (e.g., lime, olivine, collected dust and mill scale, dust from gas cleaning in blast furnaces as well as recycle material from the ironworks (particles in the range of <5 mm) (Remus, 2013).

To ensure a good mixing, the raw materials are usually layered on prepared beds in exact quantities required for the sintering process. At the beginning of the sintering process, the mixture is transported from the beds to the storage bunkers to the beginning of the sintering plant. Coke is the dominant sinter plant energy input (about 85%), with electricity and gas (COG and/or blast furnace gas and/or natural gas) supplying the remainder in equal shares. This is added to the batch to allow ignition of the entire batch. All materials are blended completely and moistened to promote the formation of micro-pellets, which improve the permeability of the sinter bed (Classen et al., 2009).

At the start of the grate, the coke breeze in the mixture is being fired by a canopy of gas burners. As the sinter mixture moves along the grate, the combustion front is drawn down and through the mixture. This process generates temperature of 1300 - 1480 °C and the fine particles fuse together to form sinter. A series of chemical and metallurgical reactions take place during the sintering process. These produces both the sinter itself, dust and gas emissions. Emissions are reduced by extracting the dust and by cleaning the collected gas that is produced (Remus, 2013). At the end of the strand, the sinter clinker falls onto a crash deck, where it is broken with the help of a crusher. In many plants, the broken pieces of sinter then pass through a hot sieving process in which fines of less than 5 mm are separated and returned to the feed material. The sinter is cooled by air. The heat in the exhaust gas of the sinter cooling system (which can have a temperature of up to 300 °C) can be used in a waste heat boiler by recirculating the hot gases to preheat the combustion air in the firing canopy and to preheat the sinter raw mixture or for the sintering process. Cooled sinter then passes screens, which separate the pieces to be used in the blast furnace (4 - 50 mm) from the pieces which are returned to the sintering process (0 - 5 mm) as return fines (Remus, 2013).

5.2.2 Emissions, wastes and by-products

Emissions to air

Gaseous emissions from the sinter plant contribute significantly to the overall air emissions of an integrated steel plant. Off-gas from sinter plants contains particulates and heavy metals, mainly iron compounds but also lead compounds, alkali chlorides, sulphur oxides (SO_x), nitrogen oxides (NO_x), hydrogen chloride (HCl), hydrogen fluoride (HF), hydrocarbons (C_nH_{2n+2}), carbon monoxide (CO) and also significant trace amounts of PAHs and PCDD/F and PCBs from the burning of the fuel gas and some of the coke. These processes are also a major source of dioxins. Heavy metal emissions from sinter plants can be of high significance, especially for lead.

During sintering, dust emissions (secondary emissions) from the handling, crushing, screening and conveying of sinter feedstock and products occur. The abatement used in sinter plants is more efficient in removing larger particles, while the smaller alkali and lead chlorides are difficult to remove in electrostatic precipitators (ESP) due to their high specific resistance. ESP remove dust and fine particles from a flowing gas using the force of an induced electrostatic charge. Thus, a particle size of < 2.5 µm is assumed for the dust emission after abatement. Many of the sinter plants in Europe are operated using closed-filter dust cycles. This means that all precipitated filter dust from the ESP is recycled to the strand (Remus, 2013).

Emissions to water

Waste water from waste gas treatment is only generated if a wet abatement system is applied. The water flow contains suspended solids (including heavy metals), persistent organic pollutant compounds such as PCDD/F and PCB, PAH, sulphur compounds, fluorides and chlorides. Wastewater is usually treated before discharge (Remus, 2013).

Waste and by-products

Usually, all solid wastes that are generated during sintering process are recycled back to the strand. Nevertheless, during sintering process also sludge and dust are produced. The sludge produced by wet waste gas treatment systems s usually deposited on landfills.
Most European sinter plants are operated with fully closed dust cycles. However, as mentioned above, some plants exclude fine dust from the last field of the ESP. This dust mainly consists of alkali and metal chlorides. This partly open filter dust cycle is carried out in order to improve the operation of the ESP or to reduce alkali and metal chloride emissions (Classen et al., 2009; Remus, 2013).

5.2.3 Sinter, iron, at plant/RER in DETEC

Metadata is presented in an X-process table (see Table 2) and raw process data are presented in X-Echange table (see Table 3).

Where Remus (2013) is given as the source, the arithmetic mean of the low and high value is used in this project. No data on the infrastructure was available. Thus, the aluminum oxide plant (calcination plant) was chosen to represent the sinter plant. Existing transportation distances and transportation means were used based on UVEK:2018. Dust emissions correspond to overall emissions from mixing and blending, main stack emissions, secondary dedusting and sinter cooling after abatement. Waste water is assumed to be treated in a class 3 waste water treatment plant.

Data basis

The publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production has gathered data that show a significant number of sinter plants in the former Europe-25 representing the production of 91.13 million tonnes of sinter production in 2004. Other input data which include water input and the input of compressed air were collected from five sinter plants in four European countries representing 52.6 million tonnes of sinter production in 1999.

Table 2: Metadata of European sinter production

Name	sinter, iron, at plant
Location	RER
InfrastructureProcess	0
Unit	kg
IncludedProcesses	Included processes: Blending, mixing and sintering. Dust emissions are abated
Amount	1
LocalName	Sinter, Eisen, ab Werk
Synonyms	In UVEK2018 enthalten
GeneralComment	The data was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production and represent the arithmetic mean of lowest and highest values (Remus, 2013). Specific input factors and specific emissions factors have been determined for sinter plants. These data show a significant number of sinter plants in Europe representing 91.13 million tonnes of sinter production in 2004. Other input data, which include water input and the input of compressed air, were collected from five sinter plants in Europe representing 52.6 million tonnes of sinter production in 1999. Remark: Air emissions are average values and relate to European plants after abatement for sinter production in the EU-25 in 2004.
InfrastructureIncluded	1
Category	metals
SubCategory	extraction
LocalCategory	Metalle
LocalSubCategory	Gewinnung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Europe
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 3: Unit process raw data of 1 kg sinter production in Europe

	Name	Location	Infrastructure Process	Unit	sinter, iron, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER			
	Infrastructure Process				0			
	Unit				kg			
product	sinter, iron, at plant	RER	0	kg	1	0		
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	1.80E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); Water for cooling;
technosphere	iron ore, 65% Fe, at beneficiation	GLO	0	kg	8.13E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	sinter, iron, at plant	RER	0	kg	2.51E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); internal return fines, Undersized sinter product collected within the sinter process; Remus (2013)
	dolomite, at plant	RER	0	kg	1.31E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); Limestone / Dolomite; Remus (2013)
	sinter, iron, at plant	RER	0	kg	6.30E-2	1	1.13	(2,2,3,1,1,nA,BU:1.05); BF returned fines, Undersized sinter screened out prior to charging to the blast furnace; Remus (2013)
	pellets, iron, at plant	RER	0	kg	5.18E-2	1	1.13	(2,2,3,1,1,nA,BU:1.05); returned materials, Materials from different I&S production activities including recovered fluxes; Remus (2013)
	pellets, iron, at plant	RER	0	kg	3.10E-2	1	1.13	(2,2,3,1,1,nA,BU:1.05); Includes pellets and direct charge lump ores creenings, undersized sinter from other strands, etc.); Remus (2013)
	quicklime, in pieces, loose, at plant	CH	0	kg	1.02E-2	1	1.13	(2,2,3,1,1,nA,BU:1.05); lime; Remus (2013)
	hard coal coke, at plant	RER	0	MJ	1.28E+0	1	1.13	(2,2,3,1,1,nA,BU:1.05); Solid fuel, E.g.coke breeze, anthracite, excluding the energy contribution by BF gas dus; Remus (2013)
	blast furnace gas, burned in power plant	RER	0	MJ	6.70E-2	1	1.13	(2,2,3,1,1,nA,BU:1.05); COG/ BF gas/natural gas; Remus (2013)
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	1.24E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); Total electricity; Remus (2013)
	transport, freight, lorry, fleet average	RER	0	tkm	2.00E-3	1	2.02	(2,2,3,1,1,nA,BU:2); based on UVEK:2018;
	transport, barge	RER	0	tkm	3.15E-2	1	2.02	(2,2,3,1,1,nA,BU:2); based on UVEK:2018;
	transport, freight, rail	RER	0	tkm	3.09E-1	1	2.02	(2,2,3,1,1,nA,BU:2); based on UVEK:2018;
	transport, transoceanic freight ship	OCE	0	tkm	2.84E+0	1	2.02	(2,2,3,1,1,nA,BU:2); based on UVEK:2018;
	aluminium oxide, plant	RER	1	unit	2.50E-11	1	3.02	(2,2,3,1,1,nA,BU:3); based on UVEK:2018; as proxy
	compressed air, average installation, <30kW, 8 bar gauge, at supply network	RER	0	m3	2.10E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); compressed air; Remus (2013)
emission air, unspecified	Cadmium	-	-	kg	1.38E-7	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Carbon dioxide, fossil	-	-	kg	2.65E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	Carbon monoxide, fossil	-	-	kg	2.29E-2	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Chromium VI	-	-	kg	6.43E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Copper	-	-	kg	3.01E-7	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	8.08E-12	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Hydrogen chloride	-	-	kg	4.25E-4	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Hydrogen fluoride	-	-	kg	4.30E-6	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Lead	-	-	kg	2.84E-6	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Manganese	-	-	kg	2.71E-7	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Mercury	-	-	kg	1.04E-7	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Nickel	-	-	kg	8.85E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Nitrogen oxides	-	-	kg	6.67E-4	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	2.96E-7	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Polychlorinated biphenyls	-	-	kg	1.01E-13	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Sulfur dioxide	-	-	kg	5.97E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	Vanadium	-	-	kg	7.96E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Zinc	-	-	kg	9.67E-7	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Particulates, < 2.5 um	-	-	kg	2.08E-4	1	3.02	(2,2,3,1,1,nA,BU:3); dust, main stack emissions +blending and mixing + secondary dedusting + sinter cooling after abatement (< 2.5um); Remus (2013)
	Particulates, > 2.5 um, and < 10um	-	-	kg	1.72E-4	1	2.02	(2,2,3,1,1,nA,BU:2); PM10, main stack emissions +blending and mixing + secondary dedusting + sinter cooling; Remus (2013)
	Arsenic	-	-	kg	7.80E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Selenium	-	-	kg	7.12E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Methane, fossil	-	-	kg	2.24E-4	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	1.31E-4	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Benzo(a)pyrene	-	-	kg	2.08E-8	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
emission water, unspecified	Water	-	-	kg	3.15E-3	1	1.52	(2,2,3,1,1,nA,BU:1.5); waste water; Remus (2013)
technosphere	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.91E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); BF gas dust, coarse dust from the blast furnace gas treatment; Remus (2013)
	disposal, sludge, pig iron production, 8.6% water, to residual material landfill	CH	0	kg	2.48E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); Sludge; Remus (2013)
	treatment, pig iron production effluent, to wastewater treatment, class 3	CH	0	m3	4.50E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); wastewater; Remus (2013)

5.3 Pellets

This part is mainly based on (Remus (2013)).

5.3.1 Production process and infrastructure

As mentioned in Chapter 3.2, the pelletization and sintering of iron ore are complementary process routes for the preparation of iron oxide for primary iron and steel making. Pellets are small spheres and are formed from the raw material's fine ore and additives of <0.05 mm into 9 – 16 mm spheres using very high temperatures. Pelletization plants are principally located at iron mines or at shipping ports but can also be located onsite as part of an integrated ironwork (EEA, 2019; Remus, 2013).

Pelletization consists out of various process steps: grinding and drying or dewatering, wetting and mixing, balling and induration followed by screening and handling. At first the raw materials are blended and grinded, typically, limestone, dolomite and olivine are added and bentonite is used as a binder. These processes are carried out wet. This moist raw mixture is then processed in the (green) ball preparation plant. Undersized and oversized fractions are screened off and recirculated within the balling stage in order to obtain a well-defined green ball size, typically in the range of 9 to 16 mm. The green balls are then subjected to a thermal process for induration, which includes drying, heating and cooling. The duration of each stage and the temperature that the pellets are subjected to have a strong influence on the final product quality. At the end of the induration strand the pellets are collected and screened. Undersized or broken pellets can be recycled. Significant dust emissions may occur during this process (Remus, 2013).

5.3.2 Emissions, wastes and by-products

Emissions to air

Pelletization process is primarily a source of particulates and gaseous emissions. Dust emissions occur during grinding and consist mainly of iron. These emissions can be abated by means of electrostatic precipitation (ESP). Dust emissions also occur during screening and handling process. These emissions are mainly abated by wetting the green balls. The third emission source is the firing zone of the induration strand, here emissions are abated by ESPs, bag filters or scrubbing.
Gaseous emissions occur during combustion and thermal process of induration. Main gaseous emissions are CO_2, NO_x, SO_2, HCl and HF, PCDD/F (Remus, 2013).

Emissions to water

Waste water is discharged from the wet rinsing of the plant and equipment. In some plants, waste water is recycled to 100%, in other plants the waste water is treated in waste water plants (Remus, 2013).

Waste and by-products

Sorting and beneficiation of the raw materials before pelletization are the primary sources of waste. During pelletization, whenever dust emissions are abated, solid waste is produced, which end up as sludge in the waste water treatment plant.

5.3.3 Pellets, iron, at plant/RER in DETEC

Metadata is presented in an X-process table (see Table 4) and and raw process data are presented in X-Echange table (see Table 5).

Where Remus (2013) is given as the source, the arithmetic mean of the low and high value is used in this project. No data on the infrastructure are available. Thus, the aluminium oxide plant (calcination plant) was chosen to represent the sinter plant. Existing transportation distances and transportation means were used based on UVEK:2018. The data correspond to a pelletisation plant that is part of an integrated steelwork (not a standalone). No data was found on genereated amounts of wastes, such as waste water and sludge from abated dust emissions.

Data basis

The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production. Data are from 2004 and relate to three pellet plant sites that produced almost 13 million tons of pellets in 2004 among them, representing around 63 % of the production in the EU-25 (Remus, 2013).

Table 4: Metadata of European pellets production

Name	pellets, iron, at plant
Location	RER
InfrastructureProcess	0
Unit	kg
IncludedProcesses	Included processes: Blending, mixing and sintering. Emissions are abated
Amount	1
LocalName	Pellets, Eisen, ab Werk
Synonyms	In UVEK2018 enthalten
GeneralComment	The data was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production and represent the arithmetic mean of lowest and highest values (Remus, 2013). Specific input factors and specific emissions factors have been determined for pelletization plants. Remark: Input/output data from three pellet plant sites in the EU-25. No transport of iron ore because pellets are fabricated at mine; Geography: Inputs relate to three pellent plant sites in EU-25. Emissions relate to European plants.
InfrastructureIncluded	1
Category	metals
SubCategory	extraction
LocalCategory	Metalle
LocalSubCategory	Gewinnung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Europe
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 5: Unit process raw data of 1 kg pellet production in Europe

	Name	Location	Infrastructure Process	Unit	pellets, iron, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER			
	Infrastructure Process				0			
	Unit				kg			
product	pellets, iron, at plant	RER	0	kg	1	0		
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	6.80E-04	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; Remus (2013)
technosphere	iron ore, 65% Fe, at beneficiation	GLO	0	kg	9.50E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	bentonite, at processing	DE	0	kg	5.45E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	limestone, crushed, for mill	CH	0	kg	2.50E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); Limestone not from CH; Remus (2013)
	dolomite, at plant	RER	0	kg	1.38E-2	1	1.13	(2,2,3,1,1,nA,BU:1.05); dolomite instead of olivine; Remus (2013)
	aluminium oxide, plant	RER	1	unit	2.50E-11	1	3.00	(2,2,1,1,1,nA,BU:3); as proxy;
	basic oxygen furnace gas, burned in power plant	RER	0	MJ	3.06E-1	1	1.07	(2,2,1,1,1,nA,BU:1.05); Coke oven gas or BOF gas; Remus (2013)
	natural gas, high pressure, at consumer	RER	0	MJ	1.40E-2	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
	hard coal coke, at plant	RER	0	MJ	3.42E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); (coke breeze); Remus (2013)
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	2.41E-2	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; Remus (2013)
	transport, freight, rail	RER	0	tkm	4.01E-3	1	2.00	(2,2,1,1,1,nA,BU:2); based on UVEK:2016;
	transport, freight, lorry, fleet average	RER	0	tkm	9.50E-3	1	2.00	(2,2,1,1,1,nA,BU:2); based on UVEK:2016;
	compressed air, average installation, <30kW, 8 bar gauge, at supply network	RER	0	m3	2.13E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
emission air, unspecified	Particulates, < 2.5 um	-	-	kg	8.20E-5	1	3.02	(2,2,3,1,1,nA,BU:3); dust after abatement (< 2.5 um); Remus (2013)
	Cadmium	-	-	kg	1.11E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Chromium	-	-	kg	1.38E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Copper	-	-	kg	4.10E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Mercury	-	-	kg	1.23E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Manganese	-	-	kg	3.47E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Nickel	-	-	kg	9.60E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Lead	-	-	kg	4.32E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Vanadium	-	-	kg	1.43E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Thallium	-	-	kg	1.80E-10	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Zinc	-	-	kg	6.52E-7	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Hydrogen fluoride	-	-	kg	3.80E-6	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Hydrogen chloride	-	-	kg	2.17E-5	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Sulfur dioxide	-	-	kg	1.12E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	Nitrogen oxides	-	-	kg	3.50E-4	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Carbon monoxide, fossil	-	-	kg	2.10E-4	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Carbon dioxide, fossil	-	-	kg	1.05E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	2.25E-5	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	9.00E-10	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	1.02E-13	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)

5.4 Pig iron and blast furnace gas

This part is mainly based on Remus (2013).

5.4.1 Production process and infrastructure

The BF is a closed system and the main operational unit in the steel making process. Most of the iron ore is reduced to iron in BFs. The hot blast in the BF comes from the hot stove, which is an auxiliary installation to heat the blast (see Figure 2). The hot blast provides the oxygen that is needed for the gasification of the coke (carbon source). In the reduction process, carbon binds with the oxygen and forms CO_2. Carbon serves a dual purpose in the iron making process, primarily as a reducing agent to convert iron oxides to iron but also as an energy source to provide heat when carbon and oxygen react exothermically. The main carbon sources and reducing agents are coke and coal forming CO and hydrogen, which reduce the iron oxides (EEA, 2019).

The blast furnace is loaded from the top with alternating coke layers with pellets, sinter and lump ore as well as additives (slag formers such as limestone). The furnace is loaded through a charging system that prevents escape of blast furnace gas (BFG). Figure 2 shows a simplified scheme of a blast furnace consisting of the furnace itself, the cast house, the hot stoves and two-stage treatment of BFG.

In the BF pig iron and slag are produced and collected at the bottom of the furnace. Hot metal from the BF is about 1,500 degrees Celsius hot when it leaves the furnace. The slag is granulated and is usually sold to cement manufacturing companies or used in road construction. Pig iron from the BF is then transported to a basic oxygen furnace, where the carbon content (approximately 4 %) is lowered to less than 1 %, and therefore resulting in steel (Remus, 2013).

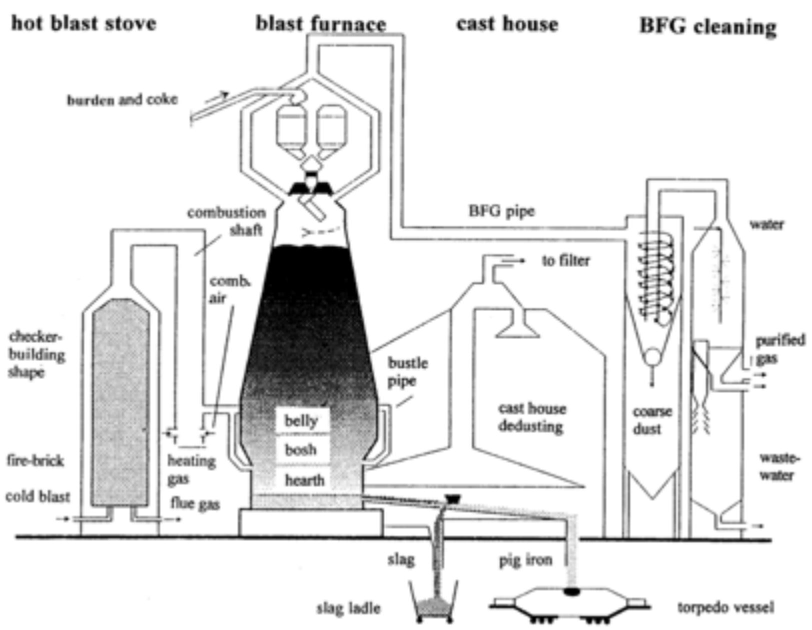

Figure 2: Simplified scheme of a blast furnace (IPPC, 2001)

5.4.2 Emissions, wastes and by-products

Emissions to air

The BF is primarily a source of dust and gaseous emissions into air. During preparation and loading of the burden, relevant emissions can occur. Therefore, dust-containing air is usually captured and dry-dedusted.
When the BF is being charged all components present in the BFG can be emitted at this point. Here, emissions of CO and dust are the most relevant emissions. With the use of a gas recovery system, emissions from charging and conveying are much lower. To reduce air pollution the air is extracted and treated in ESPs or bag filters before it is released into the atmosphere.

BFG contains dust, CO, CO_2, NO_x, SO_x and heavy metals, cyanide compounds, hydrocarbons and PAH. BFG is purified and is reused as an energy source for various firing processes in the hot stoves or the coke oven firing. BFG is usually treated in two steps; first the separation of coarse dust and second the separation of fine dust in a wet ESP or a scrubber where sludge is produced. During this two-stage treatment of BFG, dust is removed with high efficiency rate as are compounds associated with dust such as most heavy metals and PAH. However, indirect emissions from BF combustion occur (Remus, 2013).

In Remus (2013) no CO2 emissions are given. To estimate CO2 emissions from the blast furnace, all the carbon in the coke and the coal brought in the blast furnace is supposed to be converted to CO2 and are considered as process emissions. Therefore, CO2 emissions were calculated as shown in Table 6.

Table 6: Calculation of CO2 emissions from the blast furnace

	Flow	amount input/output kg/kg pig iron	kg CO2-eq / kg pig iron
input (tuyére injection)	coke	0.359	1.01238
	oil	0.0301	0.09331
	coal	0.162	0.51516
	COG	0.0011	0.00253
	natural gas	0.1702	0.01445
to stoves (hot blast production)	BF gas	1.536	0.78571
	COG	0.284	0.02139
	BOF gas	0.213	0.11864
output	CO	0.5	0.786
	CO2	0.65	0.65
	pig iron	1	
	Total CO2 emissions from Input tuyère injection minus CO2 emissions from CO burning		0.85212

The calculated value (0.85212 kg CO2) shown in Table 6 is used in the new inventory.

Emissions to water

Waste water from BFG scrubbing is usually treated and recycled to the scrubber. Waste water is also generated from slag granulation. The slag contains metals and suspended solids, as well as chloride (Remus, 2013).

Waste and by-products

During the production of pig iron, several waste streams are generated. Emissions from casting are generated as a consequence of oxidation. It is common practice to separate this dust in a bag filter so that it can easily be recycled (e.g. sinter strand or back to the BF). To reduce the pollution to the atmosphere from this minor oxidation of the hot metal, the runners are covered and a suction is applied at both the tap hole and the torpedo filling station.

Blast furnace gas and blast furnace slag are produced as a by-products. More than 94 % of the blast furnace slag produced is reused, among other things as granulated blast furnace slag in cement production (Fachstelle Nachhaltiges Bauen, 2016). Small parts of the overall quantity of residues from an integrated steelworks have no economic use and some disposal is inevitable (Remus, 2013). Gas scrubber sludge generated in pig iron production contains heavy metals, especially zinc and lead. Disposal in a residual material landfill type with cement solidification is assumed.
Blast furnace gas is usually reused after purification as an energy source in the BF process.

The wastewater generated in pig iron production contains some heavy metals and some carbon.

5.4.3 Pig iron, at plant/RER in DETEC

Metadata is presented in an X-process table (see Table 7) and raw process data are presented in X-Echange table (see Table 8).

Where Remus (2013) is given as the source, the arithmetic mean of the lowest and highest value are used in this project. Existing transportation distances and transportation means were used based on UVEK:2018.
Several different waste streams are generated. Some of them are recycled or used for different purposes, such as blast furnace slag others are deposited in landfills. Blast furnace slag is inventoried as a by-product. Treatment of waste water is assumed to be done in a class 3 waste water treatment plant.

Data basis

The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production (Remus, 2013). The Inputs and outputs correspond to data for 2004, based on the production of 73.4 Mt HM in Europe. The data represent emissions to air as particulates <2.5 µm from BF cast house, which refer to discharge from the abatement equipment. Particulates (PM_{10} and dust) are released into the air during coal preparation for injection, from the charging zone and from casting (Remus, 2013). These emissions are inventoried as particulates <2.5 and >10 µm.

Allocation of by-products

According to Remus (2013) a total amount of 0.248 kg of blast furnace slag is produced per kg of pig iron extracted. 94% of the slag that is produced from pig iron production in the BF is reused (Fachstelle Nachhaltiges Bauen, 2016) and 6% of the slag is landfilled.
The slag produced as a by-product was allocated economically. For economic allocation, as proposed by the authors of the report (Fachstelle Nachhaltiges Bauen, 2016), an average price for blast furnace slag of 27 EUR/t was determined and an average price for pig iron of 420 EUR/t (Meps, 2021). This results in an allocation factor for blast furnace slag of 0.015, the remaining inputs and emissions are allocated to pig iron with the factor of 0.985.
Blast furnace gas was allocated physically, since it is reused in the BF process. The process is described in the following chapter 0.

Table 7: Metadata of the production of pig iron in Europe

Name	pig iron, at plant	blast furnace slag, at plant
Location	RER	RER
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Blast furnace process. Emissions are abated	
Amount	1	1
LocalName	Roheisen, ab Werk	Hochofenschlacke, ab Werk
Synonyms	In UVEK2018 enthalten	In UVEK2018 enthalten
GeneralComment	The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production and represent the arithmetic mean of lowest and highest values (Remus, 2013). The Inputs and outputs correspond to data for 2004, based on the production of 73.4 Mt HM in Europe. The data represent emissions to air as particulates <2.5 µm from BF cast house, which refer to discharge from the abatement equipment. Particulates (PM_{10} and dust) are released into the air during coal preparation for injection, from the charging zone and from casting (Remus, 2013). These emissions are inventoried as particulates <2.5 and >10 µm. Economically allocated with factor 0.985. assumption: 94% of slag is reused, 6% is landfilled.	BF slag is produced as a by-product. According to Remus (2013) Total amount of produced slag is 0.248 kg/kg pig iron. Slag is economically allocated with factor 0.015, assumption: 94% of slag is reused, 6% is landfilled.
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	extraction	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula		
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Data apply to the production in Europe	Data apply to the production in Europe
Technolgy	Industry data.	Industry data.
Representativeness		
ProductionVolume		
SamplingProcedure	Data from literature	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 8: Unit process data for the production of 1kg pig iron from the blast furnace

	Name	Location	Infrastructure Process	Unit	pig iron, at plant	blast furnace slag, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER	RER			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	pig iron, at plant	RER	0	kg	1.00E+00	0.00E+00	0		
product	blast furnace slag, at plant	RER	0	kg	0.00E+00	1.00E+00	0		
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	1.15E-02	1.72E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
technosphere	blast furnace	RER	1	unit	1.31E-11	1.97E-13	1	3.02	(2,2,3,1,1,nA,BU:3); based on UVEK:2018;
	sinter, iron, at plant	RER	0	kg	1.07E+00	1.61E-02	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	iron ore, 65% Fe, at beneficiation	GLO	0	kg	1.77E-01	2.66E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	pellets, iron, at plant	RER	0	kg	3.53E-01	5.29E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	hard coal coke, at plant	RER	0	MJ	3.54E-01	5.30E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	pig iron, at plant	RER	0	kg	1.98E-02	2.97E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); returned materials; Remus (2013)
	limestone, at mine	CH	0	kg	2.53E-02	3.79E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	light fuel oil, at regional storage	RER	0	kg	2.97E-02	4.44E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	hard coal mix, at regional storage	UCTE	0	kg	1.60E-01	2.39E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	coke oven gas, at plant	GLO	0	MJ	2.11E-02	3.17E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	natural gas, high pressure, at consumer	RER	0	MJ	8.02E-02	1.20E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	oxygen, liquid, at plant	RER	0	kg	5.36E-02	8.03E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	basic oxygen furnace gas, burned in power plant	RER	0	MJ	2.10E-01	3.14E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	blast furnace gas, burned in power plant	RER	0	MJ	1.51E+00	2.27E-02	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	natural gas, high pressure, at consumer	RER	0	MJ	1.66E-01	2.48E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	coke oven gas, at plant	GLO	0	MJ	2.80E-01	4.19E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	7.33E-02	1.10E-03	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	oxygen, liquid, at plant	RER	0	kg	6.05E-02	9.07E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	nitrogen, liquid, at plant	RER	0	kg	5.67E-02	8.50E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	steam, for chemical processes, at plant	RER	0	kg	5.92E-02	8.87E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); steam; Remus (2013)
	compressed air, average installation, <30kW, 8 bar gauge, at supply network	RER	0	m3	8.97E-03	1.34E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	tap water, at user	CH	0	kg	3.35E-03	5.02E-05	1	1.13	(2,2,3,1,1,nA,BU:1.05); process water; Remus (2013)
	transport, barge	RER	0	tkm	1.63E-02	2.44E-04	1	2.02	(2,2,3,1,1,nA,BU:2); ; Remus (2013)
	transport, transoceanic freight ship	OCE	0	tkm	1.46E+00	2.19E-02	1	2.02	(2,2,3,1,1,nA,BU:2); ; Remus (2013)
	transport, freight, rail	RER	0	tkm	2.48E-01	3.72E-03	1	2.02	(2,2,3,1,1,nA,BU:2); ; Remus (2013)
	transport, freight, lorry, fleet average	RER	0	tkm	9.89E-03	1.48E-04	1	2.02	(2,2,3,1,1,nA,BU:2); ; Remus (2013)
emission air, unspecified	Particulates, > 2.5 um, and < 10um	-	-	kg	1.84E-05	2.76E-07	1	2.02	(2,2,3,2,2,nA,BU:2); PM10, emissions to air from BF cast house + emissions from the charging zone ; Remus (2013)
	Particulates, < 2.5 um	-	-	kg	8.99E-05	1.35E-06	1	3.02	(2,2,3,2,2,nA,BU:3); dust, emissions to air from BF cast house + emissions from coal preparation for injection + emissions from the charging zone after abatement (2.5 um); Remus (2013)
	Sulfur dioxide	-	-	kg	9.95E-05	1.49E-06	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	Nitrogen oxides	-	-	kg	2.05E-06	3.07E-08	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Carbon monoxide, fossil	-	-	kg	2.82E-05	4.22E-07	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Carbon dioxide, fossil	-	-	kg	8.40E-01	1.26E-02	1	1.13	(2,2,3,1,1,nA,BU:1.05); calculated CO2 emissions from burned CO without the share of emitted CO2 that is credited to energy production; Remus (2013)
	Chromium	-	-	kg	6.49E-09	9.73E-11	1	5.02	(2,2,3,1,1,nA,BU:5); dust, emissions to air from BF cast house + emissions from coal preparation for injection + emissions from the charging zone after
	Manganese	-	-	kg	4.84E-08	7.25E-10	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Nickel	-	-	kg	6.21E-09	9.30E-11	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Lead	-	-	kg	1.31E-08	1.96E-10	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Zinc	-	-	kg	8.24E-09	1.23E-10	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Mercury	-	-	kg	1.26E-10	1.89E-12	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Arsenic	-	-	kg	1.26E-10	1.89E-12	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Cadmium	-	-	kg	1.42E-10	2.13E-12	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
technosphere	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	1.47E-02	2.20E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); slag, 6 % landfilled; Remus (2013)
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	3.05E-03	4.58E-05	1	1.13	(2,2,3,1,1,nA,BU:1.05); used fractory - alltough partially recycled total amount is assumed to be diposited in intert material landfill; Remus (2013)
	disposal, sludge, pig iron production, 8.6% water, to residual material landfill	CH	0	kg	1.20E-02	1.80E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); top gas sludge; Remus (2013)
	treatment, pig iron production effluent, to wastewater treatment, class 3	CH	0	m3	6.81E-03	1.02E-04	1	1.13	(2,2,3,1,1,nA,BU:1.05); waste water; Remus (2013)

5.4.4 Blast furnace gas, burned in power plant/RER in DETEC

Blast furnace gas is produced as a by-product and contains about 20-28% CO, 1–5% H_2, inert compounds (50-55% N_2, 17-25% CO_2), some sulphur and cyanide compounds and large amounts of dust from the burden. After cleaning, the BFG is often used as a fuel after enriching with coke oven gas, basic oxygen gas or natural gas, which have higher heating values (Remus, 2013).
Dust generated from BFG treatment mainly contains carbon and iron from coke and sinter abrasion respectively. This coarse dust is normally returned to the sinter strand.

The CO2 emissions from the blast furnace gas that is reused for pig iron production are considered as process emissions and are allocated to the blast furnace gas. The emissions of the blast furnace gas, that is used in other industries (energy production) are allocated as energy emissions to the energy sector. According to our calculation and in comparison with the explanation in the NIR of Belgium (UNFCCC, 2021) approximately 25% of the CO2 emissions from the blast furnace are allocated to the energy sector and the 75% are allocated as process emissions to the iron production. Consequantially only CO2 emissions from pig iron production are accounted for in this inventory.

Table 9 shows metadata in an X-process table for the composition of blast furnace gas, generated from pig iron production in blast furnaces in Europe. Raw process data are presented in X-Echange (see Table 10). The values represent blast furnace output data after a two-stage treatment of the BFG from Remus (2013) the energy value of BFG was assumed to be 5.6MJ/t HS (Remus 2013).

Table 9: Metadata for the composition of BFG produced in Europe

Name	blast furnace gas, burned in power plant
Location	RER
InfrastructureProcess	0
Unit	MJ
IncludedProcesses	Included processes: The module does not include input of fuel (blast furnace gas) because blast furnace gas is treated as a waste product of steel production (i.e. zero allocation to blast furnace gas). Nevertheless, the module includes the emissions caused by the burning of the gas in the power plant. It includes also power plant infrastructure.
Amount	1
LocalName	Hochofengas, in Kraftwerk
Synonyms	In UVEK2018 enthalten
GeneralComment	
InfrastructureIncluded	1
Category	natural gas
SubCategory	power plants
LocalCategory	Erdgas
LocalSubCategory	Kraftwerke
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Europe
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 10: Unit process data of BFG from pig iron production after two-stage treatment

	Name	Location	Infrastructure Process	Unit	blast furnace gas, burned in power plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER			
	Infrastructure Process				0			
	Unit				MJ			
product	blast furnace gas, burned in power plant	RER	0	MJ	1			BF gas composition after 2 stage treatment
technosphere	gas power plant, 100MWe	RER	1	unit	1.21E-12	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
emission air, unspecified	Hydrogen sulfide	-	-	kg	3.84E-6	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Manganese	-	-	kg	5.27E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Lead	-	-	kg	8.04E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Zinc	-	-	kg	2.59E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Carbon dioxide, fossil	-	-	kg	1.41E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); only CO2 emissions allocated to steelwork; Remus (2013)
	Hydrogen	-	-	kg	7.59E-4	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Particulates, < 2.5 um	-	-	kg	1.88E-6	1	3.02	(2,2,3,1,1,nA,BU:3); dust after abatement (< 2.5 um); Remus (2013)

5.5 Steel produced in Basic Oxygen Furnace (Converter)

This part is mainly based on Remus (2013).

5.5.1 Production process and infrastructure:

Iron is turned into steel in a basic oxygen furnace (BOF). The objective in oxygen steelmaking is to oxidize undesirable impurities contained in the hot metal feedstock. The main elements that are converted into oxides are carbon, silicon, manganese and phosphorus.

The purpose of this oxidation process is:

- to reduce the carbon content to a specified level (from approximately 4 – 5 % to typically 0.01 – 0.4 %)
- to adjust the contents of desirable foreign elements
- to remove undesirable impurities to the greatest possible extent.

The production of steel by the BOF converter route is a discontinuous process which involves different steps. The single steps and their associated emissions are listed below and summarized in Figure 3 (Eurofer, 2020; Remus, 2013):

- transfer from the BF and discharge to BOF
- pre-treatment of hot metal (desulphurisation, deslagging)
- weighing and reladling
- oxidation in the BOF (decarburisation and oxidation of impurities)
- secondary metallurgical treatment
- casting (continuous or/and ingot).

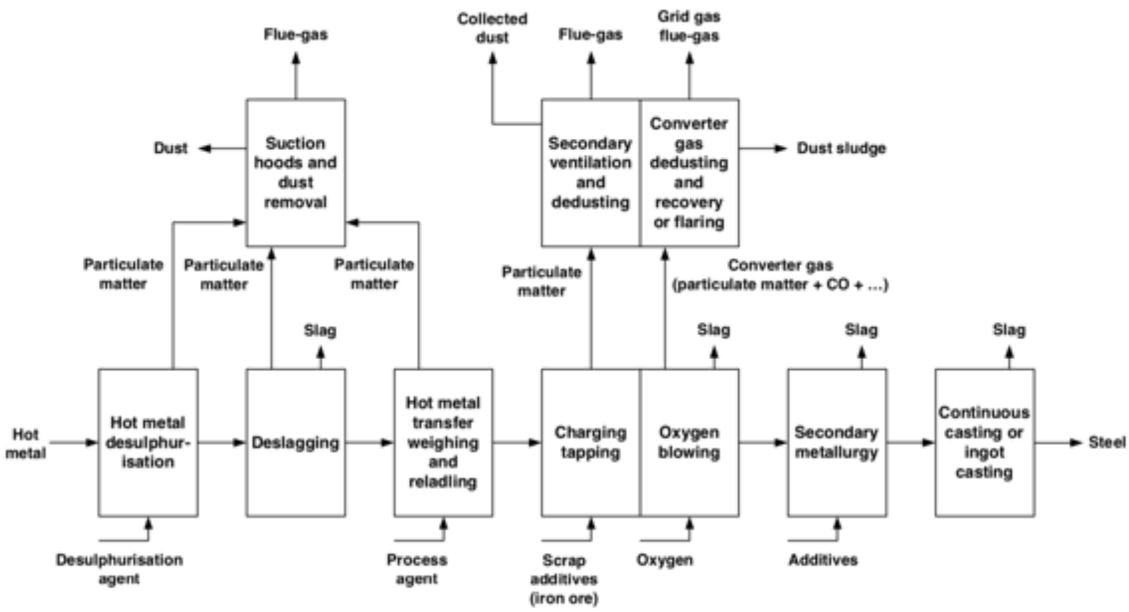

Figure 3: Overview of the different steps in basic oxygen steel making and their associated emissions, wastes, by-products and products (Remus, 2013)

Pre-treatment of hot metal

Hot metal is pretreated mainly to reduce the content of sulphur, phosphorous and silicon in the hot metal. Desulphurisation is the only pre-treatment done in Europe when preparing the hot metal for the BOF process. Today, specified sulphur concentrations (typically between 0.001 and 0.020 %) for charging in the converter are commonly adjusted in a hot metal desulphurisation facility located at the ironworks. With an upstream blast furnace process, these generally include reduced consumption of coke and sinter, lower losses of hot metal and improved quality of the metallurgical slag. This finally results in a decrease of consumption of the refractory linings and oxygen.

The desulphurization process is performed by different methods and systems. The most widespread method of desulphurization in Europe today is that based on calcium carbide, which has replaced the previous soda process for waste disposal and air quality management reasons (Remus, 2013).

Oxidation in the basic oxygen furnace

In order to meet the objectives mentioned above, undesired impurities are oxidised with subsequent removal of the off-gas or slag. Steel production in a BOF begins by charging the vessel with 70–90 % liquid iron and 10–30 % steel scrap. High purity oxygen then combines with the carbon in the iron to create an exothermic reaction that melts the charge while lowering the carbon content. Iron from the blast furnace usually contains 3–4 % carbon, which must be reduced to less than 1 %, refined and alloyed to produce the desired grade of steel. During the process, a number of additives are used to adapt the steel quality slag is formed.

There are several types of reactors used for the basic oxygen steelmaking process. The most commonly used type is the LD converter (Linz-Donawitz) applied for hot metal with a low phosphorus content. The converter is a pear-shaped, refractory-lined reactor into which a water-cooled oxygen lance is lowered. Through this lance, pure oxygen (>99 %) from an air separation plant is blown onto the liquid hot metal (see Figure 4). The amount of oxygen consumed, depends on the content of C, Si, P etc. in the hot metal (Remus, 2013).

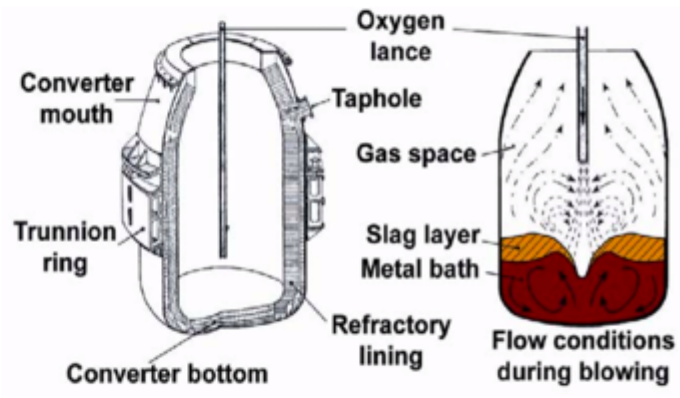

Figure 4: Basic oxygen steel maker converter (Remus, 2013)

Secondary metallurgy

Secondary metallurgy is the post-treatment performed to meet certain steel quality requirements (Remus, 2013).

Casting

Once the final steel quality has been achieved, the steel is conveyed in a casting ladle to the casting machine. Today, continuous casting is mostly applied, hereby the steel is cast in a continuous strand (Remus, 2013).

5.5.2 Emissions, wastes and by-products

Emissions to air

The oxygen steelmaking process generates considerable quantities of dust. All steelmaking shops in the EU have taken measures to reduce dust emissions:

- Secondary ventilation and dust extraction systems in BOF plants:
  Dust is emitted during charging of scrap and hot metal, oxygen blowing and tapping from the BOF. The converter is tilted during loading or tapping. Often a secondary ventilation and dust removal system is installed to reduce the dust emissions that occur. The secondary ventilation system usually consists of a canopy hood directly above the converter in a tilted position and a doghouse around the remaining part of the converter. During blowing, the secondary system extracts a large part of the emissions.
- Primary ventilation and dust extraction systems in BOF plants:
  During oxygen blowing, converter gas (BOF gas) is released from the converter. Converter gas is classified as a lean gas in terms of its caloric value. This gas contains about 65% CO, 15% CO_2, 15 % nitrogen and small amounts of hydrogen and methane and large amounts of dust (mainly consisting of metal oxides, including heavy metals). Emissions of PCDD/F and PAH are only emitted in small quantities. In many steel making plants, measures have been taken to recover the converter gas and use it as an energy source. Generally, two systems can be applied to rcover energy from BOF gas: open combustion or suppressed combustion.
  - Open combustion systems introduce air into the converter flue gas duct, thus combusting the carbon monoxide. The heat generated is later recovered in a waste heat boiler.
  - In suppressed combustion, a skirt is lowered over the converter mouth during oxygen blowing. Thus, ambient oxygen cannot enter the flue gas duct and the combustion of carbon monoxide is prevented. Dust is usually removed from BOF gas by means of venturi scrubbers but also by dry or wet electrostatic precipitators (Remus, 2013).

Other emissions occur during:

- Hot metal pre-treatment (desulphurization)
- Tapping operations (i.e. ladles, ladle furnaces, converters and other equipment used in secondary metallurgy)
- Degassing
- Refractory preheating (ladle, tundish, degasser)
- The handling of additives
- Continuous casting.

Some of the above-mentioned processes are connected with the secondary ventilation and dedusting systems.

The oxygen steel making process also generates considerable quantities of particulate matter, during charging of scrap and hot metal, blowing and during tapping of slag and liquid steel. These diffuse emissions occur from all of the above-mentioned processes whenever the emissions are not fully captured. All steel making shops in the EU have taken measures to reduce particulate matter emissions. The overall emissions given are in the lowest range and thus all particles are assumed to be below 2.5 μm (Remus, 2013).

Emissions to water

Waste water from BOF gas treatment is either treated wet of dry. In the case of wet cleaning, waste water is produced which is normally recycled after treatment (Remus, 2013).

Waste and by-products

Various solid residues are generated from basic oxygen steelmaking (Remus, 2013):

- Desulphurisation slag - The relatively high sulphur content and unsatisfactory mechanical properties do not make desulphurisation slag ideal for reuse. It is normally recycled to the sinter mix of the integrated steelworks or landfilled (41%) (see Figure 7.12 in Remus (2013)).
- BOF slag - Slag from BOF makes up the largest share of residues from BOF steel making. Most of the BOF slag is used as an aggregate in road construction work or in asphalt mixtures but there is also a percentage of BOF slag that is still put to landfill (11%) due to market conditions (see Figure 7.13 in Remus (2013)).
- Slag from secondary metallurgy - The composition of secondary metallurgy slag is quite different and a very wide range of compositions can be found because they depend on the production technology and on the kind of steels produced. In this project slag from secondary metallurgy is assumed to be composed and used/disposed as BOF slag.
- Dust from BOF gas treatment - dust is generated from the first dedusting step and from the second one. Fine dust from the second dedusting step contains high amounts of zinc and lead. The main source of these heavy metals is scrap charged to the BOF. Because of the high zinc content, the dust or sludge cannot be fully recycled back tp the oxygen steelmaking process and is partially put in landfills (12%) (see Figure 7.14 in Remus (2013)).
- Sludge from BOF gas treatment - Sludge is generated in the scrubbing water circuit. This sludge can be 100 % recycled within the iron and steelmaking process if the zinc input via the scrap is strictly limited. At many other steelmaking plants in the world, the sludge cannot be used and is either externally used in the cement making industry or stored or disposed of.
- Spittings - Spittings occur from slopping caused by extreme foaming in the converter during blowing. The spittings have a high content of iron, which is separated and recycled back to the sinter plant. The rest of the slag (with less iron) is normally landfilled.
- Mill scale from continuous casting – mill scale consists of mainly iron ad is usually recycled back to the sinter plant.
- Rubble – rubble mainly consists of spent refractories. In some plants it is partially recycled in the BOF. Although partly recycled, in this project, the total amount is assumed to be disposed in inert material landfill.
- BOF gas (converter gas) is produced during oxygen blowing and is classified as a lean gas in terms of its caloric value.

5.5.3 Steel, converter, unalloyed, at plant/RER in DETEC

Metadata is presented in an X-process table (see Table 11) and raw process data are presented in X-Echange table (see Table 12).

Where Remus (2013) is given as the source, the arithmetic mean of the lowest and highest values are used in this project. No values for steel alloys are represented. For transportation values, existing transportation distances and transportation means were used based on UVEK:2018.

The following assupmtions have been made regarding the wastes and by-products generated from the production of converter steel:

- 41% of the desulphurisation slag is assumed to be landfilled, 59% is assumed to be recycled back to the sinter mix. Therefore only 41% of the desulphurization slag has been inventoried.
- 11% of BOF slag is assumed to be landfilled. 89% of produced BOF slag is reused mainly in road construction and is therefore inventoried as a by-product "blast furnace slag cement" and allocated economically (see sub-chapter Allocaton of by-products).
- Slag from secondary metallurgy is assumed to be composed and used/disposed as BOF slag (11% landfilled, 89% reused).
- 12% of dust from BOF gas treatment is landfilled. Representative data of the composition of BOF dusts are hardly available. Data for the electric arc furnace (EAF) dusts are much more comprehensive. For this reason, the disposal modules of EAF dusts are inventoried as proxy for the disposal of the BOF dust. Coarse dust is usually returned to the oxygen steelmaking process. Therefore only 12% of dust emissions are inventoried in this process.
- Spitting and mill scales are recycled to the sinter plant and are therefore not inventoried in this process.
- Rubble, although partially recycled, it assumed to be totally disposed of in inert material landfills.
- BOF gas is inventoried as a by-product and allocated physically. For this reason, BOF gas was inventoried as a own process (see chapter 5.5.4).

Data basis

The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production (Remus, 2013). Data represent 21 existing basic oxygen steelmaking plants in different EU Member States.

Allocation of by-products

According to Remus (2013) 0.125 kg of BOF slag is produced per kg of LS. Additionally, 0.012 kg/kg LS from secondary metallurgy is produced, which is is assumed to be composed and used/disposed as BOF slag. 89% of the slag that is produced from steel production in the BOF and from secondary metallurgy is reused mainly in road construction. The rest (11%) of the BOF slag is landfilled.

The by-product BOF slag has therefore been allocated economically. An average price for steel of 420 EUR/t (Meps, 2021) and an average price for blast furnace slag of 27 EUR/t (Fachstelle Nachhaltiges Bauen, 2016) was assumed. This results in an average allocation factor for BOF slag of 0.0078, the remaining inputs and emissions are allocated to liquid steel with an allocation factor of 0.9922.

BOF gas is produced next to BOF slag as a by-product and has been allocated physically and inventoried as an own process (see chapter 5.5.4).

Table 11: Metadata for the production of 1 kg steel from BOF converter in Europe

Name	steel, converter, unalloyed, at plant	basic oxygen furnace slag, at plant
Location	RER	RER
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Transports of hot metal and other input materials to converter, steel making process and casting.	
Amount	1	1
LocalName	Blasstahl, unlegiert, ab Werk	Blasstahlschlacke, ab Werk
Synonyms	In UVEK2018 enthalten	In UVEK2018 enthalten
GeneralComment	The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production and represent the arithmetic mean of lowest and highest values (Remus, 2013). Remark: This process produces primary steel. Scrap is only used for cooling the liquid steel.; Geography: Input/output-data from 21 existing basic oxygen steelmaking plants in different EU Member States. Economical allocation factor is 0.9922	BOF slag is produced as a by-product. According to Remus (2013) 0.125 kg/kg LS of BOF slag is produced and 0.012 kg /kgLS of slag is produced from secondary metallurgy - assumed to be composed and used / disposed as BOF slag. 89% of total slag amount is reused, 11% is landfiled. Economical allocation factor is 0.0077.
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	extraction	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula		
StatisticalClassification		
CASNumber		
StartDate	2018	2019
EndDate	2020	2021
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Data from literature, refer to Europe	Data from literature, referr to Europe
Technolgy	Industry data.	Industry data.
Representativeness		
ProductionVolume		
SamplingProcedure	Data from literature	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 12: Unit process data for the production of iron via basic oxygen furnace route

	Name	Location	Infrastructure Process	Unit	steel, converter, unalloyed, at plant	basic oxygen furnace slag, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER	RER			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	steel, converter, unalloyed, at plant	RER	0	kg	1	0			
product	basic oxygen furnace slag, at plant	RER	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	2.11E-2	1.66E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
technosphere	basic oxygen furnace gas, burned in power plant	RER	0	MJ	5.21E-1	4.08E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
technosphere	blast oxygen furnace converter	RER	1	unit	1.32E-11	1.04E-13	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
technosphere	pig iron, at plant	RER	0	kg	8.53E-1	6.69E-3	1	2.29	(4,2,5,5,5,nA,BU:1.05); hot metal; Remus (2013)
	iron scrap, at plant	RER	0	kg	2.19E-1	1.72E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	iron ore, 65% Fe, at beneficiation	GLO	0	kg	9.63E-3	7.55E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	sinter, iron, at plant	RER	0	kg	2.98E-2	2.33E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); other Fe material ; Remus (2013)
	hard coal coke, at plant	RER	0	MJ	5.64E-3	4.42E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	quicklime, in pieces, loose, at plant	CH	0	kg	4.81E-2	3.77E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	dolomite, at plant	RER	0	kg	1.41E-2	1.10E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	oxygen, liquid, at plant	RER	0	kg	7.93E-2	6.21E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	argon, liquid, at plant	RER	0	kg	1.37E-3	1.07E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	nitrogen, liquid, at plant	RER	0	kg	1.19E-2	9.33E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	natural gas, high pressure, at consumer	RER	0	MJ	3.84E-1	3.01E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	3.47E-2	2.72E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	coke oven gas, at plant	GLO	0	MJ	3.97E-1	3.11E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	blast furnace gas, burned in power plant	RER	0	MJ	9.64E-3	7.56E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	compressed air, average installation, <30kW, 8 bar gauge, at supply network	RER	0	m3	1.69E-2	1.32E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	transport, barge	RER	0	tkm	6.55E-4	5.13E-6	1	2.00	(2,2,1,1,1,nA,BU:2); ; based on UVEK:2018
	transport, freight, lorry, fleet average	RER	0	tkm	2.21E-2	1.73E-4	1	2.00	(2,2,1,1,1,nA,BU:2); ; based on UVEK:2018
	transport, transoceanic freight ship	OCE	0	tkm	5.89E-2	4.62E-4	1	2.00	(2,2,1,1,1,nA,BU:2); ; based on UVEK:2018
	transport, freight, rail	RER	0	tkm	1.43E-1	1.12E-3	1	2.00	(2,2,1,1,1,nA,BU:2); ; based on UVEK:2018
	disposal, basic oxygen furnace wastes, 0% water, to residual material landfill	CH	0	kg	8.14E-4	6.38E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); slag from desulphurization - amount inventoried corresponds to the 41% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
	disposal, basic oxygen furnace wastes, 0%	CH	0	kg	1.36E-3	1.07E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); BOF slag - amount inventoried corresponds to the 11% of the slag that is landfilled. The rest is recycled or reused; (Remus 2013)
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	3.20E-3	2.51E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); rubble - allthough partly recycled total amount is assumed to be disposed in inert material landfill.; (Remus 2013)
	disposal, basic oxygen furnace wastes, 0% water, to residual material landfill	CH	0	kg	1.31E-4	1.03E-6	1	1.08	(2,2,2,2,2,nA,BU:1.05); slag from secondary metallurgy - assumed to be composed and used / disposed as BOF slag --> amount inventoried represents only 11% of total slag; (Remus 2013)
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.48E-3	1.16E-5	1	1.08	(2,2,2,2,2,nA,BU:1.05); dusts from BOF gas treatment - approximation with EAF dust - amount inventoried corresponds to the 12% of the total dust that is landfilled. The rest is recycled or reused; (Remus 2013)
emission air, unspecified	Particulates, < 10 um	-	-	kg	7.79E-5	6.11E-7	1	1.52	(2,2,3,1,1,nA,BU:1.5); dust, Information on PM10 and PM2.5 are generally not available today.; (Remus 2013)
	Chromium	-	-	kg	4.22E-8	3.31E-10	1	5.02	(2,2,3,1,1,nA,BU:5); ; (Remus 2013)
	Iron	-	-	kg	4.48E-5	3.52E-7	1	5.02	(2,2,3,1,1,nA,BU:5); ; (Remus 2013)
	Copper	-	-	kg	1.36E-6	1.07E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; (Remus 2013)
	Manganese	-	-	kg	9.23E-7	7.23E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; (Remus 2013)
	Lead	-	-	kg	5.71E-7	4.47E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; (Remus 2013)
	Nitrogen oxides	-	-	kg	3.14E-5	2.46E-7	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; (Remus 2013)
	Carbon monoxide, fossil	-	-	kg	3.77E-3	2.96E-5	1	5.02	(2,2,3,1,1,nA,BU:5); ; (Remus 2013)
	Carbon dioxide, fossil	-	-	kg	9.75E-2	7.65E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; (Remus 2013)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	9.92E-9	7.78E-11	1	3.02	(2,2,3,1,1,nA,BU:3); ; (Remus 2013)
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	6.80E-14	5.33E-16	1	3.02	(2,2,3,1,1,nA,BU:3); ; (Remus 2013)

5.5.4 Basic oxygen furnace gas, burned in power plant/ RER in DETEC

A newly modeld inventory for basic oxygen furnace gas, burned in power plant, was created. The inventory includes specific emissions to air from a basic oxygen furnace with supressed combustion after abatement. The energy value of BOF gas was assumed to be 0.525 MJ/kg LS (see Table 14).

Energy use from BOF gas was not considered and therefore not inventoried in this update.

Metadata is presented in an X-process table (see

Table 13) and raw process data are presented in X-Echange table (see Table 14).

Table 13: Metadata for BOF gas with suppressed combustion after abatement

Name	basic oxygen furnace gas, burned in power plant
Location	RER
InfrastructureProcess	0
Unit	MJ
IncludedProcesses	Included processes: The module does not include input of fuel (basic oxygen furnace gas) because basic oxygen furnace gas is treated as a waste product of steel production (i.e. zero allocation to basic oxygen furnace gas). Nevertheless, the module includes the emissions caused by the burning of the gas in the power plant. It includes also power plant infrastructure.The inventory includes specific emissions to air from a basic oxygen furnace with supressed combustion after abatement. BOF gas (energy): 350-700 MJ/t LS -> 525 MJ/ t LS -> 0.525MJ/ kg LS - 1MJ BOF/ 1.9 kg LS
Amount	1
LocalName	Blasstahlgas, in Kraftwerk
Synonyms	0
GeneralComment	
InfrastructureIncluded	1
Category	metals
SubCategory	production
LocalCategory	Metalle
LocalSubCategory	Gewinnung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Europe
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 14: Unit process data for the composition of BOF gas

	Name	Location	Infrastructure Process	Unit	basic oxygen furnace gas, burned in power plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER			
	Infrastructure Process				0			
	Unit				MJ			
product	basic oxygen furnace gas, burned in power plant	RER	0	MJ	1	0		; Remus (2013)BOF gas (energy): 350-700 MJ/t LS -> 525 MJ/ t LS -> 0.525MJ/ kg LS - 1MJ BOF/ 1.9 kg LS;
technosphere	gas power plant, 100MWe	RER	1	unit		1	3.02	(2,2,3,1,1,nA,BU:3); Remus (2013);
emission air, unspecified	Aluminium	-	-	kg	1.22E-6	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Arsenic	-	-	kg	1.90E-8	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Cadmium	-	-	kg	2.57E-7	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Chromium	-	-	kg	3.81E-8	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Copper	-	-	kg	7.62E-8	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Iron	-	-	kg	8.17E-5	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Mercury	-	-	kg	1.90E-8	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Manganese	-	-	kg	5.97E-5	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Lead	-	-	kg	4.19E-6	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Zinc	-	-	kg	1.56E-5	1	5.02	(2,2,3,1,1,nA,BU:5); Remus (2013);
	Sulfur dioxide	-	-	kg	5.62E-6	1	1.13	(2,2,3,1,1,nA,BU:1.05); Remus (2013);
	Nitrogen oxides	-	-	kg	2.38E-5	1	1.52	(2,2,3,1,1,nA,BU:1.5); Remus (2013);
	Carbon monoxide, fossil	-	-	kg	2.19E-2	1	5.00	(2,2,1,1,1,nA,BU:5); calculated value for BOF-gas. based on information provided by https://link.springer.com/article/10.1007/s11367-011-0370-y => 72.5 Vol.-% CO, 16 Vol.-% CO2;
	Carbon dioxide, fossil	-	-	kg	5.58E-1	1	1.13	(2,2,3,1,1,nA,BU:1.05); Remus (2013);
	Hydrogen fluoride	-	-	kg	1.71E-8	1	1.52	(2,2,3,1,1,nA,BU:1.5); Remus (2013);
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	2.29E-10	1	3.02	(2,2,3,1,1,nA,BU:3); Remus (2013);
	Particulates, < 2.5 um	-	-	kg	5.52E-5	1	3.02	(2,2,3,1,1,nA,BU:3); Dust from oxygen blowing - After primary (BOF gas) dedusting;
	Particulates, < 2.5 um	-	-	kg	5.90E-5	1	3.02	(2,2,3,1,1,nA,BU:3); Dust from charging and tapping after secondary dedusting;
technosphere	disposal, sludge, pig iron production, 8.6% water, to residual material landfill	CH	0	kg	2.86E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); Dust from secondary dedusting - filtered dust - sludge;
emission air, unspecified	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	1.06E-13	1	3.02	(2,2,3,1,1,nA,BU:3); Remus (2013);

5.6 Steel produced in Electric Arc Furnace

This part is mainly based on Remus (2013).

5.6.1 Production process and infrastructure

The direct smelting of iron-bearing materials, such as scrap is usually performed in electric arc furnaces, which play an increasingly important role in modern steelwork concepts. Today, the percentage of electric arc furnace steel of the overall steel production in the EU-27 is 41.8 % (Remus, 2013). The major feed stock for the EAF is ferrous scrap, which may comprise of scrap from inside the steelworks, cut-offs from steel product manufacturers (e.g. vehicle builders) and capital or post-consumer scrap (e.g. end of life products) (Remus, 2013).

Through carbon or graphite electrodes, electricity is added to the scrap in the furnace, thus raising the temperature to 1700 °C. Lime, anthracite and pig-iron are then added. As in the BOF, a slag is formed from lime to collect undesirable components in the steel. Depending on the desired quality and properties of the steel, chromium, manganese, molybdenum or vanadium compounds can be added. Each cycle consists of the same steps: charging of scrap, preheating, refining with addition of other material and tapping. Further process steps like casting and rolling are comparable to the blast furnace route (EEA, 2019).

Figure 5: Overview of the process chain of steel produced in EAF (Remus, 2013)gives an overview of the process chain for EAF steel, which involves the following steps:

- Raw material handling and storage
- Furnace charging with/without scrap preheating
- EAF scrap melting
- Steel and slag tapping
- Ladle furnace treatments for quality adjustment
- Slag handling
- Continuous casting

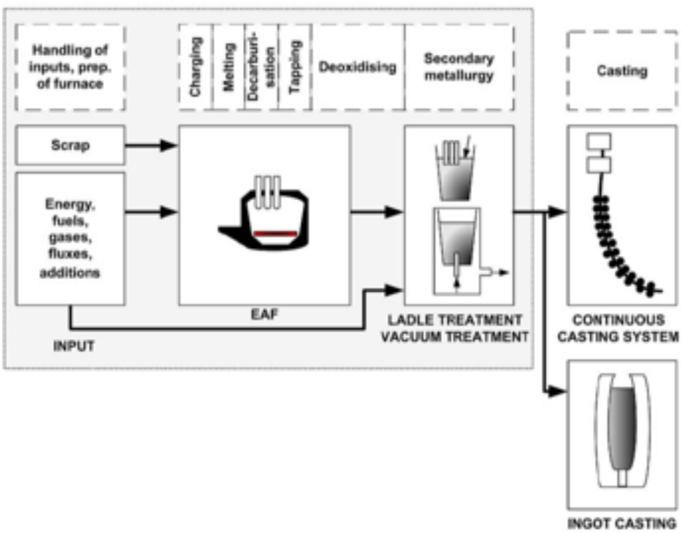

Figure 5: Overview of the process chain of steel produced in EAF (Remus, 2013)

For high-alloyed and special steels, the operation sequence is more complex and tailor-made for the end-products. The process is split in two steps: melting in an EAF and a decarburisation process. The decarburisation is followed by various ladle treatments (secondary metallurgy) such as:

- desulphurisation
- degassing for the elimination of dissolved gases like nitrogen and hydrogen

The actual melting is done by lowering graphite electrodes to the scrap until they strike an arc that melts the scrap.

5.6.2 Emissions, wastes and by-products

Emissions to air

Primary off-gases represent approximately 95 % of total emissions from an EAF and are extracted directly from the EAF.

Secondary off-gases that are generated during scrap handling, charging and tapping as well as those escaping from the furnace openings like fumes are captured by a canopy hood generally located above the furnace. Off-gas consists, besides carbon monoxide and carbon dioxide, mainly of dust. Because polluted scrap is used, the dust contains heavy metals such as lead and zinc. Also, copper, chromium, nickel, arsenic, cadmium, and mercury are present. Small amounts of BC, hexachlorobenzene, dioxins and furans are also emitted. Organic matter emissions mainly depend on the scrap quality. Some scraps contain paints, oils and other organic substances.

A reduction of the emissions to air can be achieved by technological process changes as well as by abatement equipment. Changing operating conditions or the design of the furnace may lead to a reduction in the amount of dust produced. The use of an „after burner" reduces the amount of CO emitted. The use of abatement equipment such as fabric filters or ESPs, reduces the amount of dust emitted. Diffuse emissions can be reduced by placing the furnace in a doghouse (a „hall") and using abatement equipment to clean the effluent from the doghouse (EEA, 2019).

Emissions to water and soil

Drainage water form unpaved scrap-yards can be contaminated, especially in case of oil/emulsion containing scrap like turnings. There is no information available on quantities and pollution of drainage water. Usually it is at least treated in an oil separator prior to be discharged.

Soil contamination may arise from contaminated scrap in scrap-yards. No information on quantities and pollutants is available.

Waste and by-products

The electric arc furnace steelmaking process is a source of primarily dust and solid wastes/by-products. The main waste generated in EAF steel making are slags. Their composition depends on the alloy and on the sub-process they are generated in.
While slag from carbon steel and low-alloyed steel production are landfilled to 69% and 59%, respectively, only 53% of the slag from high-alloyed steel production is landfilled. The percentage of EAF slag that is landfilled in Europe is 61.4% (see Figure 8.8 in Remus (2013)).

If the non-ferrous metal content of the dusts or sludges arising in the integrated steelworks is sufficiently high, it can be technically and economically feasible to recover some non-ferrous metals in external metal production and recycling plants. For example, steelmaking dusts with enriched zinc concentrations can be used as a raw material within the zinc sector instead of zinc ores.

EAF slag is reused as gravel substitute in construction work and mill scale can be recycled as clinker in the cement industry. EAF slag has been allocated as a by-product form EAF steel production.

5.6.3 Steel, electric, un- and low-alloyed, at plant/RER in DETEC

Where Remus (2013) is given as the source, the arithmetic means of the lowest and highest values are used in this project.

Data presented refer to un- and low-alloyed electric steel. For transportation values, existing transportation distances and transportation means were used based on UVEK:2018. The percentage of EAF slag and dust as well as refractory waste that is landfilled is calculated according to Remus (2013) and corresponds to 61.4%.

Data basis

The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production (Remus, 2013). Input/output-data refer to 21 existing basic oxygen steelmaking plants in different EU Member States. The information in the BAT reference document has been collated and assessed by the European IPCC. This is the result of collected data from various steel production plants in the EU showing partially a very high variation.

For some processes the data is reported as minimum/best values and maximum/worst values; for some processes the average value of inputs and outputs of the respective process is given. The wide ranges of the presented values may be explained by different inputs (esp. the energy mix), variations in emission limit values and environmental protection equipment, different plant characteristics and plant productivity.

In the following, the update of un- and low-alloyed electric steel is presented. Three inventories were created: One representing the arithmetic mean- average plants, one with the minimum (best plants) and a third with the maximum values (worst plants) given in Remus (2013). All data is provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation.

Allocation of by-products

The average total amount of slag from furnace and slag from ladle produced from European EAF is 0.21 kg/kg LS. According to Remus (2013) 38.6% of the producted EAF slag is reused and 61.4% is landfilled (see Table 8.8 Remus (2013)). EAF slag as a by-product has been allocated economically. An average price for steel of 420 EUR/t (Meps, 2021) was assumed and an average price for blast furnace slag of 27 EUR/t (Fachstelle Nachhaltiges Bauen, 2016) was assumed in interest of simplification also for EAF slag. This results in an average allocation factor for EAF slag of 0.0052, assuming that 38.6% of the slag produced is reused, the remaining inputs and emissions with an allocation factor of 0.9948 are allocated to liquid steel.
The amount of EAF slag for the production of un- and low-alloyed electric steel in Europe with minimum values is according to Remus (2013) 0.07 kg/kg LS, assuming that 38.6% if slag is reused. The allocation factor for EAF slag with minimum value is 0.0017 and for steel is 0.9983.
The amount of EAF slag for the production of un- and low-alloyed electric steel in Europe with maximum values are according to Remus (2013) 0.35 kg/kg LS, assuming that 38.6% if slag is reused. The allocation factor for EAF slag with minimum value is 0.0086 and for steel is 0.9914

Arithmetic mean

Metadata of the process production of un- and lowalloyed electric steel in Europe with mean values is presented in an X-process table (see Table 15) and and raw process data are presented in X-Echange table (see Table 16).

Table 15: Metadata for the production of 1 kg unalloyed electric steel in Europe (arithmetic mean

Name	steel, electric, un- and low-alloyed, at plant	electric arc furnace slag, at plant
Location	RER	RER
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Transports of scrap metal and other input materials to electric arc furnace, steel making process and casting.	
Amount	1	1
LocalName	Elektrostahl, un- und niedriglegiert, ab Werk	Elektrostahlschlacke, ab Werk
Synonyms	In UVEK2018 enthalten	0
GeneralComment	The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production and represent the arithmetic mean of lowest and highest values (Remus, 2013). Input/output-data refer to 21 existing basic oxygen steelmaking plants in different EU Member States. The information in the BAT reference document has been collated and assessed by the European IPCC. This is the result of collected data from various steel production plants in the EU showing partially a very high variation. This process produces secondary steel. Only scrap is used as iron bearing input.; Geography: Data relate to plants in the EU. Economical allocation with allocation factor of 0.9948 for liquid steel.	EAF slag is produced as a by-product. According to Remus (2013) Total amount of slag produced: 0.21 kg/kg LS. economical allocation: allocation factor for EAF slag of 0.0052, assuming that 38.6% of the slag produced is reused, the remaining inputs and emissions (0.9948) are allocated to liquid steel.
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	extraction	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula		
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Data from literature, referring to Europe	Data from literature, referring to Europe
Technolgy	Industry data.	Industry data.
Representativeness		
ProductionVolume		
SamplingProcedure	Data from literature	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 16: Unit process data for 1 kg of unalloyed electric steel produced in Europe (arithmetic mean)

	Name	Location	Infrastructure Process	Unit	steel, electric, un- and low-alloyed, at plant	electric arc furnace slag, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER	RER			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	steel, electric, un- and low-alloyed, at plant	RER	0	kg	1	0			
product	electric arc furnace slag, at plant	RER	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	9.95E-4	5.18E-6	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
technosphere	anode, for metal electrolysis	RER	0	kg	3.98E-3	2.07E-5	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	electric arc furnace converter	RER	1	unit	3.98E-11	2.07E-13	1	3.95	(4,2,5,3,5,nA,BU:3); ; Remus (2013)
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	5.73E-1	2.99E-3	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	hard coal mix, at regional storage	UCTE	0	kg	1.54E-2	8.04E-5	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	iron scrap, at plant	RER	0	kg	1.13E+0	5.91E-3	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	natural gas, high pressure, at consumer	RER	0	MJ	2.14E-2	1.11E-4	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	oxygen, liquid, at plant	RER	0	kg	4.66E-2	2.43E-4	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	quicklime, in pieces, loose, at plant	CH	0	kg	8.21E-2	4.28E-4	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	transport, freight, rail	RER	0	tkm	1.20E-1	6.25E-4	1	2.00	(2,2,1,3,1,nA,BU:2); ; Remus (2013)
	refractory, basic, packed, at plant	DE	0	kg	3.18E-2	1.66E-4	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	transport, freight, lorry, fleet average	RER	0	tkm	1.18E-1	6.17E-4	1	2.00	(2,2,1,3,1,nA,BU:2); ; Remus (2013)
	argon, liquid, at plant	RER	0	kg	1.45E-3	7.57E-6	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	nitrogen, liquid, at plant	RER	0	kg	7.44E-3	3.88E-5	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	1.28E-1	6.68E-4	1	1.08	(2,2,2,3,2,nA,BU:1.05); slag from furnace and slag from ladle - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.22E-2	6.37E-5	1	1.08	(2,2,2,3,2,nA,BU:1.05); Dusts - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	7.45E-3	3.88E-5	1	1.08	(2,2,2,3,2,nA,BU:1.05); waste refractories - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
emission air, unspecified	Benzene, hexachloro-	-	-	kg	6.07E-9	3.16E-11	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Benzene	-	-	kg	2.21E-6	1.15E-8	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Cadmium	-	-	kg	7.41E-8	3.86E-10	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Carbon monoxide, fossil	-	-	kg	2.27E-3	1.18E-5	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Chromium	-	-	kg	1.40E-6	7.31E-9	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Copper	-	-	kg	2.60E-7	1.35E-9	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	3.00E-12	1.57E-14	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Hydrogen chloride	-	-	kg	1.79E-5	9.33E-8	1	1.51	(2,2,1,3,1,nA,BU:1.5); ; Remus (2013)
	Hydrogen fluoride	-	-	kg	7.46E-6	3.89E-8	1	1.51	(2,2,1,3,1,nA,BU:1.5); ; Remus (2013)
	Lead	-	-	kg	1.45E-6	7.57E-9	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Mercury	-	-	kg	1.00E-7	5.24E-10	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Nickel	-	-	kg	9.95E-7	5.18E-9	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Nitrogen oxides	-	-	kg	2.36E-4	1.23E-6	1	1.51	(2,2,1,3,1,nA,BU:1.5); ; Remus (2013)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	4.87E-7	2.54E-9	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Particulates, < 10 um	-	-	kg	1.51E-4	7.88E-7	1	1.51	(2,2,1,3,1,nA,BU:1.5); dust ; Remus (2013)
	Polychlorinated biphenyls	-	-	kg	2.50E-9	1.30E-11	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Sulfur dioxide	-	-	kg	1.07E-4	5.60E-7	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	Zinc	-	-	kg	1.20E-5	6.27E-8	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Carbon dioxide, fossil	-	-	kg	1.25E-1	6.53E-4	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
emission water, fossil-	TOC, Total Organic Carbon	-	-	kg	1.47E-4	7.67E-7	1	1.51	(2,2,1,3,1,nA,BU:1.5); Emissions into air according to literature; Remus (2013)

Best plants, minimum values

Metadata of the life cycle inventory for the production of un- and low-alloyed electric steel in Europe with minimum values is presented in an X-process table (see
Table 17) and and raw process data are presented in X-Echange table (see

Table 18).

Table 17: Metadata for the production of 1 kg unalloyed electric steel in Europe (best plants, minimum values)

Name	steel, electric, low-alloyed, at plant, best plants (min. values)	electric arc furnace slag, low-alloyed, at plant, best plants (min. values)
Location	RER	RER
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Transports of scrap metal and other input materials to electric arc furnace, steel making process and casting.	
Amount	1	1
LocalName	Elektrostahl, niedriglegiert, ab Werk, beste Werke (min. Werte)	Elektrostahlschlacke, niedriglegiert, ab Werk, beste Werke (min. Werte)
Synonyms	0	0
GeneralComment	The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production and represent the lowest values (Remus, 2013). Input/output-data refer to 21 existing basic oxygen steelmaking plants in different EU Member States. The information in the BAT reference document has been collated and assessed by the European IPCC. This is the result of collected data from various steel production plants in the EU showing partially a very high variation. This process produces secondary steel. Only scrap is used as iron bearing input.; Geography: Data relate to plants in the EU. Economical allocation with allocation factor of 0.9983 for EAF steel.	EAF slag is produced as a by-product. According to Remus (2013) Total amount of slag produced is 0.07kg/kg LS allocation factor for EAF slag of 0.0017, assuming that 38.6% of the slag produced is reused, the remaining inputs and emissions (0.9983) are allocated to liquid steel.
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	production	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula		
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Data from literature for Europe	Data from literature for Europe
Technolgy	Industry data.	Industry data.

Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 18: Unit process data for 1 kg of unalloyed electric steel produced in Europe (best plants, minimum values)

	Name	Location	Infrastructure Process	Unit	steel, electric, low-alloyed, at plant, best plants (min. values)	electric arc furnace slag, low-alloyed, at plant, best plants (min. values)	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER	RER			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	steel, electric, low-alloyed, at plant, best plants (min. values)	RER	0	kg	1	0			
product	electric arc furnace slag, low-alloyed, at plant, best plants (min. values)	RER	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	9.95E-4	1.73E-6	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
technosphere	anode, for metal electrolysis	RER	0	kg	1.99E-3	3.47E-6	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	electric arc furnace converter	RER	1	unit	3.98E-11	6.94E-14	1	3.95	(4,2,5,3,5,nA,BU:3); ; Remus (2013)
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	4.02E-1	7.01E-4	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	hard coal mix, at regional storage	UCTE	0	kg	2.98E-3	5.20E-6	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	iron scrap, at plant	RER	0	kg	1.03E+0	1.80E-3	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	natural gas, high pressure, at consumer	RER	0	MJ	4.97E-2	8.67E-5	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	oxygen, liquid, at plant	RER	0	kg	6.65E-3	1.16E-5	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	quicklime, in pieces, loose, at plant	CH	0	kg	2.49E-2	4.33E-5	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	refractory, basic, packed, at plant	DE	0	kg	3.98E-3	6.94E-6	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	transport, freight, rail	RER	0	tkm	1.20E-1	2.09E-4	1	2.00	(2,2,1,3,1,nA,BU:2); ; Remus (2013)
	transport, freight, lorry, fleet average	RER	0	tkm	1.18E-1	2.06E-4	1	2.00	(2,2,1,3,1,nA,BU:2); ; Remus (2013)
	argon, liquid, at plant	RER	0	kg	4.98E-4	8.69E-7	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	nitrogen, liquid, at plant	RER	0	kg	9.30E-4	1.62E-6	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
emission air, unspecified	Benzene, hexachloro-	-	-	kg	1.99E-10	3.47E-13	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Benzene	-	-	kg	2.98E-8	5.20E-11	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Cadmium	-	-	kg	9.95E-10	1.73E-12	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Carbon monoxide, fossil	-	-	kg	4.97E-5	8.67E-8	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Chromium	-	-	kg	1.19E-8	2.08E-11	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Copper	-	-	kg	1.09E-8	1.91E-11	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	3.98E-14	6.94E-17	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Hydrogen chloride	-	-	kg	7.96E-7	1.39E-9	1	1.51	(2,2,1,3,1,nA,BU:1.5); ; Remus (2013)
	Hydrogen fluoride	-	-	kg	3.98E-11	6.94E-14	1	1.51	(2,2,1,3,1,nA,BU:1.5); ; Remus (2013)
	Lead	-	-	kg	7.46E-8	1.30E-10	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Mercury	-	-	kg	1.99E-9	3.47E-12	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Nickel	-	-	kg	2.98E-9	5.20E-12	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
	Nitrogen oxides	-	-	kg	1.29E-5	2.25E-8	1	1.51	(2,2,1,3,1,nA,BU:1.5); ; Remus (2013)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	8.95E-9	1.56E-11	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Polychlorinated biphenyls	-	-	kg	9.95E-12	1.73E-14	1	3.00	(2,2,1,3,1,nA,BU:3); ; Remus (2013)
	Particulates, < 10 um	-	-	kg	3.98E-6	6.94E-9	1	1.51	(2,2,1,3,1,nA,BU:1.5); dust ; Remus (2013)
	Sulfur dioxide	-	-	kg	4.97E-6	8.67E-9	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	Carbon dioxide, fossil	-	-	kg	7.16E-2	1.25E-4	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; Remus (2013)
	Zinc	-	-	kg	1.99E-7	3.47E-10	1	5.00	(2,2,1,3,1,nA,BU:5); ; Remus (2013)
emission water, fossil-	TOC, Total Organic Carbon	-	-	kg	3.48E-5	6.07E-8	1	1.51	(2,2,1,3,1,nA,BU:1.5); Emissions into air according to literature; Remus (2013)
technosphere	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	6.11E-3	1.06E-5	1	1.08	(2,2,1,3,1,nA,BU:1.05); slag from furnace and slag from ladle - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	9.77E-4	1.70E-6	1	1.08	(2,2,1,3,1,nA,BU:1.05); Dusts - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	4.28E-2	7.45E-5	1	1.08	(2,2,1,3,1,nA,BU:1.05); waste refractories - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)

Worst plants, maximum values

Metadata of the process production of un- and lowalloyed electric steel in Europe with maximum values is presented in an X-process table (see
Table 19) and and raw process data are presented in X-Echange table (see Table 20).

Table 19: Metadata for the production of 1 kg unalloyed electric steel in Europe (worst plants, maximum values)

Name	steel, electric, low-alloyed, at plant, worst plants (max. values)	electric arc furnace slag, low-alloyed, at plant, worst plants (max. values)
Location	RER	RER
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Transports of scrap metal and other input materials to electric arc furnace, steel making process and casting.	
Amount	1	1
LocalName	Elektrostahl, niedriglegiert, ab Werk, schlechteste Werke (max. Werte)	Elektrostahlschlacke, niedriglegiert, ab Werk, schlechteste Werke (max. Werte)
Synonyms	0	0
GeneralComment	The new data for the process update was taken from the publication by the European Commission 2013 with the Best Available Techniques (BAT) for iron and steel production and represent the lowest values (Remus, 2013). Input/output-data refer to 21 existing basic oxygen steelmaking plants in different EU Member States. The information in the BAT reference document has been collated and assessed by the European IPCC. This is the result of collected data from various steel production plants in the EU showing partially a very high variation. This process produces secondary steel. Only scrap is used as iron bearing input.; Geography: Data relate to plants in the EU. Economical allocation with allocation factor of 0.9914 for EAF steel.	EAF slag is produced as a by-product. According to Remus (2013) Total amount of slag produced is 0.35kg/kg LS. economical allocation: allocation factor for EAF slag of 0.0086, assuming that 38.6% of the slag produced is reused, the remaining inputs and emissions (0.9914) are allocated to liquid steel.
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	production	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula		
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Data from literature, referring to Europe	Data from literature, referring to Europe
Technolgy	Industry data.	Industry data.
Representativeness		

ProductionVolume		
SamplingProcedure	Data from literature	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 20: Unit process data for 1 kg of unalloyed electric steel produced in Europe (worst plants, maximum values)

	Name	Location	Infrastructure Process	Unit	steel, electric, low-alloyed, at plant, worst plants (max. values)	electric arc furnace slag, low-alloyed, at plant, worst plants (max. values)	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				RER	RER			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	steel, electric, low-alloyed, at plant, worst plants (max. values)	RER	0	kg	1	0			
product	electric arc furnace slag, low-alloyed, at plant, worst plants (max. values)	RER	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	4.24E-2	3.69E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
technosphere	anode, for metal electrolysis	RER	0	kg	5.95E-3	5.17E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	electric arc furnace converter	RER	1	unit	3.97E-11	3.44E-13	1	3.74	(4,2,3,5,5,nA,BU:3); ; Remus (2013)
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	7.42E-1	6.44E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	hard coal mix, at regional storage	UCTE	0	kg	2.78E-2	2.41E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	iron scrap, at plant	RER	0	kg	1.22E+0	1.06E-2	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	natural gas, high pressure, at consumer	RER	0	MJ	4.13E-2	3.59E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	oxygen, liquid, at plant	RER	0	kg	8.62E-2	7.48E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	quicklime, in pieces, loose, at plant	CH	0	kg	1.39E-1	1.21E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	transport, freight, rail	RER	0	tkm	5.95E-2	5.17E-4	1	2.02	(2,2,3,1,1,nA,BU:2); ; Remus (2013)
	refractory, basic, packed, at plant	DE	0	kg	1.20E-1	1.04E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	transport, freight, lorry, fleet average	RER	0	tkm	1.18E-1	1.03E-3	1	2.02	(2,2,3,1,1,nA,BU:2); ; Remus (2013)
	argon, liquid, at plant	RER	0	kg	2.40E-3	2.08E-5	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	nitrogen, liquid, at plant	RER	0	kg	1.39E-2	1.21E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	3.47E-1	3.01E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
emission air, unspecified	Benzene, hexachloro-	-	-	kg	1.19E-8	1.03E-10	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Benzene	-	-	kg	4.36E-6	3.79E-8	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Cadmium	-	-	kg	1.47E-7	1.27E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Carbon monoxide, fossil	-	-	kg	4.46E-3	3.87E-5	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Chromium	-	-	kg	2.78E-6	2.41E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Copper	-	-	kg	5.06E-7	4.39E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	5.95E-12	5.17E-14	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Hydrogen chloride	-	-	kg	3.49E-5	3.04E-7	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Hydrogen fluoride	-	-	kg	1.49E-5	1.29E-7	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	Lead	-	-	kg	2.83E-6	2.45E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Mercury	-	-	kg	1.98E-7	1.72E-9	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Nitrogen oxides	-	-	kg	4.56E-4	3.96E-6	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	9.62E-7	8.35E-9	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Polychlorinated biphenyls	-	-	kg	4.96E-9	4.31E-11	1	3.02	(2,2,3,1,1,nA,BU:3); ; Remus (2013)
	Sulfur dioxide	-	-	kg	2.08E-4	1.81E-6	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	Nickel	-	-	kg	1.98E-6	1.72E-8	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Zinc	-	-	kg	2.38E-5	2.07E-7	1	5.02	(2,2,3,1,1,nA,BU:5); ; Remus (2013)
	Carbon dioxide, fossil	-	-	kg	1.78E-1	1.55E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); ; Remus (2013)
	Particulates, < 10 um	-	-	kg	2.97E-4	2.58E-6	1	1.52	(2,2,3,1,1,nA,BU:1.5); dusts - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
emission water, fossil-	TOC, Total Organic Carbon	-	-	kg	2.58E-4	2.24E-6	1	1.52	(2,2,3,1,1,nA,BU:1.5); ; Remus (2013)
technosphere	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	2.13E-1	1.85E-3	1	1.13	(2,2,3,1,1,nA,BU:1.05); slag from furnace and slag from ladle - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.83E-2	1.59E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); Dusts - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	1.39E-2	1.21E-4	1	1.13	(2,2,3,1,1,nA,BU:1.05); waste refractories - amount inventoried corresponds to the 61.4% of the slag that is landfilled. The rest is recycled or reused; Remus (2013)

5.6.4 Steel, electric, alloyed, 42CrMoS4, at plant/CH in DETEC

In Switzerland, steel is produced only by the EAF route with iron scrap as the main iron input. Around 50% of the iron scrap that is used in EAF is collected in Switzerland and 50% is imported from Europe (Germany, France, Italy and Austria). There are two EAF plants in Switzerland. Stahl Gerlafingen AG produces mainly steel for the construction industry such as reinforcing steel. Swiss Steel Group in Emmen, produces mainly steel for the automotive, machinery and apparatus industry. Both plants use the electric arc furnace slag as a by-product, which is used in road construction (Swiss Steel) or as gravel substitute material (Stahl Gerlafingen). Dusts with enriched zinc concentrations can be used as a raw material within the zinc sector instead of zinc ores.
EAF slag is reused as gravel substitute in construction work and mill scale can be recycled as clinker in de cement industry. EAF slag has been allocated as a by-product form EAF steel production.

In this chapter, the life cycle inventory for the newly modelled 42CrMoS4 alloyed electric steel is presented. All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 21) and and raw process data are presented in X-Echange table (see Table 22).

Data basis

Data for the new inventory of steel, electric, alloy 42CrMoS4 produced in Switzerland was obtained by Silvan Gassman, within the framework of his Masters Thesis at Swiss Steel Group. Swiss Steel Group produces steel for the automotive, machinery and apparatus industry with special alloys. The production of EAF steel from SwissSteel produces EAF slag and ladle slag. EAF slag is reused by 91% and ladle slag is deposited by 100%. Emissions to air are listed according to the applied filter used for abatement.
The electric arc furnace slag is produced as a by-product, which is used in road construction (Swiss Steel) or as gravel substitute material (Stahl Gerlafingen). Dusts with enriched zinc concentrations can be used as a raw material within the zinc sector instead of zinc ores.

Allocation of by-products

The total amount of EAF slag produced per kg steel is 0.0106 kg/kg LS, assuming that 91% of the produced EAF slag is reused. EAF slag has been allocated economically with an average price for steel of 420 EUR/t (Meps, 2021) and an average price for electric arc furnace slag of 27 EUR/t assuming the same price for EAF slag like blast furncace slag (Fachstelle Nachhaltiges Bauen, 2016). This results in an average allocation factor for EAF slag of 0.0006, the remaining inputs and emissions with an allocation factor of 0.9994 are allocated to steel.

Table 21: Metadata for the production of 1 kg of steel with 42CrMoS4 alloyed, produced by EAF route in Switzerland

Name	steel, electric, alloyed, 42CrMoS4, at plant	electric arc furnace slag, alloyed, 42CrMoS4, at plant
Location	CH	CH
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Transports of scrap metal and other input materials to electric arc furnace, steel making process and casting.	
Amount	1	1
LocalName	Elektrostahl, legiert, 42CrMoS4, ab Werk	Elektrostahlschlacke, legiert, ab Werk
Synonyms	0	0
GeneralComment	Data for the new inventory of steel, electric, alloy 42CrMoS4 produced in Switzerland was obtained by Silvan Gassman, within the framework of his Masters Thesis at Swiss Steel Group. Swiss Steel Group produces steel for the automotive, machinery and apparatus industry with special alloys. The production of EAF steel from SwissSteel produces EAF slag and ladle slag. EAF slag is reused by 91% and ladle slag is deposited by 100%. Emissions to air are listed according to the applied filter used for abatement. Remark: This process produces secondary steel. Only scrap is used as iron bearing input.; Geography: Data relate to plants from Swisssteel in Switzerland. Economical allocation factor of 0.9994	Total amount of EAF slag produced is 0.0106 kg/kg LS. economical allocation of EAF slag with allocation factor: 0.0006
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	production	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula	1	
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Data from industry referring to Switzerland	Data from industry referring to Switzerland
Technolgy	Industry data.	Industry data.
Representativeness		
ProductionVolume		
SamplingProcedure	Data from industry referring to Switzerland	Data from industry referring to Switzerland
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 22: Unit process data for the production of 1 kg 42CrMoS4 electric steel in Switzerland

	Name	Location	Infrastructure Process	Unit	steel, electric, alloyed, 42CrMoS4, at plant	electric arc furnace slag, alloyed, 42CrMoS4, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH	CH			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	steel, electric, alloyed, 42CrMoS4, at plant	CH	0	kg	1	0			
product	electric arc furnace slag, alloyed, 42CrMoS4, at plant	CH	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	6.00E-3	3.70E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
technosphere	iron scrap, at plant	CH	0	kg	1.10E+0	6.77E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
	electricity, medium voltage, at grid	CH	0	kWh	4.96E-1	3.06E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); Metling current 496 kWh/t;
	electricity, medium voltage, at grid	CH	0	kWh	7.13E-2	4.40E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); Auxiliary energy 71.3 kWh/t;
	compressed air, average installation, >30kW, 6 bar gauge, at supply network	RER	0	m3	6.61E-2	4.08E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 63.4 Nm³/t;
	anode, aluminium electrolysis	RER	0	kg	2.50E-3	1.54E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 2.5 kg/t;
	electric arc furnace converter	RER	1	unit	4.00E-11	2.47E-14	1	3.00	(2,2,1,1,1,nA,BU:3); not modified;
	oxygen, liquid, at plant	RER	0	kg	2.36E-2	1.46E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 16.51 Nm³/t;
	argon, liquid, at plant	RER	0	kg	3.92E-4	2.42E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.220 Nm³/t;
	nitrogen, liquid, at plant	RER	0	kg	3.98E-5	2.45E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 25 t/a;
	acetylene, at regional storehouse	CH	0	kg	3.98E-5	2.45E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 25 t/a;
	refractory, basic, packed, at plant	DE	0	kg	8.71E-3	5.38E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 5'475 t/a;
	refractory, fireclay, packed, at plant	DE	0	kg	6.49E-3	4.00E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 4'079 t/a;
	quicklime, in pieces, loose, at plant	CH	0	kg	3.98E-2	2.46E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 39.8 kg/t;
	sand, at mine	CH	0	kg	7.76E-3	4.79E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 4'877 t/a;
	clay, at mine	CH	0	kg	6.22E-3	3.84E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 3'913 t/a;
	hard coal mix, at regional storage	UCTE	0	kg	7.79E-3	4.81E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); Anthracite + blow carbon 7.79 kg/t;
	natural gas, high pressure, at consumer	CH	0	MJ	1.70E-1	1.05E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.0045915 m3 * 37 MJ/m3;
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	2.05E-4	1.26E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.205 kg/t steel mill, wihtout H2O;
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	5.30E-5	3.27E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.053 kg/t Häldeli;
	lubricating oil, at plant	RER	0	kg	5.30E-5	3.27E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.053 kg/t;
	solvents, organic, unspecified, at plant	GLO	0	kg	3.30E-5	2.04E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.033 kg/t;
	diesel, at regional storage	CH	0	kg	2.46E-3	1.52E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); EAF slag transport;
	aluminium alloy, AlMg3, at plant	RER	0	kg	4.68E-4	2.89E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); Alloys 0.47 kg/t;
	hard coal mix, at regional storage	UCTE	0	kg	3.36E-3	2.07E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); C-Draht 3.36 kg/t;
	calcium carbide, technical grade, at plant	RER	0	kg	5.54E-5	3.42E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); CaSi (30% Ca / 65% Si) 0.18 kg/t;
	silicon carbide, at plant	RER	0	kg	1.20E-4	7.42E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); CaSi (30% Ca / 65% Si) 0.18 kg/t;
	ferrochromium, high-carbon, 68% Cr, at plant	GLO	0	kg	1.38E-2	8.54E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeCr 13.85 kg/t;
	ferromanganese, high-coal, 74.5% Mn, at regional storage	RER	0	kg	1.40E-3	8.63E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeMn 1.4 kg/t;
	molybdenite, at plant	GLO	0	kg	2.07E-3	1.27E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeMo (70% Mo) 2.95 kg/t;
	silica sand, at plant	DE	0	kg	1.17E-3	7.20E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeSi 1.17 kg/t;
	sulphite, at plant	RER	0	kg	4.55E-5	2.81E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); S 0.05 kg/t;
	manganese, at regional storage	RER	0	kg	5.87E-3	3.62E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); SiMn (65% Mn / 18.5% Si) 9.03 kg/t;
	silicon carbide, at plant	RER	0	kg	1.67E-3	1.03E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); SiMn (65% Mn / 18.5% Si) 9.03 kg/t;
	transport, freight, rail, electricity with shunting	CH	0	tkm	2.04E-2	1.26E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Scrap transport by freight train CH;
	transport, freight, rail, electricity only	RER	0	tkm	6.44E-2	3.98E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Scrap transport by freight train EU;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	1.12E-1	6.94E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Scrap transport by lorry, CH/EU;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	4.79E-2	2.96E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), lorry;
	transport, freight, rail, electricity only	RER	0	tkm	1.23E-1	7.59E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), freight train;
	transport, transoceanic tanker	OCE	0	tkm	2.80E-1	1.73E-4	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), ship freight;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	1.16E-2	7.15E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by lorry;
	transport, freight, rail	RER	0	tkm	1.58E-2	9.73E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by freight train;
	transport, transoceanic tanker	OCE	0	tkm	3.27E-3	2.02E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by ship freight;
#BEZUG!	Particulates, > 10 um	-	-	kg	1.29E-7	7.97E-11	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter 87 (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	3.66E-7	2.26E-10	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 87 (42 % of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	3.66E-7	2.26E-10	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 87 (42 % of total dust amount);
	Lead	-	-	kg	1.44E-8	8.86E-12	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 87;
	Zinc	-	-	kg	1.44E-7	8.86E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 87;
	Particulates, > 10 um	-	-	kg	7.46E-8	4.61E-11	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter CCM (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	2.11E-7	1.30E-10	1	3.00	(2,2,1,1,1,nA,BU:3); Filter CCM (42 % of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	2.11E-7	1.30E-10	1	2.00	(2,2,1,1,1,nA,BU:2); Filter CCM (42 % of total dust amount);
	Lead	-	-	kg	3.55E-7	2.19E-10	1	5.00	(2,2,1,1,1,nA,BU:5); Filter CCM;
	Zinc	-	-	kg	3.55E-8	2.19E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter CCM;
	Particulates, > 10 um	-	-	kg	5.85E-7	3.61E-10	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter 99 EAF (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	1.66E-6	1.02E-9	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF (42% of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	1.66E-6	1.02E-9	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 99 EAF (42 % of total dust amount);
	Lead	-	-	kg	2.89E-7	1.78E-10	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Chromium	-	-	kg	7.80E-9	4.82E-12	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Nickel	-	-	kg	7.80E-9	4.82E-12	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Zinc	-	-	kg	3.20E-6	1.97E-9	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Cadmium	-	-	kg	4.68E-8	2.89E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Mercury	-	-	kg	6.24E-8	3.85E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	1.40E-13	8.67E-17	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF;
	Polychlorinated biphenyls	-	-	kg	2.18E-9	1.35E-12	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF;
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.40E-7	8.67E-11	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF;
	Sulfur dioxide	-	-	kg	6.48E-5	4.00E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); Filter 99 EAF, reduced by a factor 100;
	Carbon monoxide, fossil	-	-	kg	2.32E-3	1.43E-6	1	5.00	(2,2,1,1,1,nA,BU:5); ;
	Hydrogen fluoride	-	-	kg	2.35E-6	1.45E-9	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Hydrogen chloride	-	-	kg	5.20E-6	3.21E-9	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Nitrogen oxides	-	-	kg	1.80E-4	1.11E-7	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Benzene	-	-	kg	2.28E-6	1.41E-9	1	3.00	(2,2,1,1,1,nA,BU:3); ;
	Benzene, hexachloro-	-	-	kg	2.00E-8	1.23E-11	1	3.00	(2,2,1,1,1,nA,BU:3); ;
	Copper	-	-	kg	2.31E-7	1.43E-10	1	5.00	(2,2,1,1,1,nA,BU:5); ;
	Water, CH	-	-	kg	2.92E+0	1.80E-3	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
emission water, unspecified	Water, CH	-	-	m3	2.92E-3	1.80E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
technosphere	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	1.05E-2	6.51E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); EAF slag 9% deposited, rest ist used as gravel substitute;
	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	1.28E-2	7.89E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); laddle slag, 100% deposited;
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.15E-2	7.08E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); dust from filter;
	disposal, hazardous waste, 25% water, to hazardous waste incineration	CH	0	kg	1.63E-2	1.00E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); A09 - mineral waste, heavily polluted (10'232 t/a);
	disposal, solvents mixture, 16.5% water, to hazardous waste incineration	CH	0	kg	3.18E-6	1.96E-9	1	1.07	(2,2,1,1,1,nA,BU:1.05); A05 - solvents (2 t/a);
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	3.18E-5	1.96E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); A04 - 20 t/a;
	disposal, separator sludge, 90% water, to hazardous waste incineration	CH	0	kg	5.55E-4	3.43E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); A01 + B01 (234 t/a + 115 t/a);
	disposal, refractory SPL, Al elec.lysis, 0% water, to residual material landfill	CH	0	kg	3.89E-3	2.40E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); C05 - fireproof material;
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	1.98E-2	1.23E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); C06 - inert waste deposit (12'478 t/a);

5.6.5 Steel, electric, alloyed, 44FMn38, at plant/CH in DETEC

In this chapter the life cycle inventory for the newly modelled 44FMn38 alloyed electric steel is presented. All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 23) and and raw process data are presented in X-Echange table (see Table 24).

Data basis

Data for the new inventory of steel, electric, alloy 44FMn38 produced in Switzerland was obtained by by Silvan Gassman, within the framework of his Masters Thesis at Swiss Steel Group. Swiss Steel Group produces steel for the automotive, machinery and apparatus industry with special alloys. The production of EAF steel from SwissSteel produces EAF slag and ladle slag. EAF slag is reused by 91% and ladle slag is deposited by 100%. Emissions to air are listed according to the applied filter used for abatement.
The electric arc furnace slag is produced as a by-product, which is used in road construction (Swiss Steel) or as gravel substitute material (Stahl Gerlafingen). Dusts with enriched zinc concentrations can be used as a raw material within the zinc sector instead of zinc ores.

Allocation of by-products

The total amount of EAF slag produced per kg steel is 0.0108 kg/kg LS, assuming that 91% of the produced EAF slag is reused. EAF slag has been allocated economically with an average price for steel of 420 EUR/t (Meps, 2021) and an average price for electric arc furnace slag of 27 EUR/t assuming the same price for EAF slag like blast furncace slag (Fachstelle Nachhaltiges Bauen, 2016). This results in an average allocation factor for EAF slag of 0.0006, the remaining inputs and emissions with an allocation factor of 0.9994 are allocated to steel.

Table 23: Metadata for the production of 1 kg of steel with 44FMn28 alloyed, produced by EAF route in Switzerland

Name	steel, electric, alloyed, 44FMn28, at plant	electric arc furnace slag, alloyed, 44FMn28, at plant
Location	CH	CH
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Transports of scrap metal and other input materials to electric arc furnace, steel making process and casting.	
Amount	1	1
LocalName	Elektrostahl, legiert, 44FMn28, ab Werk	Elektrostahlschlacke, legiert, ab Werk
Synonyms	0	0
GeneralComment	Data for the new inventory of steel, electric, alloy 44FMn38 produced in Switzerland was obtained by by Silvan Gassman, within the framework of his Masters Thesis at Swiss Steel Group. Swiss Steel Group produces steel for the automotive, machinery and apparatus industry with special alloys. The production of EAF steel from SwissSteel produces EAF slag and ladle slag. EAF slag is reused by 91% and ladle slag is deposited by 100%. Emissions to air are listed according to the applied filter used for abatement. Remark: This process produces secondary steel. Only scrap is used as iron bearing input.; Geography: Data relate to plants from Swisssteel in Switzerland, economical allocation factor: 0.9994	Total amount of EAF slag produced is 0.0108 kg/kg LS. economical allocation of EAF slag with allocation factor: 0.0006
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	production	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula	1	
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Data from industry, referring to Switzerland	Data from industry, referring to Switzerland
Technolgy	Industry data.	Industry data.
Representativeness		
ProductionVolume		
SamplingProcedure	Data from industry, referring to Switzerland	Data from industry, referring to Switzerland
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 24: Unit process data for the production of 1 kg 44FMn28 electric steel in Switzerland

	Name	Location	Infrastructure Process	Unit	steel, electric, alloyed, 44FMn28, at plant	electric arc furnace slag, alloyed, 44FMn28, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH	CH			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	steel, electric, alloyed, 44FMn28, at plant	CH	0	kg	1	0			
product	electric arc furnace slag, alloyed, 44FMn28, at plant	CH	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	6.00E-4	3.80E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
technosphere	iron scrap, at plant	CH	0	kg	1.10E+0	7.01E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); Application 91.36%;
	compressed air, average installation, >30kW, 6 bar gauge, at supply network	RER	0	m3	6.61E-2	4.20E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 63.4 Nm³/t;
	anode, aluminium electrolysis	RER	0	kg	2.50E-3	1.59E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 2.5 kg/t;
	electric arc furnace converter	RER	1	unit	4.00E-11	2.54E-14	1	1.07	(2,2,1,1,1,nA,BU:1.05); not modified;
	oxygen, liquid, at plant	RER	0	kg	2.25E-2	1.43E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 15.74 Nm³/t;
	argon, liquid, at plant	RER	0	kg	4.14E-4	2.62E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.232 Nm³/t;
	nitrogen, liquid, at plant	RER	0	kg	3.98E-5	2.52E-8	1	3.00	(2,2,1,1,1,nA,BU:3); 25 t/a;
	acetylene, at regional storehouse	CH	0	kg	3.98E-5	2.52E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 25 t/a;
	refractory, basic, packed, at plant	DE	0	kg	8.71E-3	5.53E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 5'475 t/a;
	refractory, fireclay, packed, at plant	DE	0	kg	6.49E-3	4.12E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 4'079 t/a;
	quicklime, in pieces, loose, at plant	CH	0	kg	2.14E-2	1.36E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 21 kg/t;
	sand, at mine	CH	0	kg	7.76E-3	4.92E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 4'877 t/a;
	clay, at mine	CH	0	kg	6.22E-3	3.95E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 3'913 t/a;
	hard coal mix, at regional storage	UCTE	0	kg	5.81E-3	3.69E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); Anthracite + blow carbon 7.79 kg/t;
	natural gas, high pressure, at consumer	CH	0	MJ	1.70E-1	1.08E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.0045915 m3 * 37 MJ/m3;
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	2.05E-4	1.30E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.205 kg/t steel mill, wihtout H2O;
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	5.30E-5	3.36E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.053 kg/t Häldeli;
	lubricating oil, at plant	RER	0	kg	5.30E-5	3.36E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.053 kg/t;
	solvents, organic, unspecified, at plant	GLO	0	kg	3.30E-5	2.09E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.033 kg/t;
	diesel, at regional storage	CH	0	kg	2.46E-3	1.56E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); EAF slag transport;
	aluminium alloy, AlMg3, at plant	RER	0	kg	4.68E-4	2.97E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); Alloys: 0.47 kg/t;
	hard coal mix, at regional storage	UCTE	0	kg	4.01E-3	2.54E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); C-wire 4 kg/t;
	calcium carbide, technical grade, at plant	RER	0	kg	2.67E-3	1.70E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); Alloys: CaSi (30% Ca / 65% Si) 0.14 kg/t;
	silicon carbide, at plant	RER	0	kg	5.79E-3	3.67E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); CaSi (30% Ca / 65% Si) 0.14 kg/t;
	ferromanganese, high-coal, 74.5% Mn, at regional storage	RER	0	kg	1.25E-2	7.95E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeMn 12.54 kg/t;
	silica sand, at plant	DE	0	kg	9.14E-4	5.80E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeSi 0.9 kg/t;
	sulphite, at plant	RER	0	kg	3.16E-3	2.01E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); S 3.17 kg/t;
	manganese, at regional storage	RER	0	kg	5.79E-3	3.67E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); SiMn (65% Mn / 18.5% Si) 8.91 kg/t;
	silicon carbide, at plant	RER	0	kg	1.65E-3	1.05E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); SiMn (65% Mn / 18.5% Si) 8.91 kg/t;
	transport, freight, rail, electricity with shunting	CH	0	tkm	2.06E-2	1.31E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); Scrap transport by freight train CH;
	transport, freight, rail, electricity only	RER	0	tkm	6.50E-2	4.12E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); Scrap transport by freight train EU;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	1.13E-1	7.19E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); Scrap transport by lorry, CH/EU;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	6.57E-2	4.17E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), lorry;
	transport, freight, rail, electricity only	RER	0	tkm	7.49E-2	4.75E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), freight train;
	transport, transoceanic tanker	OCE	0	tkm	4.07E-1	2.58E-4	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), ship freight;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	1.19E-2	7.54E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by lorry;
	transport, freight, rail	RER	0	tkm	1.59E-2	1.01E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by freight train;
	transport, transoceanic tanker	OCE	0	tkm	3.35E-3	2.12E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by ship freight;
	electricity, medium voltage, at grid	CH	0	kWh	4.79E-1	3.04E-4	1	2.00	(2,2,1,1,1,nA,BU:2); Melting current 496 kWh/t;
	electricity, medium voltage, at grid	CH	0	kWh	7.13E-2	4.52E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Auxiliary energy 71.3 kWh/t;
emission air, unspecified	Particulates, > 10 um	-	-	kg	1.29E-7	8.19E-11	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 87 (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	3.66E-7	2.32E-10	1	1.07	(2,2,1,1,1,nA,BU:1.05); Filter 87 (42 % of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	3.66E-7	2.32E-10	1	1.07	(2,2,1,1,1,nA,BU:1.05); Filter 87 (42 % of total dust amount);
	Lead	-	-	kg	1.44E-8	9.11E-12	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter 87;
	Zinc	-	-	kg	1.44E-7	9.11E-11	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 87;
	Particulates, > 10 um	-	-	kg	7.46E-8	4.73E-11	1	2.00	(2,2,1,1,1,nA,BU:2); Filter CCM (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	2.11E-7	1.34E-10	1	5.00	(2,2,1,1,1,nA,BU:5); Filter CCM (42 % of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	2.11E-7	1.34E-10	1	5.00	(2,2,1,1,1,nA,BU:5); Filter CCM (42 % of total dust amount);
	Lead	-	-	kg	3.55E-7	2.25E-10	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter CCM;
	Zinc	-	-	kg	3.55E-8	2.25E-11	1	3.00	(2,2,1,1,1,nA,BU:3); Filter CCM;
	Particulates, > 10 um	-	-	kg	5.85E-7	3.71E-10	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 99 EAF (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	1.66E-6	1.05E-9	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF (42% of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	1.66E-6	1.05E-9	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF (42 % of total dust amount);
	Lead	-	-	kg	2.89E-7	1.83E-10	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter 99 EAF;
	Chromium	-	-	kg	7.80E-9	4.95E-12	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF;
	Nickel	-	-	kg	7.80E-9	4.95E-12	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 99 EAF;
	Zinc	-	-	kg	3.20E-6	2.03E-9	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Cadmium	-	-	kg	4.68E-8	2.97E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Mercury	-	-	kg	6.24E-8	3.96E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	1.40E-13	8.91E-17	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Polychlorinated biphenyls	-	-	kg	2.18E-9	1.39E-12	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.40E-7	8.91E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Sulfur dioxide	-	-	kg	6.48E-5	4.11E-8	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF, reduced by a factor 100;
	Carbon monoxide, fossil	-	-	kg	2.32E-3	1.47E-6	1	3.00	(2,2,1,1,1,nA,BU:3); ;
	Hydrogen fluoride	-	-	kg	2.35E-6	1.49E-9	1	3.00	(2,2,1,1,1,nA,BU:3); ;
	Hydrogen chloride	-	-	kg	5.20E-6	3.30E-9	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
	Nitrogen oxides	-	-	kg	1.80E-4	1.14E-7	1	5.00	(2,2,1,1,1,nA,BU:5); ;
	Benzene	-	-	kg	2.29E-6	1.45E-9	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Benzene, hexachloro-	-	-	kg	2.00E-8	1.27E-11	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Copper	-	-	kg	2.31E-7	1.46E-10	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Water, CH	-	-	kg	2.92E+0	1.85E-3	1	3.00	(2,2,1,1,1,nA,BU:3); ;
emission water, unspecified	Water, CH	-	-	m3	2.92E-3	1.85E-6	1	3.00	(2,2,1,1,1,nA,BU:3); ;
technosphere	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	9.76E-4	6.19E-7	1	5.00	(2,2,1,1,1,nA,BU:5); EAF slag 9% deposited, rest is reused;
	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	1.28E-2	8.10E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); laddle slag, 100% deposited;
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.15E-2	7.27E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); dust from filter;
	disposal, hazardous waste, 25% water, to hazardous waste incineration	CH	0	kg	1.63E-2	1.03E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); A09 - mineral waste, heavily polluted (10'232 t/a);
	disposal, solvents mixture, 16.5% water, to hazardous waste incineration	CH	0	kg	3.18E-6	2.02E-9	1	1.07	(2,2,1,1,1,nA,BU:1.05); A05 - solvents (2 t/a);
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	3.18E-5	2.02E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); A04 - 20 t/a;
	disposal, separator sludge, 90% water, to hazardous waste incineration	CH	0	kg	5.55E-4	3.52E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); A01 + B01 (234 t/a + 115 t/a);
	disposal, refractory SPL, Al elec.lysis, 0% water, to residual material landfill	CH	0	kg	3.89E-3	2.47E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); C05 - fireproof material;
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	1.98E-2	1.26E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); C06 - inert waste deposit (12'478 t/a);

5.6.6 Steel, electric, alloyed, 23MnCrSiMoF66, at plant/CH in DETEC

In this chapter the life cycle inventory for the newly modelled 23MnCrSiMoF66 alloyed electric steel is presented. All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 25) and and raw process data are presented in X-Echange table (see Table 26).

Data basis

Data for the new inventory of steel, electric, alloy 23MnCrSiMoF66 produced in Switzerland was obtained by Silvan Gassman, within the framework of his Masters Thesis at Swiss Steel Group. Swiss Steel Group produces steel for the automotive, machinery and apparatus industry with special alloys. The production of EAF steel from SwissSteel produces EAF slag and ladle slag. EAF slag is reused by 91% and ladle slag is deposited by 100%. Emissions to air are listed according to the applied filter used for abatement.

The electric arc furnace slag is produced as a by-product, which is used in road construction (Swiss Steel) or as gravel substitute material (Stahl Gerlafingen). Dusts with enriched zinc concentrations can be used as a raw material within the zinc sector instead of zinc ores.

Allocation of by-products

The total amount of EAF slag produced per kg steel is 0.0099 kg/kg LS, assuming that 91% of the produced EAF slag is reused. EAF slag has been allocated economically with an average price for steel of 420 EUR/t (Meps, 2021) and an average price for electric arc furnace slag of 27 EUR/t assuming the same price for EAF slag like blast furncace slag (Fachstelle Nachhaltiges Bauen, 2016). This results in an average allocation factor for EAF slag of 0.0006, the remaining inputs and emissions with an allocation factor of 0.9994 are allocated to steel.

Table 25: Metadata for the production of 1 kg of steel with 23MnCrSiMoF66 alloyed, produced by EAF route in Switzerland

Name	steel, electric, alloyed, 23MnCrSiMoF66, at plant	electric arc furnace slag, alloyed, 23MnCrSi-MoF66, at plant
Location	CH	CH
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Transports of scrap metal and other input materials to electric arc furnace, steel making process and casting.	
Amount	1	1
LocalName	Elektrostahl, legiert, 23MnCrSiMoF66, ab Werk	Elektrostahlschlacke, legiert, ab Werk
Synonyms	0	0
GeneralComment	Data for the new inventory of steel, electric, alloy 23MnCrSiMoF66 produced in Switzerland was obtained by Silvan Gassman, within the framework of his Masters Thesis at Swiss Steel Group. Swiss Steel Group produces steel for the automotive, machinery and apparatus industry with special alloys. The production of EAF steel from SwissSteel produces EAF slag and ladle slag. EAF slag is reused by 91% and ladle slag is deposited by 100%. Emissions to air are listed according to the applied filter used for abatement. Remark: This process produces secondary steel. Only scrap is used as iron bearing input.; Geography: Data relate to plants from Swisssteel in Switzerland, Allocation factor: 0.9994	Total amount of EAF slag produced is 0.0099 kg/kg LS is produced. Economical allocation of EAF slag with allocation factor 0.0006,
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	production	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula	1	
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Data from industry, referring to Switzerland	Data from industry, referring to Switzerland
Technolgy	Industry data.	Industry data.
Representativeness		
ProductionVolume		
SamplingProcedure	Data from industry, referring to Switzerland	Data from industry, referring to Switzerland
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 26: Unit process data for the production of 1 kg 23MnCrSiMoF66 alloyed electric steel in Switzerland

	Name	Location	Infrastructure Process	Unit	steel, electric, alloyed, 23MnCrSiMoF66, at plant	electric arc furnace slag, alloyed, 23MnCrSiMoF66, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH	CH			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	steel, electric, alloyed, 23MnCrSiMoF66, at plant	CH	0	kg	1	0			
product	electric arc furnace slag, alloyed, 23MnCrSiMoF66, at plant	CH	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	6.00E-4	3.46E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
technosphere	iron scrap, at plant	CH	0	kg	1.10E+0	6.32E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); Application 91.36%;
	electricity, medium voltage, at grid	CH	0	kWh	4.94E-1	2.85E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); Melting current 493 kWh/t;
	electricity, medium voltage, at grid	CH	0	kWh	7.13E-2	4.11E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); Auxiliary energy 71.3 kWh/t;
	compressed air, average installation, >30kW, 6 bar gauge, at supply network	RER	0	m3	6.61E-2	3.81E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 63.4 Nm³/t;
	anode, aluminium electrolysis	RER	0	kg	2.50E-3	1.44E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 2.5 kg/t;
	electric arc furnace converter	RER	1	unit	4.00E-11	2.30E-14	1	3.00	(2,2,1,1,1,nA,BU:3); not modified;
	oxygen, liquid, at plant	RER	0	kg	2.40E-2	1.38E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 16.76 Nm³/t;
	argon, liquid, at plant	RER	0	kg	4.69E-4	2.70E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.263 Nm³/t;
	nitrogen, liquid, at plant	RER	0	kg	3.98E-5	2.29E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 25 t/a;
	acetylene, at regional storehouse	CH	0	kg	3.98E-5	2.29E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 25 t/a;
	refractory, basic, packed, at plant	DE	0	kg	8.71E-3	5.02E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 5'475 t/a;
	refractory, fireclay, packed, at plant	DE	0	kg	6.49E-3	3.74E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 4'079 t/a;
	quicklime, in pieces, loose, at plant	CH	0	kg	5.36E-2	3.09E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 53.6 kg/t;
	sand, at mine	CH	0	kg	7.76E-3	4.47E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 4'877 t/a;
	clay, at mine	CH	0	kg	6.22E-3	3.59E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 3'913 t/a;
	hard coal mix, at regional storage	UCTE	0	kg	8.09E-3	4.66E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); Anthracite + blow carbon 7.79 kg/t;
	natural gas, high pressure, at consumer	CH	0	MJ	1.70E-1	9.79E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.0045915 m3 * 37 MJ/m3;
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	2.05E-4	1.18E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.205 kg/t steel mill, wihtout H2O;
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	5.30E-5	3.05E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.053 kg/t Häldeli;
	lubricating oil, at plant	RER	0	kg	5.30E-5	3.05E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.053 kg/t;
	solvents, organic, unspecified, at plant	GLO	0	kg	3.30E-5	1.90E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.033 kg/t;
	diesel, at regional storage	CH	0	kg	2.46E-3	1.42E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); EAF slag transport;
	hard coal mix, at regional storage	UCTE	0	kg	6.34E-5	3.65E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); C-wire 0.06 kg/t;
	calcium carbide, technical grade, at plant	RER	0	kg	1.96E-5	1.13E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); Legierungen: CaSi (30% Ca / 65% Si) 0.07 kg/t;
	silicon carbide, at plant	RER	0	kg	4.24E-5	2.44E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); CaSi (30% Ca / 65% Si) 0.07 kg/t;
	ferrochromium, high-carbon, 68% Cr, at plant	GLO	0	kg	2.18E-2	1.26E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeCr 21.73 kg/t;
	ferromanganese, high-coal, 74.5% Mn, at regional storage	RER	0	kg	4.04E-3	2.33E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeMn 4.04 kg/t;
	molybdenite, at plant	GLO	0	kg	1.27E-3	7.32E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeMo (70% Mo) 1.81 kg/t;
	silica sand, at plant	DE	0	kg	1.09E-2	6.29E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeSi 10.89 kg/t;
	titanium dioxide, production mix, at plant	RER	0	kg	8.82E-5	5.08E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeTi (75% Ti / 5% Al) 0.12 kg/t;
	aluminium alloy, AlMg3, at plant	RER	0	kg	5.88E-6	3.39E-9	1	1.07	(2,2,1,1,1,nA,BU:1.05); FeTi (75% Ti / 5% Al) 0.12 kg/t;
	sulphite, at plant	RER	0	kg	1.24E-3	7.15E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); S 1.24 kg/t;
	manganese, at regional storage	RER	0	kg	1.19E-2	6.83E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); SiMn (65% Mn / 18.5% Si) 18.19 kg/t;
	silicon carbide, at plant	RER	0	kg	3.37E-3	1.94E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); SiMn (65% Mn / 18.5% Si) 18.19 kg/t;
	transport, freight, rail, electricity with shunting	CH	0	tkm	6.47E-2	3.73E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Scrap transport by freight train CH;
	transport, freight, rail, electricity only	RER	0	tkm	2.05E-2	1.18E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Scrap transport by freight train EU;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	1.13E-1	6.51E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Scrap transport by lorry, CH/EU;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	5.94E-2	3.42E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), lorry;
	transport, freight, rail, electricity only	RER	0	tkm	2.28E-1	1.31E-4	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), freight train;
	transport, transoceanic tanker	OCE	0	tkm	3.92E-1	2.26E-4	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), ship freight;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	1.09E-2	6.27E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by lorry;
	transport, freight, rail	RER	0	tkm	1.57E-2	9.04E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by freight train;
	transport, transoceanic tanker	OCE	0	tkm	3.24E-3	1.87E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by ship freight;
#BEZUG!	Particulates, > 10 um	-	-	kg	1.29E-7	7.45E-11	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter 87 (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	3.66E-7	2.11E-10	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 87 (42 % of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	3.66E-7	2.11E-10	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 87 (42 % of total dust amount);
	Lead	-	-	kg	1.44E-8	8.27E-12	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 87;
	Zinc	-	-	kg	1.44E-7	8.27E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 87;
	Particulates, > 10 um	-	-	kg	7.46E-8	4.30E-11	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter CCM (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	2.11E-7	1.22E-10	1	3.00	(2,2,1,1,1,nA,BU:3); Filter CCM (42 % of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	2.11E-7	1.22E-10	1	2.00	(2,2,1,1,1,nA,BU:2); Filter CCM (42 % of total dust amount);
	Lead	-	-	kg	3.55E-7	2.05E-10	1	5.00	(2,2,1,1,1,nA,BU:5); Filter CCM;
	Zinc	-	-	kg	3.55E-8	2.05E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter CCM;
	Particulates, > 10 um	-	-	kg	5.85E-7	3.37E-10	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter 99 EAF (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	1.66E-6	9.56E-10	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF (42% of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	1.66E-6	9.56E-10	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 99 EAF (42 % of total dust amount);
	Lead	-	-	kg	2.89E-7	1.66E-10	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Chromium	-	-	kg	7.80E-9	4.50E-12	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Nickel	-	-	kg	7.80E-9	4.50E-12	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Zinc	-	-	kg	3.20E-6	1.84E-9	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Cadmium	-	-	kg	4.68E-8	2.70E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Mercury	-	-	kg	6.24E-8	3.60E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	1.40E-13	8.10E-17	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF;
	Polychlorinated biphenyls	-	-	kg	2.18E-9	1.26E-12	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF;
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.40E-7	8.10E-11	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF;
	Sulfur dioxide	-	-	kg	6.48E-5	3.73E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); Filter 99 EAF, reduced by a factor 100;
	Carbon monoxide, fossil	-	-	kg	2.32E-3	1.34E-6	1	5.00	(2,2,1,1,1,nA,BU:5); ;
	Hydrogen fluoride	-	-	kg	2.35E-6	1.35E-9	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Hydrogen chloride	-	-	kg	5.20E-6	3.00E-9	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Nitrogen oxides	-	-	kg	1.80E-4	1.04E-7	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Benzene	-	-	kg	2.29E-6	1.32E-9	1	3.00	(2,2,1,1,1,nA,BU:3); ;
	Benzene, hexachloro-	-	-	kg	2.00E-8	1.15E-11	1	3.00	(2,2,1,1,1,nA,BU:3); ;
	Copper	-	-	kg	2.31E-7	1.33E-10	1	5.00	(2,2,1,1,1,nA,BU:5); ;
	Water, CH	-	-	kg	2.92E+0	1.68E-3	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
emission water, unspecified	Water, CH	-	-	m3	2.92E-3	1.68E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
technosphere	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	8.86E-4	5.11E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); EAF slag 9% deposited, rest ist used as gravel substitute;
	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	1.28E-2	7.36E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); laddle slag, 100% deposited;
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.07E-2	6.18E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); dust from filter;
	disposal, hazardous waste, 25% water, to hazardous waste incineration	CH	0	kg	1.63E-2	9.38E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); A09 - mineral waste, heavily polluted (10'232 t/a);
	disposal, solvents mixture, 16.5% water, to hazardous waste incineration	CH	0	kg	3.18E-6	1.83E-9	1	1.07	(2,2,1,1,1,nA,BU:1.05); A05 - solvents (2 t/a);
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	3.18E-5	1.83E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); A04 - 20 t/a;
	disposal, separator sludge, 90% water, to hazardous waste incineration	CH	0	kg	5.55E-4	3.20E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); A01 + B01 (234 t/a + 115 t/a);
	disposal, refractory SPL, Al elec.lysis, 0% water, to residual material landfill	CH	0	kg	3.89E-3	2.24E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); C05 - fireproof material;
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	1.98E-2	1.14E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); C06 - inert waste deposit (12'478 t/a);

5.6.7 Steel, electric, unalloyed, at plant/CH in DETEC

In this chapter the life cycle inventory for the newly modelled unalloyed electric steel is presented. All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 27) and raw process data are presented in X-Echange table (see Table 28).

Data basis

This inventory was created by Carbotech AG on the basis of the Swiss Steel Group data for „steel, electric, alloyed, 42CrMoS4, at plant, CH". In order to create an inventory for an unalloyed steel, all alloy inputs were removed and transport amounts were adapted to the input amounts. The production of EAF steel from SwissSteel produces EAF slag and ladle slag. EAF slag is reused by 91% and ladle slag is deposited by 100%. Emissions to air are listed according to the applied filter used for abatement.
The electric arc furnace slag is produced as a by-product, which is used in road construction (Swiss Steel) or as gravel substitute material (Stahl Gerlafingen) and ladle slag is deposited. Dusts with enriched zinc concentrations can be used as a raw material within the zinc sector instead of zinc ores.

Allocation of by-products

The total amount of EAF slag produced per kg steel is 0.0106 kg/kg LS assuming that 91% of the produced EAF slag is reused. EAF slag has been allocated economically with an average price for steel of 420 EUR/t (Meps, 2021) and an average price for electric arc furnace slag of 27 EUR/t assuming the same price for EAF slag like blast furncace slag (Fachstelle Nachhaltiges Bauen, 2016). This results in an average allocation factor for EAF slag of 0.0006, the remaining inputs and emissions with an allocation factor of 0.9994 are allocated to steel.

Table 27: Metadata for the production of 1kg unalloyed steel produced by EAF route in Switzerland.

Name	steel, electric, unalloyed, at plant	electric arc furnace slag, unalloyed, at plant
Location	CH	CH
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	Included processes: Transports of scrap metal and other input materials to electric arc furnace, steel making process and casting.	
Amount	1	1
LocalName	Elektrstahl, unlegiert, ab Werk	Elektrostahlschlacke, unlegiert, ab Werk
Synonyms	0	0
GeneralComment	This inventory was created by Carbotech AG on the basis of the Swiss Steel Group data for „steel, electric, alloyed, 42CrMoS4, at plant, CH". In order to create an inventory for an unalloyed steel, all alloy inputs were removed and transport amounts were adapted to the input amounts. The production of EAF steel from SwissSteel produces EAF slag and ladle slag. EAF slag is reused by 91% and ladle slag is deposited by 100%. Emissions to air are listed according to the applied filter used for abatement. Remark: This process produces secondary steel. Only scrap is used as iron bearing input.; Geography: Data relate to plants from Swisssteel in Switzerland, Allocation factor: 0.9994	Total amount of EAF slag produced is 0.0106 kg/kg LS. economical allocation of EAF slag with allocation factor 0.0006
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	production	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula	1	
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Switzerland	Switzerland
Technolgy	Industry data.	Industry data.
Representativeness		
ProductionVolume		
SamplingProcedure	Data from industry	Data from industry
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 28: Unit process data for the production of 1 kg unalloyed electric steel in Switzerland

	Name	Location	Infrastructure Process	Unit	steel, electric, unalloyed, at plant	electric arc furnace slag, unalloyed, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH	CH			
	Infrastructure Process				0	0			
	Unit				kg	kg			
product	steel, electric, unalloyed, at plant	CH	0	kg	1	0			
product	electric arc furnace slag, unalloyed, at plant	CH	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	-	m3	6.00E-4	3.72E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
technosphere	iron scrap, at plant	CH	0	kg	1.10E+0	6.80E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); Application 91.36%;
	compressed air, average generation, >30kW, 8 bar gauge, at compressor	RER	0	m3	6.61E-2	4.10E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 63.4 Nm^3/t;
	anode, aluminium electrolysis	RER	0	kg	2.50E-3	1.55E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 2.5 kg/t;
	electric arc furnace converter	RER	1	unit	4.00E-11	2.48E-14	1	1.07	(2,2,1,1,1,nA,BU:1.05); not modified;
	oxygen, liquid, at plant	RER	0	kg	2.36E-2	1.46E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 16.51 Nm^3/t;
	argon, liquid, at plant	RER	0	kg	3.92E-4	2.43E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.220 Nm^3/t;
	nitrogen, liquid, at plant	RER	0	kg	3.98E-5	2.47E-8	1	3.00	(2,2,1,1,1,nA,BU:3); 25 t/a;
	acetylene, at regional storehouse	CH	0	kg	3.98E-5	2.47E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 25 t/a;
	refractory, basic, packed, at plant	DE	0	kg	8.71E-3	5.40E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 5'475 t/a;
	refractory, fireclay, packed, at plant	DE	0	kg	6.49E-3	4.02E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 4'079 t/a;
	quicklime, in pieces, loose, at plant	CH	0	kg	3.98E-2	2.47E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); 39.8 kg/t;
	sand, at mine	CH	0	kg	7.76E-3	4.81E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 4'877 t/a;
	clay, at mine	CH	0	kg	6.22E-3	3.86E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); 3'913 t/a;
	hard coal mix, at regional storage	UCTE	0	kg	7.79E-3	4.83E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); Anthracite + blow carbon 7.79 kg/t;
	natural gas, high pressure, at consumer	CH	0	MJ	1.70E-1	1.05E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.0045915 m3 * 37 MJ/m3;
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	2.05E-4	1.27E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.205 kg/t steel mill, wihtout H2O;
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	5.30E-5	3.28E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.053 kg/t Häldeli;
	lubricating oil, at plant	RER	0	kg	5.30E-5	3.28E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.053 kg/t;
	solvents, organic, unspecified, at plant	GLO	0	kg	3.30E-5	2.05E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); 0.033 kg/t;
	diesel, at regional storage	CH	0	kg	2.46E-3	1.53E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); EAF slag transport;
	transport, freight, rail, electricity with shunting	CH	0	tkm	1.90E-2	1.18E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); Scrap transport by freight train CH;
	transport, freight, rail, electricity only	RER	0	tkm	5.90E-2	3.66E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); Scrap transport by freight train EU;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	1.03E-1	6.38E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); Scrap transport by lorry, CH/EU;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	3.29E-2	2.04E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), lorry;
	transport, freight, rail, electricity only	RER	0	tkm	4.22E-2	2.62E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), freight train;
	transport, transoceanic tanker	OCE	0	tkm	1.31E-1	8.15E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Transport input material (alloys, resources), ship freight;
	transport, freight, lorry 16-32 metric ton, EURO 6	RER	0	tkm	1.10E-2	6.82E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by lorry;
	transport, freight, rail	RER	0	tkm	1.60E-2	9.92E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by freight train;
	transport, transoceanic tanker	OCE	0	tkm	3.20E-3	1.98E-6	1	2.00	(2,2,1,1,1,nA,BU:2); Transport waste material by ship freight;
	electricity, medium voltage, at grid	CH	0	kWh	4.96E-1	3.08E-4	1	2.00	(2,2,1,1,1,nA,BU:2); Melting current 496 kWh/t;
	electricity, medium voltage, at grid	CH	0	kWh	7.13E-2	4.42E-5	1	2.00	(2,2,1,1,1,nA,BU:2); Auxiliary energy 71.3 kWh/t;
emission air, unspecified	Particulates, > 10 um	-	-	kg	1.29E-7	8.01E-11	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 87 (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	3.66E-7	2.27E-10	1	1.07	(2,2,1,1,1,nA,BU:1.05); Filter 87 (42 % of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	3.66E-7	2.27E-10	1	1.07	(2,2,1,1,1,nA,BU:1.05); Filter 87 (42 % of total dust amount);
	Lead	-	-	kg	1.44E-8	8.90E-12	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter 87;
	Zinc	-	-	kg	1.44E-7	8.90E-11	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 87;
	Particulates, > 10 um	-	-	kg	7.46E-8	4.63E-11	1	2.00	(2,2,1,1,1,nA,BU:2); Filter CCM (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	2.11E-7	1.31E-10	1	5.00	(2,2,1,1,1,nA,BU:5); Filter CCM (42 % of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	2.11E-7	1.31E-10	1	5.00	(2,2,1,1,1,nA,BU:5); Filter CCM (42 % of total dust amount);
	Lead	-	-	kg	3.55E-7	2.20E-10	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter CCM;
	Zinc	-	-	kg	3.55E-8	2.20E-11	1	3.00	(2,2,1,1,1,nA,BU:3); Filter CCM;
	Particulates, > 10 um	-	-	kg	5.85E-7	3.63E-10	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 99 EAF (15 % of total dust amount);
	Particulates, < 2.5 um	-	-	kg	1.66E-6	1.03E-9	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF (42% of total dust amount);
	Particulates, > 2.5 um, and < 10um	-	-	kg	1.66E-6	1.03E-9	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF (42 % of total dust amount);
	Lead	-	-	kg	2.89E-7	1.79E-10	1	1.51	(2,2,1,1,1,nA,BU:1.5); Filter 99 EAF;
	Chromium	-	-	kg	7.80E-9	4.84E-12	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF;
	Nickel	-	-	kg	7.80E-9	4.84E-12	1	2.00	(2,2,1,1,1,nA,BU:2); Filter 99 EAF;
	Zinc	-	-	kg	3.20E-6	1.98E-9	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Cadmium	-	-	kg	4.68E-8	2.90E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Mercury	-	-	kg	6.24E-8	3.87E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	1.40E-13	8.71E-17	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Polychlorinated biphenyls	-	-	kg	2.18E-9	1.35E-12	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.40E-7	8.71E-11	1	5.00	(2,2,1,1,1,nA,BU:5); Filter 99 EAF;
	Sulfur dioxide	-	-	kg	6.48E-5	4.02E-8	1	3.00	(2,2,1,1,1,nA,BU:3); Filter 99 EAF, reduced by a factor 100;
	Carbon monoxide, fossil	-	-	kg	2.32E-3	1.44E-6	1	3.00	(2,2,1,1,1,nA,BU:3); ;
	Hydrogen fluoride	-	-	kg	2.35E-6	1.46E-9	1	3.00	(2,2,1,1,1,nA,BU:3); ;
	Hydrogen chloride	-	-	kg	5.20E-6	3.22E-9	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
	Nitrogen oxides	-	-	kg	1.80E-4	1.12E-7	1	5.00	(2,2,1,1,1,nA,BU:5); ;
	Benzene	-	-	kg	2.28E-6	1.42E-9	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Benzene, hexachloro-	-	-	kg	2.00E-8	1.24E-11	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Copper	-	-	kg	2.31E-7	1.43E-10	1	1.51	(2,2,1,1,1,nA,BU:1.5); ;
	Water, CH	-	-	kg	2.92E+0	1.81E-3	1	3.00	(2,2,1,1,1,nA,BU:3); ;
emission water, unspecified	Water, CH	-	-	m3	2.92E-3	1.81E-6	1	3.00	(2,2,1,1,1,nA,BU:3); ;
technosphere	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	9.49E-4	5.89E-7	1	5.00	(2,2,1,1,1,nA,BU:5); EAF slag 9% deposited, rest ist used as gravel substitute;
	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	0	kg	1.28E-2	7.92E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); laddle slag, 100% deposited;
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.15E-2	7.11E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); dust from filter;
	disposal, hazardous waste, 25% water, to hazardous waste incineration	CH	0	kg	1.63E-2	1.01E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); A09 - mineral waste, heavily polluted (10'232 t/a);
	disposal, solvents mixture, 16.5% water, to hazardous waste incineration	CH	0	kg	3.18E-6	1.97E-9	1	1.07	(2,2,1,1,1,nA,BU:1.05); A05 - solvents (2 t/a);
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	3.18E-5	1.97E-8	1	1.07	(2,2,1,1,1,nA,BU:1.05); A04 - 20 t/a;
	disposal, separator sludge, 90% water, to hazardous waste incineration	CH	0	kg	5.55E-4	3.44E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); A01 + B01 (234 t/a + 115 t/a);
	disposal, refractory SPL, Al elec.lysis, 0% water, to residual material landfill	CH	0	kg	3.89E-3	2.41E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); C05 - fireproof material;
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	1.98E-2	1.23E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); C06 - inert waste deposit (12'478 t/a);

5.6.8 Steel, electric, low-alloyed, at plant/CH in DETEC

In this chapter the life cycle inventory for the newly modelled low-alloyed electric steel from Switzerland is presented. All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 29) and raw process data are presented in X-Echange table (see Table 30).

Data basis

The inventory for the process low-alloyed steel produced by EAF route in Switzerland was created with data from Stahl Gerlafingen. Stahl Gerlafingen produces mainly reinforcing steel for construction. The data was collected by Melanie Haupt as part of her PhD thesis (2018). The data include emissions to water.

Allocation of by-products

The total amount of slag produced is 0.1728 kg/kg LS. 91% of the produced slag is reused, which results in 0.1572 kg/kg LS and 9% of the slag is deposited. The EAF slag has been allocated economically with an average price for steel of 420 EUR/t (Meps, 2021) and an average price for electric arc furnace slag of 27 EUR/t assuming the same price for EAF slag like blast furncace slag (Fachstelle Nachhaltiges Bauen, 2016). This results in an average allocation factor for EAF slag of 0.01, the remaining inputs and emissions with an allocation factor of 0.99 are allocated to steel.

Table 29: Metadata for the production of 1 kg low-alloyed steel in EAF in Switzerland

Name	steel, electric, low-alloyed, at plant	electric arc furnace slag, low-alloyed, at plant
Location	CH	CH
InfrastructureProcess	0	0
Unit	kg	kg
IncludedProcesses	The inventory for the process low-alloyed steel produced by EAF route in Switzerland was created with data from Stahl Gerlafingen. Stahl Gerlafingen produces mainly reinforcing steel for construction. The data was collected by Melanie Haupt as part of her PhD thesis (2018). The data include emissions to water. Included processes: Transports of scrap metal and other input materials to electric arc furnace, steel making process and casting. Remark: This process produces secondary steel. Only scrap is used as iron bearing input. EAF steel hass been allocated economically with an allocation factor of 0.99.	Total amount of EAF salg produced is 0.17276 kg/kg LS. Economical allocation of EAF slag with allocation factor of 0.01.
Amount	1	1
LocalName	Elektrostahl, niedriglegiert, ab Werk	Elektrostahlschlacke, niedriglegiert, ab Werk
Synonyms	0	0
GeneralComment	Inventory for 1 kg steel, based on data from (Haupt, 2020) economical allocation of EAF slag. Allocation factor of steel: 0.99	economical allocation of EAF slag. Allocation factor: 0.01, assumption 91% reused and 9% landfilled
InfrastructureIncluded	1	1
Category	metals	metals
SubCategory	extraction	extraction
LocalCategory	Metalle	Metalle
LocalSubCategory	Gewinnung	Gewinnung
Formula		
StatisticalClassification		
CASNumber		
StartDate	2018	2018
EndDate	2020	2020
DataValidForEntirePeriod	1	1
OtherPeriodText	Time of publications.	Time of publications.
Geography	Switzerland	Switzerland
Technolgy	Industry data.	Industry data.
Representativeness		
ProductionVolume		
SamplingProcedure	Data from industry	Data from industry
Extrapolations	Some generic datasets from ecoinvent have been used.	Some generic datasets from ecoinvent have been used.

Table 30: Unit process data for the production of 1 kg low-alloyed electric steel in Switzerland

	Name	Location	Category	Subcategory	Infrastructure Process	Unit	steel, electric, low-alloyed, at plant	electric arc furnace slag, low-alloyed, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location						CH	CH			
	Infrastructure Process						0	0			
	Unit						kg	kg			
product	steel, electric, low-alloyed, at plant	CH	-	-	0	kg	1	0			
product	electric arc furnace slag, low-alloyed, at plant	CH	-	-	0	kg	0	1			
resource, in water	Water, cooling, unspecified natural origin/m3	-	resource	in water	-	m3	9.56E-4	6.15E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
technosphere	anode, aluminium electrolysis	RER	-	-	0	kg	1.71E-3	1.10E-4	1	1.08	(2,2,1,3,1,nA,BU:1.05); ; (Haupt, 2020)
	electric arc furnace converter	RER	-	-	1	unit	4.27E-11	2.75E-12	1	3.96	(4,2,5,5,5,nA,BU:3); ; (Haupt, 2020)
	hard coal mix, at regional storage	UCTE	-	-	0	kg	1.64E-2	1.05E-3	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	iron scrap, at plant	CH	-	-	0	kg	7.49E-1	7.23E-2	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	iron scrap, at plant	RER	-	-	0	kg	3.76E-1	7.23E-2	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	natural gas, high pressure, at consumer	CH	-	-	0	MJ	7.51E-1	4.83E-2	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	oxygen, liquid, at plant	RER	-	-	0	kg	3.79E-2	2.43E-3	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	quicklime, in pieces, loose, at plant	CH	-	-	0	kg	4.80E-2	3.09E-3	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	refractory, basic, packed, at plant	DE	-	-	0	kg	1.08E-2	6.94E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	transport, freight, rail, electricity without shunting	CH	-	-	0	tkm	1.36E-1	8.72E-3	1	2.00	(2,2,1,1,1,nA,BU:2); ; (Haupt, 2020)
	transport, freight, lorry, fleet average	CH	-	-	0	tkm	1.34E-1	8.61E-3	1	2.00	(2,2,1,1,1,nA,BU:2); ; (Haupt, 2020)
	aluminium alloy, AlMg3, at plant	RER	-	-	0	kg	1.30E-3	8.37E-5	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	chemicals inorganic, at plant	GLO	-	-	0	kg	2.18E-5	1.40E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	ferromanganese, high-coal, 74.5% Mn, at regional storage	RER	-	-	0	kg	1.16E-2	7.45E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	sulphite, at plant	RER	-	-	0	kg	5.51E-3	3.54E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	hydrochloric acid, 30% in H2O, at plant	RER	-	-	0	kg	1.48E-4	9.53E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	sulphuric acid, liquid, at plant	RER	-	-	0	kg	8.10E-5	5.20E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	-	-	0	kg	1.54E-2	9.90E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); 91% reused, 9% landfilled; (Haupt, 2020)
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	-	-	0	kg	1.60E-2	1.03E-3	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	disposal, inert waste, 5% water, to construction waste landfill	CH	-	-	0	kg	1.92E-2	1.23E-3	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	disposal, inert waste, 5% water, to construction waste landfill	CH	-	-	0	kg	8.34E-3	5.36E-4	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
technosphere	electricity, medium voltage, at grid	CH	-	-	0	kWh	4.49E-1	2.88E-2	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
technosphere	heat, light fuel oil, at industrial furnace 1MW	CH	-	-	0	MJ	3.91E-2	2.51E-3	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
emission air, unspecified	Cadmium	-	air	unspecified	-	kg	1.46E-8	9.36E-10	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Carbon monoxide, fossil	-	air	unspecified	-	kg	4.93E-4	3.17E-5	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Chromium	-	air	unspecified	-	kg	3.56E-8	2.29E-9	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Copper	-	air	unspecified	-	kg	5.01E-8	3.22E-9	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	air	unspecified	-	kg	6.47E-14	4.16E-15	1	3.00	(2,2,1,1,1,nA,BU:3); ; (Haupt, 2020)
	Hydrogen chloride	-	air	unspecified	-	kg	6.84E-7	4.40E-8	1	1.51	(2,2,1,1,1,nA,BU:1.5); ; (Haupt, 2020)
	Lead	-	air	unspecified	-	kg	5.90E-7	3.80E-8	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Mercury	-	air	unspecified	-	kg	9.54E-8	6.14E-9	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Nickel	-	air	unspecified	-	kg	3.24E-9	2.08E-10	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Nitrogen oxides	-	air	unspecified	-	kg	8.76E-5	5.63E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); ; (Haupt, 2020)
	PAH, polycyclic aromatic hydrocarbons	-	air	unspecified	-	kg	1.37E-7	8.84E-9	1	3.00	(2,2,1,1,1,nA,BU:3); ; (Haupt, 2020)
	Particulates, < 2.5 um	-	air	unspecified	-	kg	8.53E-6	5.49E-7	1	3.00	(2,2,1,1,1,nA,BU:3); ; (Haupt, 2020)
	Particulates, > 10 um	-	air	unspecified	-	kg	3.01E-6	1.94E-7	1	1.51	(2,2,1,1,1,nA,BU:1.5); ; (Haupt, 2020)
	Particulates, > 2.5 um, and < 10um	-	air	unspecified	-	kg	8.53E-6	5.49E-7	1	2.00	(2,2,1,1,1,nA,BU:2); ; (Haupt, 2020)
	Polychlorinated biphenyls	-	air	unspecified	-	kg	8.90E-10	5.72E-11	1	3.00	(2,2,1,1,1,nA,BU:3); ; (Haupt, 2020)
	Sulfur dioxide	-	air	unspecified	-	kg	2.28E-6	1.47E-7	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	Zinc	-	air	unspecified	-	kg	8.68E-6	5.58E-7	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Carbon dioxide, fossil	-	air	unspecified	-	kg	9.66E-2	6.21E-3	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
	Methane, fossil	-	air	unspecified	-	kg	2.44E-5	1.57E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); ; (Haupt, 2020)
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	air	unspecified	-	kg	2.44E-5	1.57E-6	1	1.51	(2,2,1,1,1,nA,BU:1.5); ; (Haupt, 2020)
emission water, unspecified	Cadmium, ion	-	water	unspecified	-	kg	1.94E-10	1.25E-11	1	3.00	(2,2,1,1,1,nA,BU:3); ; (Haupt, 2020)
	Copper, ion	-	water	unspecified	-	kg	9.54E-8	6.14E-9	1	3.00	(2,2,1,1,1,nA,BU:3); ; (Haupt, 2020)
	Lead	-	water	unspecified	-	kg	1.94E-8	1.25E-9	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Mercury	-	water	unspecified	-	kg	3.88E-10	2.50E-11	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
	Nickel, ion	-	water	unspecified	-	kg	3.88E-9	2.50E-10	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)
emission resource, in water	Water, unspecified natural origin, CH	-	resource	in water	-	m3	9.07E-5	5.83E-6	1	1.07	(2,2,1,1,1,nA,BU:1.05); ; (Haupt, 2020)
emission water, unspecified	Zinc, ion	-	water	unspecified	-	kg	3.19E-7	2.05E-8	1	5.00	(2,2,1,1,1,nA,BU:5); ; (Haupt, 2020)

5.7 Reinforcing Steel

5.7.1 Production process and infrastructure

The inventories for reinforcing steel are modelled by mixtures of differently produced steel and alloy materials. Because steel for every application is hot rolled, this process is also included in the inventories.
Reinforcing steel is produced using both EAF and BF/BOF route, depending on the location. In Switzerland as well as in some parts of the USA, reinforcing steel is typically made in electric arc furnaces where 100% of the feedstock used for producing reinforcing steel is provided by recycled iron scrap (Concrete Reinforcing Steel Institute, 2020). In Europe, usually 70% of the reinforced steel is produced by EAF route and 30% by BF/BOF route (Institut Bauen und Umwelt e.V. (IBU), 2016).

5.7.2 Reinforcing steel, converter, at plant/RER

In this chapter the life cycle inventory for the modelled European converter reinforcing steel is presented.

All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 35) and and raw process data are presented in X-Echange table (see
Table 36).

Data basis

The process „reinforcing steel, converter, at plant/RER" was created by Carbotech AG on the basis of the existing inventory „ steel, converter, low-alloyed at plant/RER U".

Table 31: Metadata for the inventory of European reinforcing converter steel

Name	reinforcing steel, converter at plant
Location	RER
InfrastructureProcess	0
Unit	kg
DataSetRelatesToProduct	1
IncludedProcesses	Included processes: reinforced steel production by BOF furnace, including hot rolling.
Amount	1
LocalName	Armierungsstahl, BOF, ab Werk
Synonyms	In UVEK2018 enthalten
GeneralComment	Remark: represents average of European production; Geography: Data relate to plants in Europe
InfrastructureIncluded	1
Category	metals
SubCategory	extraction
LocalCategory	Metalle
LocalSubCategory	Gewinnung
Formula	
StatisticalClassification	

CASNumber	
StartDate	2013
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Europe
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 32: Unit process data for the production of 1 kg reinforcing converter steel in Europe

	Name	Location	Infrastructure Process	Unit	reinforcing steel, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	reinforcing steel, converter, at plant	RER	0	kg	1	0		Remark: represents average of European production; Geography: Data relate to plants in Europe
	hot rolling, steel	RER	0	kg	1.00E+0	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
	steel, converter, low-alloyed, at plant	RER	0	kg	1.00E+0	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;

5.7.3 Reinforcing steel, electric, at plant/RER

In this chapter the life cycle inventory for the newly European electric reinforcing steel is presented.

All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 35) and and raw process data are presented in X-Echange table (see
Table 36).

Data basis

The process „reinforcing steel, electric, at plant/RER" was created by Carbotech AG on the basis of the existing inventory „ steel, electric, un- and low-alloyed, at plant/RER U".

Table 33: Metadata for the inventory of European reinforcing electric steel

Name	reinforcing steel, electric at plant
Location	RER
InfrastructureProcess	0
Unit	kg

DataSetRelatesToProduct	1
IncludedProcesses	Included processes: reinforced steel production by EAF furnace, including hot rolling.
Amount	1
LocalName	Armierungsstahl, EAF, ab Werk
Synonyms	In UVEK2018 enthalten
GeneralComment	Remark: represents average of European production; Geography: Data relate to plants in Europe
InfrastructureIncluded	1
Category	metals
SubCategory	extraction
LocalCategory	Metalle
LocalSubCategory	Gewinnung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2013
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Europe
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 34: Unit process data for the production of 1 kg reinforcing electric steel in Europe

	Name	Location	Infrastructure Process	Unit	reinforcing steel, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	reinforcing steel, electric, at plant	RER	0	kg	1	0		Remark: represents average of European production; Geography: Data relate to plants in Europe
	hot rolling, steel	RER	0	kg	1.00E+0	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
	steel, electric, un- and low-alloyed, at plant	RER	0	kg	1.00E+0	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;

5.7.4 Reinforcing steel, at plant/RER

In this chapter the life cycle inventory for the newly modelled European reinforcing steel is presented. The changes concern the steel inputs. Reinforcing steel input from EAF is considered to be 70% and reinforcing steel input from converter steel is considered to be 30%.

All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 35) and and raw process data are presented in X-Echange table (see
Table 36).

Data basis

The process „reinforcing steel, at plant/RER" was created by Carbotech AG on the basis of the existing inventory „reinforcing steel, at plant/RER U" in UVEK:2018 database.

Table 35: Metadata for the inventory of European reinforcing steel

Name	reinforcing steel, at plant
Location	RER
InfrastructureProcess	0
Unit	kg
DataSetRelatesToProduct	1
IncludedProcesses	Included processes: Mix of differently produced steels (EAF and BOF), no hot rolling included.
Amount	1
LocalName	Armierungsstahl, ab Werk
Synonyms	In UVEK2018 enthalten
GeneralComment	Remark: represents Average of European production mix; Geography: Data relate to plants in Europe
InfrastructureIncluded	1
Category	metals
SubCategory	extraction
LocalCategory	Metalle
LocalSubCategory	Gewinnung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2013
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Europe
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 36: Unit process data for the production of 1 kg reinforcing steel in Europe

	Name	Location	Infrastructure Process	Unit	reinforcing steel, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	reinforcing steel, at plant	RER	0	kg	1	0		
	reinforcing steel, converter, at plant	RER	0	kg	3.00E-1	1	1.07	(2,2,1,1,1,nA,BU:1.05)
	reinforcing steel, electric, at plant	RER	0	kg	7.00E-1	1	1.07	(2,2,1,1,1,nA,BU:1.05)

5.7.5 Reinforcing Steel, at plant/ CH

In this chapter the life cycle inventory for the newly modelled Swiss reinforcing steel is presented. The changes made concern the steel inputs. According to a verbal statement from the swiss steel industry, a steel input of 100% electric Swiss steel is assumed.

All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 37) and and raw process data are presented in X-Echange table (see Table 38).

Data basis

The process „reinforcing steel, at plant/CH" was created by Carbotech AG on the basis of the existing inventory „reinforcing steel, at plant/RER U" in UVEK:2018 database.

Table 37: Metadata for the production of 1 kg reinforced steel in Switzerland

Name	reinforcing steel, at plant
Location	CH
InfrastructureProcess	0
Unit	kg
DataSetRelatesToProduct	1
IncludedProcesses	Included processes: EAF produced reinforced steel and hot rolling
Amount	1
LocalName	Armierungsstahl, ab Werk
Synonyms	0
GeneralComment	Remark: represents Swiss production (100 % electric arc furnace). Geography: Data relate to the plant in Switzerland
InfrastructureIncluded	1
Category	metals
SubCategory	production
LocalCategory	Metalle
LocalSubCategory	Gewinnung
Formula	
StatisticalClassification	

CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Switzerland
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 38: Unit process data for the production of 1 kg reinforcing steel in Switzerland

	Name	Location	Infrastructure Process	Unit	reinforcing steel, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	reinforcing steel, at plant	CH	0	kg	1	0		
technosphere	hot rolling, steel	RER	0	kg	1.00E+0	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
	steel, electric, low-alloyed, at plant	CH	0	kg	1.00E+0	1	1.07	(2,2,1,1,1,nA,BU:1.05); 80% iron scrap from CH;

5.7.6 Reinforcing steel, import to CH, at plant/ RER

In this chapter the life cycle inventory for the newly modelled import market from Europe to Switzerland is presented. Based on data from the swiss society of engineers and architects (SIA) in the "Register normkonformer Betonstähle nach Norm SIA 262:2013" (SIA, 2020), and current data from the "Bundesamt für Zoll und Grenzsicherheit (BAZG)", 99 % of the imported reinforced steel stems from EAF steel production. The corresponding inputs for the process were modelled accordingly.

All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 41) and and raw process data are presented in X-Echange table (see Table 42).

Data basis

The process „reinforcing steel, at regional storage/CH" was created by Carbotech AG according to the imported volume of reinforced steel from the neighbouring European countries.

Table 39: Metadata for reinforcing steel, import to CH, at plant, Europe

Name	reinforcing steel, import to CH, at plant
Location	CH
InfrastructureProcess	0
Unit	kg
IncludedProcesses	Included processes: Mix of differently produced steels for reinforced steel, imported to Switzerland

Amount	1
LocalName	Armierungsstahl, Import in CH, ab Werk
Synonyms	0
GeneralComment	Remark: represents Swiss import mix of reinforced steel. Geography: Data relate to Europe
InfrastructureIncluded	1
Category	metals
SubCategory	production
LocalCategory	Metalle
LocalSubCategory	Bereitstellung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Switzerland
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 40: Unit process data for 1 kg reinforcing steel, import to CH, at plant Europe

	Name	Location	Infrastructure Process	Unit	reinforcing steel, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	reinforcing steel, import to CH, at plant	RER	0	kg	1	0		
	reinforcing steel, converter, at plant	RER	0	kg	1.00E-2	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;
	reinforcing steel, electric, at plant	RER	0	kg	9.90E-1	1	1.07	(2,2,1,1,1,nA,BU:1.05); ;

5.7.7 Reinforcing steel at regional storage/ CH

In this chapter the life cycle inventory for the newly modelled market for Swiss reinforcing steel is presented. According to the import statistics from 2020 from the swiss steel industry, 45% of reinforced steel is imported yearly mainly from Germany, France and Italy. The total production of reinforced steel in Switzerland from low-alloyed electric steel is around 55% (Experts statement).

All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 41) and and raw process data are presented in X-Echange table (see Table 42).

Data basis

The process „reinforcing steel, at regional storage/CH" was created by Carbotech AG according to the production volume of reinforced steel from Switzerland and the imported volume of reinforced steel from the neighbouring European countries. Transportation takes place mainly by train. Short distances are done by lorry.

Table 41: Metadata for reinforcing steel at regional storage in Switzerland

Name	reinforcing steel, at regional storage
Location	CH
InfrastructureProcess	0
Unit	kg
IncludedProcesses	Included processes: Mix of differently produced steels and hot rolling
Amount	1
LocalName	Armierungsstahl, ab Regionallager
Synonyms	0
GeneralComment	Remark: represents market of reinforcing steel in Switzerland. Storage volume is assumed to remain constant over time. 45% of reinforcing steel is imported mainly from D, FR and IT, approx. 40% is transported by train, 60% by lorry; 55% is produced in CH. Geography: Data relate to plants in Switzerland
InfrastructureIncluded	1
Category	metals
SubCategory	production
LocalCategory	Metalle
LocalSubCategory	Bereitstellung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Switzerland
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 42: Unit process data for 1 kg reinforcing steel at regional storage in Switzerland

	Name	Location	Infrastructure Process	Unit	reinforcing steel, at regional storage	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	reinforcing steel, at regional storage	CH	0	kg	1	0		
technosphere	transport, freight, rail	RER	0	tkm	1.00E-1	1	1.07	(2,2,1,1,1,nA,BU:1.05); transportation by train from D, FR and IT; based on own calculations from distances of production sites; average distance 540 km, 40 % importeded by train;
	transport, freight, rail, electricity with shunting	CH	0	tkm	5.00E-2	1	1.07	(2,2,1,1,1,nA,BU:1.05); assumption: average transportation distance by train in CH: 80 - 100 km;
	transport, freight, lorry 16-32 metric ton, fleet average	RER	0	tkm	1.20E-1	1	1.07	(2,2,1,1,1,nA,BU:1.05); transportation by lorry mainly from Italy; based on own calculations from distances of production sites; average distance 450 km, 60 % importeded by lorry;
	reinforcing steel, at plant	CH	0	kg	5.50E-1	1	1.07	(2,2,1,1,1,nA,BU:1.05); production from Swiss plants;
	reinforcing steel, import to CH, at plant	RER	0	kg	4.50E-1	1	1.07	(2,2,1,1,1,nA,BU:1.05); import of European reinforcing steel;

5.8 Hot rolling

The process of iron hot rolling has been adapted for Siwtzerland, based on the information from the European process. The European process remains unchanged.

5.8.1 Hot rolling, steel/ CH

In this chapter the life cycle inventory for the newly modelled process for Swiss steel hot rolling is presented.

All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 41) and and raw process data are presented in X-Echange table (see Table 42).

Data basis

The process „hot rolling steel/CH" was created by Carbotech AG according to the basis of the existing inventory „hot rolling, steel/ RER U" in UVEK:2018 database.

Table 43: Metadata for hot rolling steel in Switzerland

Name	Hot rolling steel
Location	CH
InfrastructureProcess	0
Unit	kg
IncludedProcesses	Includes the process steps scarfing, grinding heating, descaling, rolling and finishing. Semiclosed water circuit with water treatment plant is also included. Does not include the material being rolled
Amount	1
LocalName	Warm walzen, Stahl
Synonyms	0
GeneralComment	To achieve greater toughness, shock resistance and tensile strength, the raw steel production outputs cast ingots, slabs, billets and beam blanks are hot rolled to long or flat products or semifinished products.
InfrastructureIncluded	1
Category	metals
SubCategory	processing
LocalCategory	Metalle
LocalSubCategory	Verarbeitung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Switzerland
Technolgy	Average technique for CH. Assumption: heating 100% with natural gas. Furnaces of about 10 MW are approxi-mated by furnace "> 100 kW"
Representativeness	

ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from UVEK:2018 have been used.

Table 44: Unit process data for 1 kg hot rolling steel in Switzerland

	Name	Location	Infrastructure Process	Unit	reinforcing steel, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	hot rolling, steel	CH	-	kg	1			
Technosphere	chemicals inorganic, at plant	GLO	0	kg	1.45E-8	1	2.00	calculated from max value assuming lognormal distribution
	disposal, average incineration residue, 0% water, to residual material landfill	CH	0	kg	2.23E-4	1	21.70	calculated from max value assuming lognormal distribution
	disposal, basic oxygen furnace wastes, 0% water, to residual material landfill	CH	0	kg	4.83E-4	1	4.50	calculated from max value assuming lognormal distribution
	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	7.08E-11	1	1.30	(2,5,1,1,3,3);
	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	0	kg	1.31E-3	1	8.70	calculated from max value assuming lognormal distribution
	disposal, sludge from steel rolling, 20% water, to residual material landfill	CH	0	kg	1.63E-2	1	1.20	(2,5,1,1,1,3);
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	2.13E-4	1	9.50	calculated from max value assuming lognormal distribution
	electricity, medium voltage, at grid	CH	0	kWh	1.40E-1	1	1.10	(3,3,1,1,1,3); based on values for the European process, adapted to Switzerland
	lime, hydrated, loose, at plant	CH	0	kg	4.97E-5	1	1.20	calculated from max value assuming lognormal distribution
	lubricating oil, at plant	RER	0	kg	4.04E-3	1	2.80	calculated from max value assuming lognormal distribution
	natural gas, burned in industrial furnace 1MW	RER	0	MJ	1.56E+0	1	1.40	calculated from max value assuming lognormal distribution
	oxygen, liquid, at plant	RER	0	kg	7.14E-3	1	1.20	(1,5,1,1,1,3);
	packaging film, LDPE, at plant	RER	0	kg	1.89E-11	1	1.40	(4,5,1,1,3,3);
	packaging, corrugated board, mixed fibre, single wall, at plant	RER	0	kg	4.72E-12	1	1.40	(4,5,1,1,3,3);
	propane/ butane, at refinery	RER	0	kg	5.30E-4	1	1.20	(1,5,1,1,1,3);
	rolling mill	RER	1	unit	1.62E-9	1	3.00	(3,4,1,1,1,4);
	Sawn timber (SFM), azobe, planed, air dried, u=15%, CM, at sawmill	RER	0	m3	1.62E-17	1	1.40	(4,5,1,1,3,3);
	sheet rolling, steel	RER	0	kg	2.36E-11	1	1.40	(4,5,1,1,3,3);
	steel, electric, low-alloyed, at plant	CH	0	kg	5.00E-2	1	1.30	(4,5,1,1,1,3); based on values for the European process, adapted to Switzerland
	transport, freight, lorry 16-32 metric ton, fleet average	RER	0	tkm	1.71E-2	1	2.10	(4,5,n.a.,n.a.,n.a.,n.a.);
resource, in water	Water, unspecified natural origin			m3	5.50E-3	1	2.00	calculated from max value assuming lognormal distribution
water, unspecified	Aluminium			kg	1.30E-7	1	5.90	calculated from max value assuming lognormal distribution
	BOD5, Biological Oxygen Demand			kg	3.80E-5	1	3.40	twice the uncertainty of COD (assumption)
	Cadmium, ion			kg	1.37E-7	1	2.00	calculated from max value assuming lognormal distribution
	Zinc, ion			kg	2.06E-7	1	9.40	calculated from max value assuming lognormal distribution
	TOC, Total Organic Carbon			kg	1.20E-5	1	3.40	twice the uncertainty of COD (assumption)
	Suspended solids, unspecified			kg	1.46E-4	1	7.30	calculated from max value assuming lognormal distribution
	Nickel, ion			kg	7.78E-7	1	14.10	calculated from max value assuming lognormal distribution
	Mercury			kg	2.75E-8	1	2.00	calculated from max value assuming lognormal distribution
	Manganese			kg	5.61E-7	1	2.60	calculated from max value assuming lognormal distribution
	Lead			kg	2.75E-7	1	2.00	calculated from max value assuming lognormal distribution
	Iron, ion			kg	4.26E-6	1	2.60	calculated from max value assuming lognormal distribution
	Hydrocarbons, unspecified			kg	1.73E-6	1	1.70	calculated from max value assuming lognormal distribution
	DOC, Dissolved Organic Carbon			kg	1.20E-5	1	3.40	twice the uncertainty of COD (assumption)
	Copper, ion			kg	2.66E-7	1	5.40	calculated from max value assuming lognormal distribution
	COD, Chemical Oxygen Demand			kg	3.78E-5	1	1.70	calculated from max value assuming lognormal distribution
	Chromium, ion			kg	4.95E-7	1	2.00	calculated from max value assuming lognormal distribution
	Chromium VI			kg	2.75E-8	1	2.00	calculated from max value assuming lognormal distribution
	Chloride			kg	1.23E-6	1	2.20	calculated from max value assuming lognormal distribution
air, unspecified	Carbon monoxide, fossil			kg	2.24E-5	1	1.20	(1,5,1,1,1,3);
	Chromium			kg	3.74E-7	1	5.80	calculated from max value assuming lognormal distribution
	Copper			kg	7.18E-8	1	1.10	calculated from max value assuming lognormal distribution
	Heat, waste			MJ	5.04E-1	1	1.10	(2,1,1,1,1,3);
	Iron			kg	6.06E-6	1	8.90	calculated from max value assuming lognormal distribution
	Lead			kg	1.77E-8	1	1.20	calculated from max value assuming lognormal distribution
	Manganese			kg	2.19E-7	1	1.60	calculated from max value assuming lognormal distribution
	Nickel			kg	2.44E-7	1	1.80	calculated from max value assuming lognormal distribution
	Nitrogen oxides			kg	1.31E-5	1	2.10	(1,5,1,1,1,3);
	NMVOC, non-methane volatile organic compounds, unspecified origin			kg	2.83E-4	1	2.80	calculated from max value assuming lognormal distribution
	Particulates, < 2.5 um			kg	1.79E-5	1	8.90	calculated from max value assuming lognormal distribution
	Particulates, > 10 um			kg	2.75E-5	1	1.60	(1,5,1,1,1,3);
	Particulates, > 2.5 um, and < 10um			kg	2.75E-5	1	2.10	(1,5,1,1,1,3);

5.9 Iron scrap, at plant/CH in DETEC

5.9.1 Production process and infrastructure

Iron scrap is the main iron bearing input in the electric arc furnace. Scrap is the iron and steel recovered after the product has been used by the final consumer. It comes into the secondary iron and steel industry via metal merchants and waste management companies which recover metal from e.g. vehicles, household goods etc. This is usually done by shredding, magnetic separation and „sink-and-float" installations or eddy current installations successively.

Because of the high process temperature and the addition of slag builder, scrap can be remelted with little preparation (no de-coating) (Classen et al., 2009).

In this chapter, the life cycle inventory for the newly modelled Swiss iron scrap is presented. The inventory for „iron scrap, at plant/CH" was updated by adding Swiss electricity instead of European electricity mix. All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 45) and and raw process data are presented in X-Echange table (see Table 46).

Data basis

This inventory was created by Carbotech AG on the basis of the existing inventory „iron, scrap, at plant/RER U" in the UVEK:2018 database.

Table 45: Metadata of the inventory for swiss iron scrap

Name	iron scrap, at plant
Location	CH
InfrastructureProcess	0
Unit	kg
DataSetRelatesToProduct	1
IncludedProcesses	Included processes: Collecting of new and old iron scrap, transport to scrap-yard, sorting and pressing to blocks.
Amount	1
LocalName	Eisenschott, ab Werk
Synonyms	0
GeneralComment	Remark: Data based on assumptions.; Geography: Data relate to plants in the EU, Energy from Switzerland
InfrastructureIncluded	1
Category	metals
SubCategory	production
LocalCategory	Metalle
LocalSubCategory	Gewinnung
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data from literature, referring to Switzerland
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 46: Unit process data for the Swiss iron scrap

	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	iron scrap, at plant	CH	0	kg	1	0		
technosphere	diesel, burned in building machine, average	CH	0	MJ	1.00E-1	1	2.02	(2,2,3,3,1,nA,BU:2); rough estimation;
	electricity, medium voltage, production CH, at grid	CH	0	kWh	1.00E-2	1	1.13	(2,2,3,3,1,nA,BU:1.05); rough estimation with swiss electricity ;
	scrap preparation plant	RER	1	unit	1.00E-9	1	3.02	(2,2,3,3,1,nA,BU:3); rough estimation;
	transport, freight, rail	RER	0	tkm	2.00E-1	1	2.02	(2,2,3,3,1,nA,BU:2); rough estimation;
	transport, freight, lorry, fleet average	RER	0	tkm	1.00E-1	1	2.02	(2,2,3,3,1,nA,BU:2); rough estimation;
emission air, high population density	Heat, waste	-	-	MJ	3.60E-2	1	1.13	(2,2,3,3,1,nA,BU:1.05); rough estimation;

6 Disposal Processes

During the production of iron and steel, several waste streams are generated. Production slags are partly recycled (e.g. road construction, cement production) and partly landfilled. Here only the final disposal of waste streams is described.

In the following, updated disposal processes for BOF wastes, EAF dust and slag as well as sludge from hot rolling are presented. The inventories are based on existing life cycle inventories of waste treatment services by (Doka, 2009). Emissions of chromium into water were detected on having the greatest impact on the environment. Chromium plays an important role for many steel qualities. In general, the input of chromium into the various steelmaking processes is unavoidable due to scrap recycling and the use of ores, and chromium is therefore also found as a minor component of steelworks slag. Chromium in the environment can occur in different oxidation states. Chromium(VI) compounds are considered carcinogenic and mutagenic. Chromium (III) compounds are classified as harmless or even on a beneficial role on mammalian carbohydrate and fat metabolism. When chromium occurs in unstable phases it can be eluted and oxidized to the toxic hexavalent state in the natural environment. In order to minimise health and enironmental risks from products containing chromium(VI), corresponding regulations exist in Europe, e.g. for cement, leather goods and fertilisers. Slag from steel production in therefore usually treated and chromium(IV) elution is suppressed (Zhao et al., 2018).

According to Cheremisina and Schenk, the Cr (VI) composition of slag from BOF and EAF are 0.0001 wt. % and therefore most of the Cr is in the Cr_2O_3 (chromium(III)) state. These values are based on model calculations (Cheremisina & Schenk, 2017). In this project it is assumed that the sludge contains 1 mg/kg chromium(VI), and that 50% is emitted into groundwater and 50% into rivers.

6.1 Disposal, basic oxygen furnace wastes

This part is based on Doka (2009).

In basic oxygen furnaces, unwanted traces are removed to produce high quality steels (Remus, 2013). Three different waste streams are produced during desulphurisation and steel-making. These are BOF slags, desulphurisation slag, and BOF dust. All three waste streams are partly landfilled. For the BOF dust, only an incomplete composition is available, especially lacking data for chromium and nickel. BOF dust is therefore approximated with EAF dust, for which a more complete composition is known (details see Classen et al. (2009).

For the remaining two waste streams, one data module is created which contains a weighted average of both wastes: 86%BOF slags and 14% desulphurisation slag. Disposal in a residual material landfill type with cement solidification is assumed (Classen et al., 2009).

This inventory is based on existing life cycle inventories of waste treatment services by Gabor Doka (2009). Only chromium(VI) emissions into water have been updated according to the study of (Cheremisina & Schenk, 2017). All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 47) and and raw process data are presented in X-Echange table (see Table 48).

Table 47: Metadata of disposal process for basic oxygen furnace wastes, based on disposal processes by Gabor Doka, 2009. Corrected for chromium(VI) emissions into water.

Name	disposal, basic oxygen furnace wastes, 0% water, to residual material landfill
Location	CH
InfrastructureProcess	0
Unit	kg
DataSetRelatesToProduct	1
IncludedProcesses	Included processes: Waste-specific short-term emissions to water from leachate. Long-term emissions from landfill to ground water. Expenditures for solidification with cement (user-specified option)
Amount	1
LocalName	Entsorgung, Blasstahl Produktionsabfallmix, 0% Wasser, in Reststoffdeponie
Synonyms	In UVEK2018 enthalten
GeneralComment	Correction of Cr(VI) emissions according to "Chromium stability in Steel slag: Elizaveta Cheremisina and Johanna Schenk, www.steel-research.ch, steel research int. 88 (2017) No. 11. According to this literature the Cr(VI) composition of slag from BOF (basic oxygen furnace) and EAF (electric arc furnace) are 0.0001 wt %, 0.000001 kg / kg or 1 mg / kg. Because of the fact that most of the Cr is in the Cr2O3 state. These values are based on model calculations.
InfrastructureIncluded	1
Category	waste management
SubCategory	residual material landfill
LocalCategory	Entsorgungssysteme
LocalSubCategory	Reststoffdeponie
Formula	
StatisticalClassification	
CASNumber	
StartDate	2013
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Switzerland
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 48: Unit process data for the disposal of BOF wastes (BOF slags, desulphurisation slag, and BOF dust)

	Name	Location	Infrastructure Process	Unit	disposal, basic oxygen furnace wastes, 0% water, to residual material landfill	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	disposal, basic oxygen furnace wastes, 0% water, to residual material landfill	CH	0	kg	1			
technosphere	cement, unspecified, at plant	CH	0	kg	0.4	1	1.21	(2,2,1,1,1,nA,BU:1.05); ;
	transport, freight, rail	RER	0	tkm	0.04	1	1.21	(2,2,1,1,1,nA,BU:2); ;
	transport, freight, lorry 16-32 metric ton, fleet average	CH	0	tkm	0.02	1	1.21	(2,1,1,1,1,nA,BU:2); ;
	residual material landfill facility	CH	1	unit	2.0833E-09	1	1.00	(2,2,1,1,1,nA,BU:3); ;
emission water, river	Sulfate	-	-	kg	1.34E-3	1	4.64	(2,2,1,1,1,nA,BU:1.5); ;
	Phosphate	-	-	kg	3.80E-5	1	7.48	(2,2,1,1,1,nA,BU:1.5); ;
	Chromium VI	-	-	kg	2.40E-4	1	5.00	(2,2,1,1,1,nA,BU:3); ;
	Manganese	-	-	kg	1.44E-7	1	12.35	(2,2,1,1,1,nA,BU:5); ;
	Silicon	-	-	kg	1.89E-4	1	5.24	(2,2,1,1,1,nA,BU:5); ;
	Iron, ion	-	-	kg	8.83E-7	1	10.66	(2,2,1,1,1,nA,BU:5); ;
	Calcium, ion	-	-	kg	5.68E-5	1	6.86	(2,2,1,1,1,nA,BU:3); ;
	Aluminium	-	-	kg	6.57E-6	1	7.98	(2,2,1,1,1,nA,BU:5); ;
	Magnesium	-	-	kg	4.18E-6	1	8.51	(2,2,1,1,1,nA,BU:5); ;
emission water, ground-	Sulfide	-	-	kg	1.12E-2	1	3.97	(2,2,1,1,1,nA,BU:1.5); ;
	Phosphate	-	-	kg	2.28E-2	1	5.93	(2,2,1,1,1,nA,BU:1.5); ;
	Chromium VI	-	-	kg	5.00E-7	1	4.04	(1,1,5,1,1,nA,BU:3); total amount in sludge 1mg/kg: assumption 50% to river 50% to groundwater; Cheremisina & Schenk, 2017
emission water, river	Chromium VI	-	-	kg	5.00E-7	1	5.02	(1,1,5,1,1,nA,BU:3); total amount in sludge 1mg/kg: assumption 50% to river 50% to groundwater; Cheremisina & Schenk, 2017
emission water, ground-	Manganese	-	-	kg	8.61E-5	1	140.49	(2,2,1,1,1,nA,BU:5); ;
	Silicon	-	-	kg	8.37E-2	1	2.10	(2,2,1,1,1,nA,BU:5); ;
	Iron, ion	-	-	kg	5.29E-4	1	208.47	(2,2,1,1,1,nA,BU:5); ;
	Calcium, ion	-	-	kg	3.40E-2	1	11.31	(2,2,1,1,1,nA,BU:3); ;
	Aluminium	-	-	kg	3.94E-3	1	5.35	(2,2,1,1,1,nA,BU:5); ;
	Magnesium	-	-	kg	2.51E-3	1	11.19	(2,2,1,1,1,nA,BU:5); ;
technosphere	process-specific burdens, residual material landfill	CH	0	kg	1.00E+0	1	1.00	(2,2,1,1,1,nA,BU:1.05); ;
	disposal, cement, hydrated, 0% water, to residual material landfill	CH	0	kg	1.00E+0	1	1.21	(2,2,1,1,1,nA,BU:1.05); ;

6.2 Disposal, dust, unalloyed EAF steel

This part is based on Doka (2009).

Electric arc furnaces (EAF) are fed with a high share of secondary metals (new and old scrap). The collected wastes from EAF are very dependent on alloy and contamination elements in the feed materials (Classen et al., 2009). Dusts are collected during EAF steel production typically from bag filters or ESPs. Dust from production of unalloyed steel is presented in this chapter. Disposal in a residual material landfill type with cement solidification is assumed.

This inventory is based on existing life cycle inventories of waste treatment services by Gabor Doka (2009). Only chromium(VI) emissions into water have been updated according to the study of (Cheremisina & Schenk, 2017). All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. Metadata is presented in an X-process table (see Table 49) and and raw process data are presented in X-Echange table (see Table 50).

Table 49: Metadata of disposal dust from unalloyed EAF steel production

Name	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill
Location	CH
InfrastructureProcess	0
Unit	kg
DataSetRelatesToProduct	1
IncludedProcesses	Included processes: Waste-specific short-term emissions to water from leachate. Long-term emissions from landfill to ground water.
Amount	1
LocalName	Entsorgung, Staub, v. Elektrostahl unlegiert, 15.4% Wasser, in Reststoffdeponie
Synonyms	In UVEK2018 enthalten
GeneralComment	Correction of Cr(VI) emissions according to "Chromium stability in Steel slag: Elizaveta Cheremisina and Johanna Schenk, www.steel-research.ch, steel research int. 88 (2017) No. 11. According to this literature the Cr(VI) composition of slag from BOF (basic oxigen furnace) and EAF (electric arc furnace) are 0.0001 wt %, 0.000001 kg / kg or 1 mg / kg.Because of the fact that most of the Cr is in the Cr2O3 state. This values are based on model calculations.
InfrastructureIncluded	1
Category	waste management
SubCategory	residual material landfill
LocalCategory	Entsorgungssysteme
LocalSubCategory	Reststoffdeponie
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Data apply to the combustion in Switzerland.
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 50: Unit process data for the disposal of dust from the production of EAF steel

		Input Group	Output Group	Name	Location	Category	Subcategory	Infrastructure Process	Unit	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	Uncertainty Type	Standard Deviation 95%	General Comment
	401												
	662			Location						CH			
	493			Infrastructure Process						0			
	403			Unit						kg			
product		-	0	disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	CH	-	-	0	kg	1			
technosphere		5	-	residual material landfill facility	CH	-	-	1	unit	2.0833E-09	1	1.00	(2,2,1,1,1,nA,BU:1.05); ;
		5	-	process-specific burdens, residual material landfill	CH	-	-	0	kg	1.00E+0	1	1.00	(2,2,1,1,1,nA,BU:1.05); ;
emission water, river		-	4	BOD5, Biological Oxygen Demand	-	water	river	-	kg	0.000010683	1	7.31	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	COD, Chemical Oxygen Demand	-	water	river	-	kg	0.00003266	1	7.31	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	TOC, Total Organic Carbon	-	water	river	-	kg	0.000012923	1	7.31	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	DOC, Dissolved Organic Carbon	-	water	river	-	kg	0.000012923	1	7.31	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Sulfate	-	water	river	-	kg	0.0023133	1	4.24	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Phosphate	-	water	river	-	kg	1.9131E-06	1	10.41	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Chloride	-	water	river	-	kg	0.0075371	1	2.97	(2,2,1,1,1,nA,BU:3); ;
		-	4	Fluoride	-	water	river	-	kg	0.00023888	1	4.99	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Arsenic, ion	-	water	river	-	kg	0.00039769	1	5.84	(2,2,1,1,1,nA,BU:5); ;
		-	4	Cadmium, ion	-	water	river	-	kg	6.5165E-09	1	16.60	(2,2,1,1,1,nA,BU:3); ;
		-	4	Cobalt	-	water	river	-	kg	4.1026E-09	1	17.36	(2,2,1,1,1,nA,BU:3); ;
		-	4	Copper, ion	-	water	river	-	kg	1.69E-7	1	12.03	(2,2,1,1,1,nA,BU:3); ;
		-	4	Mercury	-	water	river	-	kg	4.15E-10	1	21.31	(2,2,1,1,1,nA,BU:5); ;
		-	4	Manganese	-	water	river	-	kg	4.09E-7	1	11.21	(2,2,1,1,1,nA,BU:5); ;
		-	4	Nickel, ion	-	water	river	-	kg	1.74E-7	1	11.97	(2,2,1,1,1,nA,BU:5); ;
		-	4	Lead	-	water	river	-	kg	2.82E-7	1	11.69	(2,2,1,1,1,nA,BU:5); uncertainty is calculated from uncertainties in
		-	4	Chromium VI	-	water	river	-	kg	5.00E-7	1	4.09	(2,2,1,1,1,nA,BU:3); uncertainty is calculated from uncertainties in waste composition and transfer coefficients in residual landfill; total amount in sludge 1mg/kg; assumption 50% to river 50% to groundwater; Cheremisina & Schenk, 2017
emission water, ground-, long-term		-	4	Chromium VI	-	water	ground-, long-term	-	kg	5.00E-7	1	5.02	(2,2,1,1,1,nA,BU:3); ;
emission water, river		-	4	Vanadium, ion	-	water	river	-	kg	8.23E-7	1	10.12	(2,2,1,1,1,nA,BU:5); ;
		-	4	Zinc, ion	-	water	river	-	kg	4.41E-6	1	9.15	(2,2,1,1,1,nA,BU:5); ;
		-	4	Silicon	-	water	river	-	kg	3.27E-5	1	6.47	(2,2,1,1,1,nA,BU:5); ;
		-	4	Iron, ion	-	water	river	-	kg	3.01E-6	1	9.88	(2,2,1,1,1,nA,BU:5); ;
		-	4	Calcium, ion	-	water	river	-	kg	9.81E-6	1	7.86	(2,2,1,1,1,nA,BU:3); ;
		-	4	Potassium, ion	-	water	river	-	kg	1.26E-6	1	9.63	(2,2,1,1,1,nA,BU:5); ;
		-	4	Aluminium	-	water	river	-	kg	3.03E-3	1	3.55	(2,2,1,1,1,nA,BU:5); ;
		-	4	Magnesium	-	water	river	-	kg	3.29E-6	1	8.73	(2,2,1,1,1,nA,BU:5); ;
		-	4	Sodium, ion	-	water	river	-	kg	4.54E-3	1	3.38	(2,2,1,1,1,nA,BU:5); ;
emission water, ground-, long-term		-	4	BOD5, Biological Oxygen Demand	-	water	ground-, long-term	-	kg	6.40E-3	1	3.51	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	COD, Chemical Oxygen Demand	-	water	ground-, long-term	-	kg	1.96E-2	1	3.51	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	TOC, Total Organic Carbon	-	water	ground-, long-term	-	kg	7.74E-3	1	3.51	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	DOC, Dissolved Organic Carbon	-	water	ground-, long-term	-	kg	7.74E-3	1	3.51	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Sulfate	-	water	ground-, long-term	-	kg	1.92E-2	1	3.59	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Phosphate	-	water	ground-, long-term	-	kg	1.15E-3	1	8.56	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Chloride	-	water	ground-, long-term	-	kg	1.88E-2	1	2.77	(2,2,1,1,1,nA,BU:3); ;
		-	4	Fluoride	-	water	ground-, long-term	-	kg	4.17E-3	1	3.93	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Arsenic, ion	-	water	ground-, long-term	-	kg	3.98E-13	1	6.00	(2,2,1,1,1,nA,BU:5); ;
		-	4	Cadmium, ion	-	water	ground-, long-term	-	kg	3.90E-6	1	195.75	(2,2,1,1,1,nA,BU:3); ;
		-	4	Cobalt	-	water	ground-, long-term	-	kg	2.46E-6	1	16.92	(2,2,1,1,1,nA,BU:3); ;
		-	4	Chromium VI	-	water	ground-, long-term	-	kg	7.47E-4	1	4.05	(2,2,1,1,1,nA,BU:3); ;
		-	4	Copper, ion	-	water	ground-, long-term	-	kg	1.01E-4	1	35.49	(2,2,1,1,1,nA,BU:3); ;
		-	4	Mercury	-	water	ground-, long-term	-	kg	2.49E-7	1	46.44	(2,2,1,1,1,nA,BU:5); ;
		-	4	Manganese	-	water	ground-, long-term	-	kg	2.45E-4	1	133.81	(2,2,1,1,1,nA,BU:5); ;
		-	4	Nickel, ion	-	water	ground-, long-term	-	kg	1.04E-4	1	7.99	(2,2,1,1,1,nA,BU:5); ;
		-	4	Lead	-	water	ground-, long-term	-	kg	1.69E-4	1	210.44	(2,2,1,1,1,nA,BU:5); ;
		-	4	Vanadium, ion	-	water	ground-, long-term	-	kg	2.58E-4	1	6.11	(2,2,1,1,1,nA,BU:5); ;
		-	4	Zinc, ion	-	water	ground-, long-term	-	kg	2.64E-3	1	83.84	(2,2,1,1,1,nA,BU:5); ;
		-	4	Silicon	-	water	ground-, long-term	-	kg	1.45E-2	1	3.12	(2,2,1,1,1,nA,BU:5); ;
		-	4	Iron, ion	-	water	ground-, long-term	-	kg	1.80E-3	1	201.71	(2,2,1,1,1,nA,BU:5); ;
		-	4	Calcium, ion	-	water	ground-, long-term	-	kg	5.88E-3	1	12.61	(2,2,1,1,1,nA,BU:3); ;
		-	4	Aluminium	-	water	ground-, long-term	-	kg	7.53E-4	1	6.71	(2,2,1,1,1,nA,BU:5); ;
		-	4	Magnesium	-	water	ground-, long-term	-	kg	7.71E-3	1	3.34	(2,2,1,1,1,nA,BU:5); ;
		-	4	Sodium, ion	-	water	ground-, long-term	-	kg	1.97E-3	1	11.44	(2,2,1,1,1,nA,BU:5); ;
		-	4	Aluminium	-	water	ground-, long-term	-	kg	7.55E-3	1	3.27	(2,2,1,1,1,nA,BU:5); ;

6.3 Disposal, slag, unalloyed EAF steel

This part is based on Doka (2009).

Analogous to the disposal of dust from unalloyed EAF steel, the composition of slag depends on alloy and contamination elements in the feed materials (Classen et al., 2009). Slag from EAF steel production is a Ca/Si/Al matrix that is especially rich in manganese and chrome. Disposal in a residual material landfill type without cement solidification is assumed.

This inventory is based on existing life cycle inventory of waste treatment services by Gabor Doka (2009). Only chromium(VI) emissions into water have been updated according to the study of (Cheremisina & Schenk, 2017). Metadata is presented in an X-process table (see Table 51) and raw process data are presented in X-Echange table (see Table 52).

Table 51: Metadata of disposal dust from unalloyed EAF steel production

Name	disposal, slag, unalloyed electric. steel, 0% water, to residual material landfill
Location	CH
InfrastructureProcess	0
Unit	kg
DataSetRelatesToProduct	1
IncludedProcesses	Included processes: Waste-specific short-term emissions to water from leachate. Long-term emissions from landfill to ground water.
Amount	1
LocalName	Entsorgung, Schlacke, v. Elektrostahl unlegiert, 0% Wasser, in Reststoffdeponie
Synonyms	In UVEK2018 enthalten
GeneralComment	Remark: Inventoried waste contains 100% slag from electric steel production to landfill; Correction of Cr(VI) emissions according to "Chromium stability in Steel slag: Elizaveta Cheremisina and Johanna Schenk, www.steel-research.ch, steel research int. 88 (2017) No. 11. According to this literature the Cr(VI) composition of slag from BOF (basic oxigen furnace) and EAF (electric arc furnace) are 0.0001 wt %, 0.000001 kg / kg or 1 mg / kg. Because of the fact that most of the Cr is in the Cr2O3 state. This values are based on model calculations.
InfrastructureIncluded	1
Category	waste management
SubCategory	residual material landfill
LocalCategory	Entsorgungssysteme
LocalSubCategory	Reststoffdeponie
Formula	
StatisticalClassification	
CASNumber	
StartDate	2013
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Switzerland
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 52: Unit process data for the disposal for EAF slag

	401	Input Group	Output Group	Name	Location	Category	Subcategory	Infrastructure Process	Unit	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	Uncertainty Type	Standard Deviation 95%	General Comment
	662			Location						CH			
	493			Infrastructure Process						0			
	403			Unit						kg			
product		-	0	disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill	CH	-	-	0	kg	1			
technosphere		5	-	residual material landfill facility	CH	-	-	1	unit	2.0833E-09	1	1.00	(2,2,1,1,1,nA,BU:1.05); ;
		5	-	process-specific burdens, residual material landfill	CH	-	-	0	kg	1.00E+0	1	1.00	(2,2,1,1,1,nA,BU:1.05); ;
emission water, river		-	4	Aluminium	-	water	river	-	kg	0.000014804	1	7.29	(2,2,1,1,1,nA,BU:1.05); ;
		-	4	BOD5, Biological Oxygen Demand	-	water	river	-	kg	3.0201E-06	1	8.49	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Calcium, ion	-	water	river	-	kg	4.09E-5	1	7.00	(2,2,1,1,1,nA,BU:3); ;
		-	4	COD, Chemical Oxygen Demand	-	water	river	-	kg	9.2329E-06	1	8.49	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Copper, ion	-	water	river	-	kg	1.58E-8	1	15.26	(2,2,1,1,1,nA,BU:3); ;
		-	4	DOC, Dissolved Organic Carbon	-	water	river	-	kg	3.6535E-06	1	8.49	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Iron, ion	-	water	river	-	kg	1.80E-6	1	10.16	(2,2,1,1,1,nA,BU:5); ;
		-	4	Magnesium	-	water	river	-	kg	9.98E-6	1	7.79	(2,2,1,1,1,nA,BU:5); ;
		-	4	Manganese	-	water	river	-	kg	8.77E-7	1	10.49	(2,2,1,1,1,nA,BU:5); ;
		-	4	Nickel, ion	-	water	river	-	kg	9.75E-7	1	9.90	(2,2,1,1,1,nA,BU:5); ;
		-	4	Phosphate	-	water	river	-	kg	1.5365E-06	1	10.67	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Potassium, ion	-	water	river	-	kg	2.64E-4	1	5.38	(2,2,1,1,1,nA,BU:5); ;
		-	4	Silicon	-	water	river	-	kg	1.51E-4	1	5.37	(2,2,1,1,1,nA,BU:5); ;
		-	4	Sodium, ion	-	water	river	-	kg	1.31E-3	1	4.25	(2,2,1,1,1,nA,BU:5); ;
		-	4	Sulfate	-	water	river	-	kg	0.000066058	1	7.25	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Titanium, ion	-	water	river	-	kg	1.53E-6	1	9.42	(2,2,1,1,1,nA,BU:5); ;
		-	4	TOC, Total Organic Carbon	-	water	river	-	kg	3.6535E-06	1	8.49	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Vanadium, ion	-	water	river	-	kg	2.54E-6	1	8.87	(2,2,1,1,1,nA,BU:5); ;
		-	4	Zinc, ion	-	water	river	-	kg	3.37E-9	1	17.66	(2,2,1,1,1,nA,BU:5); ;
emission water, ground-, long-term		-	4	Aluminium	-	water	ground-, long-term	-	kg	8.87E-3	1	4.77	(2,2,1,1,1,nA,BU:5); ;
		-	4	BOD5, Biological Oxygen Demand	-	water	ground-, long-term	-	kg	1.81E-3	1	4.40	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Calcium, ion	-	water	ground-, long-term	-	kg	2.45E-2	1	11.49	(2,2,1,1,1,nA,BU:3); ;
emission water, river		-	4	Chromium VI	-	water	river	-	kg	5.00E-7	1	3.36	(2,2,1,1,1,nA,BU:3); total amount in sludge 1mg/kg: assumption 50% to river 50% to groundwater; Cheremisina & Schenk, 2017
emission water, ground-, long-term		-	4	Chromium VI	-	water	ground-, long-term	-	kg	5.00E-7	1	3.36	(2,2,1,1,1,nA,BU:3); total amount in sludge 1mg/kg: assumption 50% to river 50% to groundwater; Cheremisina & Schenk, 2017
		-	4	COD, Chemical Oxygen Demand	-	water	ground-, long-term	-	kg	5.53E-3	1	4.40	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Copper, ion	-	water	ground-, long-term	-	kg	9.47E-6	1	42.05	(2,2,1,1,1,nA,BU:3); ;
		-	4	DOC, Dissolved Organic Carbon	-	water	ground-, long-term	-	kg	2.19E-3	1	4.40	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Iron, ion	-	water	ground-, long-term	-	kg	1.08E-3	1	204.09	(2,2,1,1,1,nA,BU:5); ;
		-	4	Magnesium	-	water	ground-, long-term	-	kg	5.98E-3	1	10.35	(2,2,1,1,1,nA,BU:5); ;
		-	4	Manganese	-	water	ground-, long-term	-	kg	5.25E-4	1	129.55	(2,2,1,1,1,nA,BU:5); ;
		-	4	Nickel, ion	-	water	ground-, long-term	-	kg	5.84E-4	1	6.35	(2,2,1,1,1,nA,BU:5); ;
		-	4	Phosphate	-	water	ground-, long-term	-	kg	9.20E-4	1	8.78	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Potassium, ion	-	water	ground-, long-term	-	kg	6.73E-4	1	5.14	(2,2,1,1,1,nA,BU:5); ;
		-	4	Silicon	-	water	ground-, long-term	-	kg	6.70E-2	1	2.22	(2,2,1,1,1,nA,BU:5); ;
		-	4	Sodium, ion	-	water	ground-, long-term	-	kg	2.19E-3	1	4.13	(2,2,1,1,1,nA,BU:5); ;
		-	4	Sulfate	-	water	ground-, long-term	-	kg	5.50E-4	1	6.44	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Titanium, ion	-	water	ground-, long-term	-	kg	9.14E-4	1	6.54	(2,2,1,1,1,nA,BU:5); ;
		-	4	TOC, Total Organic Carbon	-	water	ground-, long-term	-	kg	2.19E-3	1	4.40	(2,2,1,1,1,nA,BU:1.5); ;
		-	4	Vanadium, ion	-	water	ground-, long-term	-	kg	7.95E-4	1	5.14	(2,2,1,1,1,nA,BU:5); ;
		-	4	Zinc, ion	-	water	ground-, long-term	-	kg	2.02E-6	1	120.47	(2,2,1,1,1,nA,BU:5); ;

6.4 Disposal, sludge from steel rolling

This part is based on Doka (2009).

In the rolling of steel and drawing of steel pipes and wires a wastewater treatment sludge is generated. The sludge originates from internal wastewater treatment of cooling and process water. Only data on pollutants in purified wastewater and total mass of removed sludge are known. The wastewater treatment operates with addition of flocculants and polyelectrolytes only. No special heavy metal precipitating agents are used. For this reason, the unknown sludge composition is derived in linear proportion to the pollutant profile in the purified wastewater. Hydrocarbons are inventoried as 90% C and 10% H. A water content of 20% is assumed in the waste. The remainder is assumed to be oxygen. Disposal in a residual material landfill type with cement solidification is assumed.

This inventory is based on existing life cycle inventory of waste treatment services by Gabor Doka (2009). Only chromium(VI) emissions into water have been updated according to the study of (Cheremisina & Schenk, 2017). Metadata is presented in an X-process table (see Table 53) and raw process data are presented in X-Echange table (see Table 54).

Table 53: Metadata of disposal sludge from steel rolling

Name	disposal, sludge from steel rolling, 20% water, to residual material landfill
Location	CH
InfrastructureProcess	0
Unit	kg
LocalName	Entsorgung, Abwasser-Schlamm vom Stahlwalzen, 20% Wasser, in Reststoffdeponie
Synonyms	In UVEK2018 enthalten
GeneralComment	Correction of Cr(VI) emissions according to "Chromium stabilioty in Steel slag: Elizaveta Cheremisina and Johanna Schenk, www.steel-research.ch, steel research int. 88 (2017) No. 11. According to this literature the Cr(VI) composition of slag from BOF (basic oxigen furnace) and EAF (electric arc furnace) are 0.0001 wt %, 0.000001 kg / kg or 1 mg / kg. Because of the fact that most of the Cr is in the Cr2O3 state. These values are based on model calculations.
InfrastructureIncluded	1
Category	waste management
SubCategory	residual material landfill
LocalCategory	Entsorgungssysteme
LocalSubCategory	Reststoffdeponie
Formula	
StatisticalClassification	
CASNumber	
StartDate	2018
EndDate	2020
DataValidForEntirePeriod	1
OtherPeriodText	Time of publications.
Geography	Switzerland
Technolgy	Industry data.
Representativeness	
ProductionVolume	
SamplingProcedure	Data from literature
Extrapolations	Some generic datasets from ecoinvent have been used.

Table 54: Unit process data for the disposal for sludge from steel rollig

	Name	Location	Infrastructure Process	Unit	disposal, sludge from steel rolling, 20% water, to residual material landfill	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				CH			
	Infrastructure Process				0			
	Unit				kg			
product	disposal, sludge from steel rolling, 20% water, to residual material landfill	CH	0	kg	1			
technosphere	cement, unspecified, at plant	CH	0	kg	0.4	1	1.21	(2,2,1,1,1,nA,BU:1.05); ;
technosphere	transport, freight, rail	RER	0	tkm	0.04	1	1.21	(2,2,1,1,1,nA,BU:1.05); ;
technosphere	transport, freight, lorry 16-32 metric ton, fleet average	CH	0	tkm	0.02	1	1.21	(2,2,1,1,1,nA,BU:1.05); ;
technosphere	residual material landfill facility	CH	1	unit	2.0833E-09	1	1.00	(2,2,1,1,1,nA,BU:1.05); ;
emission water, river	BOD5, Biological Oxygen Demand	-	-	kg	8.8429E-06	1	7.47	(2,2,1,1,1,nA,BU:1.5); ;
emission water, river	COD, Chemical Oxygen Demand	-	-	kg	0.000027034	1	7.47	(2,2,1,1,1,nA,BU:1.5); ;
emission water, river	TOC, Total Organic Carbon	-	-	kg	0.000010698	1	7.47	(2,2,1,1,1,nA,BU:1.5); ;
emission water, river	DOC, Dissolved Organic Carbon	-	-	kg	0.000010698	1	7.47	(2,2,1,1,1,nA,BU:1.5); ;
emission water, river	Chloride	-	-	kg	0.0022374	1	3.76	(2,2,1,1,1,nA,BU:3); ;
emission water, river	Cadmium, ion	-	-	kg	9.9125E-09	1	15.96	(2,2,1,1,1,nA,BU:3); ;
	Copper, ion	-	-	kg	1.09E-7	1	12.59	(2,2,1,1,1,nA,BU:3); ;
	Mercury	-	-	kg	1.3784E-08	1	15.46	(2,2,1,1,1,nA,BU:5); ;
	Manganese	-	-	kg	4.92E-8	1	13.69	(2,2,1,1,1,nA,BU:5); ;
	Nickel, ion	-	-	kg	2.99E-6	1	8.71	(2,2,1,1,1,nA,BU:5); ;
	Lead	-	-	kg	1.51E-8	1	15.34	(2,2,1,1,1,nA,BU:5); ;
	Zinc, ion	-	-	kg	2.68E-8	1	14.50	(2,2,1,1,1,nA,BU:5); ;
	Iron, ion	-	-	kg	2.27E-7	1	11.92	(2,2,1,1,1,nA,BU:5); ;
	Aluminium	-	-	kg	4.10E-6	1	8.42	(2,2,1,1,1,nA,BU:5); ;
emission water, ground-, long-term	BOD5, Biological Oxygen Demand	-	-	kg	5.30E-3	1	3.63	(2,2,1,1,1,nA,BU:1.5); ;
emission water, ground-, long-term	COD, Chemical Oxygen Demand	-	-	kg	1.62E-2	1	3.63	(2,2,1,1,1,nA,BU:1.5); ;
emission water, ground-, long-term	TOC, Total Organic Carbon	-	-	kg	6.41E-3	1	3.63	(2,2,1,1,1,nA,BU:1.5); ;
emission water, ground-, long-term	DOC, Dissolved Organic Carbon	-	-	kg	6.41E-3	1	3.63	(2,2,1,1,1,nA,BU:1.5); ;
emission water, ground-, long-term	Chloride	-	-	kg	5.59E-3	1	3.55	(2,2,1,1,1,nA,BU:3); ;
emission water, ground-, long-term	Cadmium, ion	-	-	kg	5.94E-6	1	191.71	(2,2,1,1,1,nA,BU:3); ;
emission water, river	Chromium VI	-	-	kg	5.00E-7	1	4.21	(2,2,1,1,1,nA,BU:3); total amount in sludge 1mg/kg: assumption 50% to river 50% to groundwater; Cheremisina & Schenk, 2017
	Chromium VI	-	-	kg	5.00E-7	1	4.21	(2,2,1,1,1,nA,BU:3); total amount in sludge 1mg/kg: assumption 50% to river 50% to groundwater; Cheremisina & Schenk, 2017
	Copper, ion	-	-	kg	6.51E-5	1	36.63	(2,2,1,1,1,nA,BU:3); ;
	Mercury	-	-	kg	8.26E-6	1	36.16	(2,2,1,1,1,nA,BU:5); ;
	Manganese	-	-	kg	2.95E-5	1	148.14	(2,2,1,1,1,nA,BU:5); ;
	Nickel, ion	-	-	kg	1.79E-3	1	5.40	(2,2,1,1,1,nA,BU:5); ;
emission water, ground-, long-term	Lead	-	-	kg	9.07E-6	1	239.72	(2,2,1,1,1,nA,BU:5); ;
	Zinc, ion	-	-	kg	1.60E-5	1	107.35	(2,2,1,1,1,nA,BU:5); ;
	Iron, ion	-	-	kg	1.36E-4	1	219.30	(2,2,1,1,1,nA,BU:5); ;
	Aluminium	-	-	kg	2.46E-3	1	5.71	(2,2,1,1,1,nA,BU:5); ;
technosphere	process-specific burdens, residual material landfill	CH	0	kg	1.00E+0	1	1.00	(2,2,1,1,1,nA,BU:1.05); ;
technosphere	disposal, cement, hydrated, 0% water, to residual material landfill	CH	0	kg	1.00E+0	1	1.00	(2,2,1,1,1,nA,BU:1.05); ;

7 Life cycle impact assessment

The results of steel production processes are within the same range as the former inventories. Some of the new inventories show still somewhat higher impacts regarding the ecological scarcity, mainly due to more detailes input data.

New disposal processes for EAF slag and sludge show significantly lower environmental impact due to updated emissions of heavy metals into water and corrected Cr(IV) emissions compared to former inventories. Table 55 shows the results of all updated processes in this project, calculated with the method of Ecological Scarcity, 2013 and the method of IPCC 2013, compared to former inventories.

Table 55: LCIA results of iron and steel processes

Inventory name/unit	**Ecological Scarcity 2013**	**IPCC 2013, GWP 100a**	**former inventory (UVEK 2018) that most closely matches the update**	**Ecological Scarcity 2013**	**IPCC 2013, GWP 100a**		
	UBP	kg CO2eq		UBP	kg CO2eq	UBP ratio	kg CO2 ratio
basic oxygen furnace gas, burned in power plant/MJ/RER U	600	0.59					
basic oxygen furnace slag, at plant/kg/RER U	33	0.02					
blast furnace gas, burned in power plant/MJ/RER U	130	0.28	Blast furnace gas, burned in power plant/RER U	96	0.20	136 %	140 %
blast furnace slag, at plant/kg/RER U	63	0.05	Blast furnace slag cement, at plant/CH U	339	0.45	19 %	10 %
disposal, basic oxygen furnace wastes, 0% water, to residual material landfill/kg/CH U	3’232	0.13	Disposal, basic oxygen furnace wastes, 0% water, to residual material landfill/CH U	3’210	0.33	101 %	40 %
disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill/kg/CH U	4’039	0.01	Disposal, dust, alloyed EAF steel, 15.4% water, to residual material landfill/CH U	3’150	0.33	6 %	3 %
disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill/kg/CH U	38	0.01	Disposal, slag, unalloyed electr. steel, 0% water, to residual material landfill/CH U	7’629	0.01	1 %	100 %
disposal, sludge from steel rolling, 20% water, to residual material landfill/kg/CH U	388	0.13	Disposal, sludge from steel rolling, 20% water, to residual material landfill/CH U	2’637	.33	15 %	40 %
electric arc furnace slag, alloyed, 23MnCrSiMoF66, at plant/kg/CH U	0.7	0.00					
electric arc furnace slag, alloyed, 42CrMoS4, at plant/kg/CH U	0.7	0.00					

electric arc furnace slag, alloyed, 44FMn28, at plant/kg/CH U	0.5	0.00						
electric arc furnace slag, at plant/kg/RER U	7.4	0.00						
electric arc furnace slag, low-alloyed, at plant, best plants (min. values)/kg/RER U	0.8	0.00						
electric arc furnace slag, low-alloyed, at plant, worst plants (max. values)/kg/RER U	27.8	0.01						
electric arc furnace slag, low-alloyed, at plant/kg/CH U	7.5	0.00						
electric arc furnace slag, unalloyed, at plant/kg/CH U	0.4	0.00						
iron scrap, at plant/kg/CH U	57	0.03	Iron scrap, at plant/RER U	61	0.04	94 %	87 %	
pellets, iron, at plant/kg/RER U	763	0.37	Pellets, iron, at plant/GLO U	524	0.08	146 %	438 %	
pig iron, at plant/kg/RER U	4'193	3.06	Pig iron, at plant/GLO U	2'493	1.50	168 %	204 %	
reinforcing steel, at plant/kg/CH U	1'548	0.86						
reinforcing steel, at plant/kg/RER U	3'068	1.71	Reinforcing steel, at plant/RER U	2'962	1.42	104 %	120 %	
reinforcing steel, at regional storage/kg/RER U	2'410	1.35						
sinter, iron, at plant/kg/RER U	2'350	0.73	Sinter, iron, at plant/GLO U	1'404	0.33	167 %	219 %	
steel, converter, unalloyed, at plant/kg/RER U	4'219	3.18	Steel, converter, unalloyed, at plant/RER U	2'615	1.59	161 %	200 %	
steel, electric, alloyed, 23MnCrSiMoF66, at plant/kg/CH U	1'199	0.43						
steel, electric, alloyed, 42CrMoS4, at plant/kg/CH U	1'098	0.37						
steel, electric, alloyed, 44FMn28, at plant/kg/CH U	831	0.38						
steel, electric, low-alloyed, at plant, best plants (min. values)/kg/RER U	435	0.37						
steel, electric, low-alloyed, at plant, worst plants (max. values)/kg/RER U	3'204	1.09						
steel, electric, low-alloyed, at plant/kg/CH U	745	0.37						
steel, electric, un- and low-alloyed, at plant/kg/RER U	1'423	0.66	Steel, electric, un- and low-alloyed, at plant/RER U	2'406	0.39	59 %	168 %	
steel, electric, unalloyed, at plant/kg/CH U	642	0.30						

8 Literature

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