LIFE CYCLE ASSESSMENT OF UNALLOYED FOUNDRY PIG IRON, SLAB, HOT-ROLLED COIL AND COLD-ROLLED COIL

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Summary:

This LCA study was developed to collect all needed data Environmental Product Declaration based on ISO 14025:2006 Environmental labels and declarations -- Type III environmental declarations and EN 15804:2012+A2:2019/AC:2021 of pig iron, slab, hot-rolled coil and cold-rolled coil produced by PJSC "ZAPORIZHSTAL" For development of LCA study and the EPD Product Category Rules - PCR 2019:14 Version 1.3.4 Construction products of The International EPD® System was used.

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GENERAL CHARACTERISTICS OF THE LCA STUDY

1 GENERAL CHARACTERISTICS OF THE LCA STUDY

1.1 COMMISSIONER OF LCA STUDY, LCA PRACTITIONER

A commissioner of this LCA study is PJSC "ZAPORIZHSTAL" with the following address:

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1.2 DATE OF ISSUE OF LCA REPORT

This LCA study was issued on March 24th, 2025.

1.3 STATEMENT THAT THE LIFE CYCLE ASSESSMENT STUDY HAS BEEN PERFORMED UNDER THE REQUIREMENTS OF EN 15804 AND APPLICABLE PCRS

This Life Cycle Assessment study has been performed under the requirements of EN 15804:2012+A2:2019/AC:2021 and applicable PCR document for Construction Products 2019:14 Version 1.3.4, The International EPD® System.

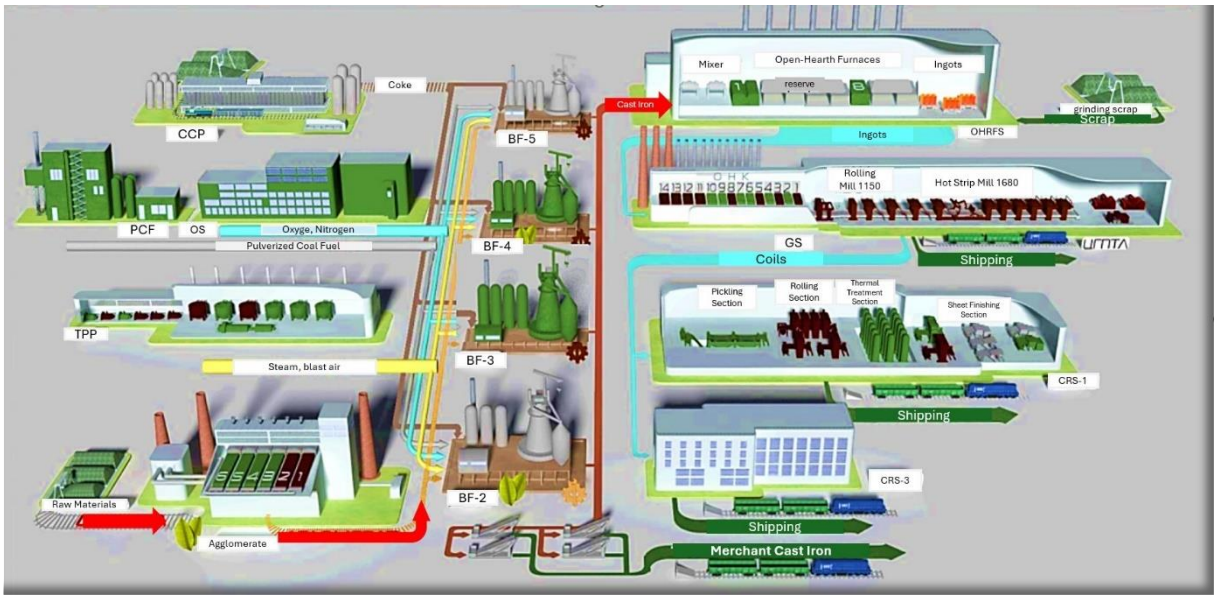
1.4 OTHER INDEPENDENT VERIFICATION OF THE DATA GIVEN IN THE LCI/LCA DOCUMENTATION?

No additional independent verification of the data given in the LCI/LCA documentation.

1.5 PRODUCT DESCRIPTION

The PJSC "ZAPORIZHSTAL"is one of Ukraine's leading enterprises with a full metallurgical cycle, specializing in the production of hot-rolled and cold-rolled sheet, tinplate, and other steel products. The production process at the plant consists of several key stages that ensure the transformation of raw materials into finished products.

Figure 1 Schematic representation of PJSC "ZAPORIZHSTAL"



Agglomerate production

Production begins in the sintering shop, which consists of six sintering machines. Here, iron ore sinter is produced from fine-grained iron ore materials mixed with fluxes and fuel. The resulting sinter serves as the primary raw material for the blast furnaces.

Unalloyed foundry pig iron production

Agglomerate, along with coke and fluxes, is loaded into the blast furnaces, of which there are four at the plant. In the blast furnaces, iron is reduced from its oxides at high temperatures (around 2000°C), resulting in the formation of molten pig iron. The

smelting of pig iron in the blast furnace is a key stage of metallurgical production at PJSC "ZAPORIZHSTAL", ensuring the production of an iron-carbon alloy—pig iron—which serves as raw material for further steelmaking or the manufacturing of cast products. The main components of the blast furnace charge are iron ore materials, fuel, and fluxes. Through the top of the furnace, iron ore materials, coke, and fluxes are loaded in batches, while preheated air (at 1000–1200°C), sometimes enriched with oxygen, is injected through tuyeres at the bottom. This promotes coke combustion and the formation of reducing gases. As these gases rise, they react with iron oxides, reducing them to metallic iron. The metallic iron then comes into contact with coke, absorbing carbon and forming pig iron, which has a lower melting point and transitions into a liquid state. Meanwhile, the fluxes

react with gangue and coke ash, forming a low-melting slag that absorbs unwanted impurities and accumulates above the layer of molten pig iron. Depending on the specifics of the technological process, the molten pig iron can either be immediately transferred to steelmaking shops for further steel production or sent to casting machines for the production of pig iron ingots. The final product—unalloyed foundry pig iron—is a multi-component iron alloy containing carbon, silicon, manganese, phosphorus, and sulfur. The product complies with DSTU 3133-95 (GOST 805-95) "Steelmaking pig iron. Specifications". Pig iron has two primary applications: steel production and cast product manufacturing. In the first case, pig iron serves as one of the metal charge components in electric arc furnaces, converters, and other steelmaking units. In the second case, pig iron is used as a substitute for steel scrap, direct reduced iron, and, to some extent, molten pig iron. Shipped in batches with an accompanying quality certificate specifying the pig iron grade, group, class, and category.

Open-hearth steel production

Molten pig iron from the blast furnaces is delivered to the open-hearth steelmaking shop, which consists of seven open-hearth furnaces and one twin-ladle steelmaking unit. In addition to pig iron, the primary components of steel include scrap—both steel and pig iron—as well as production waste and fluxes such as limestone and dolomite, which facilitate slag formation and the removal of undesirable impurities. Another crucial aspect at this stage is the addition of ferroalloys and deoxidizing agents. During this process, pig iron is converted into steel through the oxidation of impurities at high temperatures. The primary objective is to remove excess carbon, silicon, manganese, and other impurities from the pig iron. Once the refining process is complete, the finished steel is cast into ingots. The final product at this stage is a steel ingot, which is primarily used for manufacturing metal products and slabs.

Slab production

Steel ingots produced in an open-hearth furnace are directed to a reheating furnace to reach the required temperature (1200–1300°C), ensuring the steel becomes plastic and can be efficiently rolled. The heating duration depends on the ingot's dimensions and can last from 4 to 8 hours. Once heated, the ingots are fed into a rolling mill, which transforms

them into large flat semi-finished products—slabs. This stage consists of the following steps:

- The ingot is flattened, followed by a gradual reduction in thickness.
- The metal is cut into sheets of the required length.
- Scale removal is carried out.
- Defective sections, formed due to non-uniform cooling, are trimmed.
- A slab of the required size is formed.

Once the desired dimensions are achieved, the slab is sent for cooling on special racks. The final application of the product includes shipbuilding, mechanical engineering, the production of large-diameter pipes, and other industrial uses. Before dispatch, the slabs undergo quality control, which includes visual inspection for defects, ultrasonic testing, and chemical analysis. The production of slabs utilizes ingots made from carbon steels of standard quality, structural carbon steels, and low-alloy steel grades manufactured in the open-hearth furnace shop of the plant.

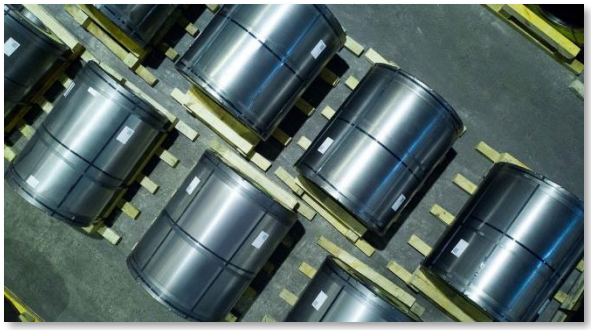
HRC production

A hot-rolled steel coil is a type of flat steel rolled product manufactured in hot rolling mills. The hot-rolled coil is produced from a slab that is heated in a furnace to a temperature of 1200°C, then rolled in a hot rolling mill, descaled using high-pressure water, and rolled again. In the next step, the steel is cooled and cut. The metal is cooled using water or air and then coiled by a winder. The next stage is heat treatment (performed optionally if required by the standard or the customer): the sheet is reheated in furnaces and cooled under specific conditions. During rolling in the mills, technological parameters are set to ensure that the metal acquires properties identical to those obtained through separate reheating in furnaces.

Hot-rolled coils made of carbon, structural carbon, and low-alloy steels are widely used in various industries, such as construction, the production of structural steel profiles and pipes, and mechanical engineering for the manufacturing of steel components, various metal products, and as feedstock for cold-rolled steel production. The high demand and diverse applications dictate certain variations in the chemical composition and physical-mechanical properties of hot-rolled steel coils. At Zaporizhstal, hot-rolled coils differ in steel grade, chemical composition, mechanical properties, geometric dimensions, and the final product's weight.

CRC production

Next, the hot-rolled coil undergoes cold rolling. Cold rolling is necessary for the production of coils with a steel thickness of less than 1.5 mm. This is due to the fact that at a certain thickness, hot rolling ceases to be effective. The metal cools rapidly, deformation resistance increases, and frequent reheating leads to the formation of even more scale on the surface. This production method allows for more precise control of the final product's thickness, improves surface quality, and enhances the mechanical properties of the rolled steel. Before undergoing cold rolling, the hot-rolled metal is treated with a solution of sulfuric or hydrochloric acid. A portion of the scale dissolves, while another portion peels off. The metal is then rinsed with clean water, and any residual acid is neutralized in an alkaline bath. Next, it is lubricated with special oils or emulsions and then rolled. Once the required thickness is achieved, the material undergoes heat treatment or galvanization. To relieve strain hardening, the steel undergoes annealing—a type of heat treatment in which the metal is heated to a specific temperature, held at that temperature for a certain period, and then gradually cooled. During annealing, the metal "relaxes," its hardness decreases, and its microstructure becomes homogeneous. After annealing, the rolled steel undergoes final processing or temper rolling—this is a form of cold rolling with slight compression and no lubrication. Temper rolling improves the surface quality of the steel. The final stage is processing. The sheets or coils are edge-trimmed, cut to length, and coated with protective layers. To make the rolled steel resistant to mechanical



damage and prevent corrosion, it is coated with zinc, tin, or aluminum. The most economical method is hot-dip galvanizing, in which the steel passes through a bath of molten zinc. Galvanized products can remain rust-free for up to 30 years. As a structural and construction material, cold-rolled coils belong to widely used products. This necessitates their production in a wide range of sizes from various grades of carbon, low-alloy, and alloy steels.

1.5.1 TECHNICAL SPECIFICATION

Unalloyed foundry pig iron

Unalloyed steelmaking pig iron is a multicomponent alloy primarily composed of iron, carbon, silicon, manganese, phosphorus, and sulfur. It is produced in accordance with DSTU 3133-95 (GOST 805-95) "Steelmaking pig iron. Specifications".

- Pig iron for foundry production (grades PL1, PL2): Intended for remelting in foundries.
- Pig iron for steelmaking production (grades P1, P2): Designed for steel production.
- High-quality pig iron (grades PVK1, PVK2, PVK3): Characterized by a low content of harmful impurities.
- Phosphorous pig iron (grades PF1, PF2, PF3): Characterized by a high phosphorus content.

UN CPC code: 41111 - Pig iron and spiegeleisen in pigs, blocks or other primary forms.

Slab

The production of slabs utilizes ingots made of carbon steel of ordinary quality, carbon structural, and low-alloy steel grades, produced in the open-hearth furnace shop of the plant.

Slab dimensions: 105-165 × 850-1520 × 2000-12300 mm.

UN CPC code: 41211 Flat-rolled products of non-alloy steel, not further worked than hot-rolled, of a width of 600 mm or more.

HRC

HRC steel is a type of flat-rolled product, which is a steel strip wound into a coil. It is produced on hot rolling mills from slabs. HRC are manufactured with a thickness ranging

from 1.5 mm to 10.0 mm and a width of 860 mm to 1500 mm, depending on the steel grade.

EN 10025-2:2019: "Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels".

UN CPC code: 41211 Flat-rolled products of non-alloy steel, not further worked than hot-rolled, of a width of 600 mm or more.

Table 1 Steel grades of hot-rolled coils

Standard	*Steel type*	Grade
DSTU 7809:2015, GOST 9045-93, EN 10130:2006, EN 10111:2008, EN 10346:2009, TU U 14-4-458-99, DSTU 2651:2005/ GOST 380-2005	*Non-alloy structural and low-carbon steels*	*08ps (kp), 10ps (kp), 15ps (kp), 20ps (kp), 25ps, St0, St1ps (kp), St2ps (kp), St3ps (kp), St4ps (kp), St3Gps, St5Gps*
	Cold-rolled and deep-drawing steels	*DC01, DX51D, DD11*
	Special-purpose steels	*08psN, 08Yu*
	High-strength steels and other grades	*ZS-7 – ZS-12, St3ps usp., St4ps usp., S235JR usp. (ZS-8) usp., ZS-13*
DSTU 7809:2015, DSTU 2651:2005/ GOST 380-2005, EN 10025:2004, TU U 14-2-1241-2000	*Carbon and structural steels*	*10, 15, 20, 25, 30*
	Non-alloy structural steels	*St0, St2sp, St3sp, St4sp*
	Low-alloy high-strength steels	*S235JR, S275JR*
	Copper-bearing steel for improved corrosion resistance	*St15 midista (copper-bearing steel)*
DSTU 8541:2015, DSTU 7806:2015, TU U 27.3-00190319-1313-2004, DSTU 2651:2005 / GOST 380-2005, TU U 27.1.4-516-2002	*High-strength low-alloy steels*	*12GS, 16GS, 09G2, 09G2D, 14G2, 09G2S, 10G2, 17GS, 17GS1*
	Weather-resistant structural steel	*10XNDP*
	General-purpose and constructional steels	*St5sp*
	Heat-resistant and corrosion-resistant steels	*07GSYF , 07GSYT, 08GSYT, 08GSYF , 08GYT*
DSTU 7809:2015, GOST 14959-79,	*High-carbon structural steels*	*45, 55*
	Spring steels	*65G, 60G, 70G*

TU 14-143-250-77	*Wear-resistant and tool steels*	*70X*
EN 10025, TU U 27.1-23365425-621:2007	*General-purpose structural steels*	*S235JR, S275JR*
	High-strength structural steels	*S355JR, S355J2, S355J0*
DSTU 7806:2015	*High-strength alloy steel*	*30XH2MA*
DSTU EN 10083-3:2006	*Wear-resistant and boron-alloyed steel*	*30MnB5*

CRC

Cold-rolled coils are manufactured with a thickness of 0.36-2.5 mm, supplied in an annealed and skin-passed condition, with dimensional tolerances, matte (rough) surface, and mechanical properties in accordance with national and international standards.

Cold-rolled coils are produced according to national standards (DSTU 2834-94 (GOST 16523-97), GOST 9045-93, DSTU 8971:2019) and international standards (EN 10130:2006, DIN 1623:2009-05), as well as manufacturers' specifications (TU SDU 01, protocol No. 14-226-209:2020) and customer requirements.

UN CPC code: 41211 Flat-rolled products of non-alloy steel, not further worked than hot-rolled, of a width of 600 mm or more.

Table 2 Steel grades and dimensions of cold-rolled coils

Steel type	*Grade*	*Dimensions*
General-purpose structural steels	*DC01, 08kp/ps, 10kp/ps*	*0.5-2.5 × 1000-1500 mm*
Mild carbon steels	*15kp/ps, 20kp/ps, 10, 15, 20*	*0.8-2.0 × 1000-1360 mm*
Deep-drawing and forming steels	*1-2kp/ps*	*0.8-2.0 × 1000-1500 mm*
High-strength structural steels	*3kp/ps, 1-3sp*	*0.8-2.0 × 1000-1360 mm*
Special-purpose steels	*S215G*	*0.6 × 1250 mm, 1.5 × 1000-1192 mm*
	DX51D	*0.36-0.49 × 1000 mm, 0.5-2.0 × 1000-1250 mm*
	S250GD	*1.38-1.88 × 1000-1250 mm*
	S320GD, S350GD	*1.48-2.0 × 1000-1250 mm*

1.5.2 PRODUCT GROUPS

This LCA study is developed for 4 products from the group of construction steel. No averages are formed. Every product type is calculated separately, and its results are expressed in a specific column.

1.5.2.1 CALCULATION RULES FOR THE FORMATION OF AVERAGES

No averages of product groups are calculated. Inventarisation and characterization for each type of product are calculated separately.

1.5.2.2 REPRESENTATIVENESS OF AVERAGES

There is no need for representativeness of average values, as no averages of product groups are calculated.

1.5.3 COMPOSITION OF THE PRODUCT

The study was conducted for 4 main products of construction steel: pig iron, slab, hot-rolled coil and cold-rolled coil, which are described in Section 1.5. And also for 2 additional products that are the base material for the aforesaid products: agglomerate and open-hearth steel. The compositions of pig iron, slab, hot-rolled coil, cold-rolled coil, agglomerate and open-earth steel are shown in the following table.

Table 3 Inputs for production of products per declared unit 1 t

Inputs	Agglomerate	Pig iron	Open-hearth steel	Slab	HRC	CRC
Iron ore (kg)	828,35	19,24	-	-	-	-
MFA-1 (kg)	31,54	27,15	-	-	-	-
Quicklime (kg)	16,84	-	-	-	-	-
Limestone (kg)	154,70	0,96	-	-	-	-
Agglomerate sludge (kg)	6,60	-	-	-	-	-
Blast furnace sludge (kg)	18,37	-	-	-	-	-
Open-hearth furnace sludge (kg)	8,39	-	-	-	-	-
Mixture containing iron (kg)	3,82	-	-	-	-	-
Blast furnace dust (kg)	13,11	-	-	-	-	-
Aspiration dust (kg)	4,66	-	-	-	-	-
Iron pellets (kg)	17,26	260,325	-	-	-	-
Sinter pellets (kg)	50,21	-	-	-	-	-
Coke (kg)	82,16	478,64	-	-	-	-
Electricity (MJ)	120,23	68,28	24,28	52,57	242,28	288,84
Natural gas (m3)	1,04	55,92	24,77	2,21	0,49	25,24
Blast furnace gas (MJ)	16,63	1,47	-	613,98	41,71	-
Coke gas (MJ)	108,14	127,30	-	75,11	40,10	-
Water MPS (m3)	0,04	22,05	6,65	1,18	7,94	6,94
Compressed air (m3)	19,52	29,24	145,74	9,82	43,33	100,61
Steam (MJ)	1,93	86,80	9,27	1,18	1,27	104,86
Agglomerate (kg)	-	1 434,99	-	-	-	-

Slag (kg)	-	8,65	-	-	-	-
Pulverized coal fuel (kg)	-	23,31	-	-	-	-
Oxygen(m3)	-	2,25	64,41	-	-	-
Nitrogen(m3)	-	25,61	-	-	-	-
Argon (m3)	-	-	0,12	-	-	-
Blast air (m3)	-	1425,07	-	-	-	-
Pig iron (kg)	-	-	882,23	-	-	-
Scrap (kg)	-	-	210,62	-	-	-
Scrap (defective product) (kg)	-	-	8,20	-	0,45	-
Waste (scrap, incomplete ingots, open-hearth sludge, ingot scrap) (kg)	-	-	99,80	-	-	-
Recycled water (m3)	-	-	10,06	-	19,55	-
Ferromanganese (kg)	-	-	1,10	-	-	-
Ferrosilicon manganese (kg)	-	-	1,10	-	-	-
Primary aluminum (kg)	-	-	1,10	-	-	-
Secondary aluminum (kg)	-	-	3,29	-	-	-
Ferrosilicon (kg)	-	-	1,10	-	-	-
Steel ingot (kg)	-	-	-	1121,80	-	-
Cutting for remelting (kg)	-	-	-	105,10	29,01	-
Iron in slag (kg)	-	-	-	13,07	-	-
Slag from slab prod. (kg)	-	-	-	7,69	-	-
Mill scale (kg)	8,55	-	130,13	23,99	20,54	12,03
Sludge (kg)	-	-	-	1,12	-	-
Cutting (kg)	-	-	-	-	1,24	58,76
HRC (kg)	-	-	-	-	-	1093,181
Refractoty (kg)	-	1,29	4,68	1,19	-	-
Lubricating oil (kg)	-	0,015	0,0017	-	0,359	2,6
Sand (kg)	-	2,53	-	-	-	-
Slab (kg)	-	-	-	-	1039,234	-
Packaging						
Metal packaging (kg)	-	-	-	-	1,39	13,78
Wood beech (kg)	-	-	-	-	-	0,09
Plastic packaging - PP (kg)	-	-	-	-	-	5,97
Paper packaging (kg)	-	-	-	-	0,0001	1,34

1.5.4 DESCRIPTION OF TECHNICAL AND FUNCTIONAL CHARACTERISTICS AND AREA OF INTENDED APPLICATION IN THE BUILDING

Products are described in section 1.5.

GOAL AND SCOPE DEFINITION

2 GOAL AND SCOPE DEFINITION

2.1 STUDY GOAL

2.1.1 REASONS FOR PERFORMING THE LIFE CYCLE ASSESSMENT

The reason for performing this LCA study is the development of EPD for PJSC "ZAPORIZHSTAL" - pig iron, slab, hot-rolled coil and cold-rolled coil.

2.1.2 INTENDED APPLICATION

The LCA study is designed in such a way that it allows B2B communication for environmental assessments of pig iron, slab, hot-rolled coil, cold-rolled coil and further development of EPD of pig iron, slab, hot-rolled coil and cold-rolled coil produced by PJSC "ZAPORIZHSTAL".

2.1.3 TARGET GROUP

Results presented in this study are used mainly for B2B, respectively B2C communication.

2.2 FUNCTIONAL / DECLARED UNIT

The functional respectively declared unit (DU) used in this study is 1 t of construction steel, specifically: pig iron, slab, hot-rolled coil and cold-rolled coil.

2.3 SYSTEM BOUNDARIES

2.3.1 DESCRIPTION OF THE LIFE-CYCLE STAGES/MODULES DECLARED

This EPD is based on system boundary Cradle to gate, modules C1–C4, module D and with optional modules A4-A5 according to EN 15804:2012+A2:2019/AC:2021.

2.3.2 COMPREHENSIVE DECLARATION OF MODULES A1 TO A3 AS A MINIMUM REQUIREMENT, IF NECESSARY, AS AN AGGREGATED MODULE A1- A3

The general description of the system boundary is shown in the following table.

Table 4 General description of the system boundary

A1 - A3 Product stage	Raw material supply	A1	X
	Transport	A2	X
	Manufacturing	A3	X
A4 - A5 Construction process stage	Transport from the gate to the site	A4	X
	Construction installation	A5	X
B1 - B7 Use stage	Use	B1	ND
	Maintenance	B2	ND
	Repair	B3	ND
	Replacement	B4	ND
	Refurbishment	B5	ND
	Operational energy use	B6	ND
	Operational water use	B7	ND
C1 - C4 End of life stage	Deconstruction, demolition	C1	X

	Transport	C2	X
	Waste processing	C3	X
	Disposal	C4	X
D Benefits and loads beyond the system boundaries	Reuse, recovery, recycling potential	D	X

X = Declared (module included in LCA)

2.4 A1 TO A3: SYSTEM BOUNDARY

2.4.1 CLEAR DESCRIPTION OF WHAT THE MODULES COVER

Module A1 covers the production of materials and components for PJSC "ZAPORIZHSTAL" and includes fuels and energy carriers (electricity, thermal energy). This consists of the production of input materials such as scrap, pig iron, ferrous metals, lime, etc.

Module A2 covers the transport of materials into the site of production PJSC "ZAPORIZHSTAL". Generic DB processes with site-specific parameters for distance were used.

Module A3 covers on-site operated processes dealing with pig iron, slab, hot-rolled coil and cold-rolled coil production (including treatment of generated waste within production) and packaging. These processes are under the operational control of PJSC "ZAPORIZHSTAL", and these are specific processes modelled based on data collection.

2.4.2 SYSTEM BOUNDARY TO NATURE (E.G. FOREST IN WOOD PRODUCTION)

Boundaries to nature cover the flow of materials and energy resources from nature into the system. All relevant elementary flows (emissions) to air, water, and soil across the system boundary when they are emitted from or leaving the product system are accounted for.

2.4.3 USE OF SECONDARY MATERIALS AND SECONDARY FUELS AND WASTE PRODUCED (CHECK END-OF- WASTE STATE)

PJSC "ZAPORIZHSTAL" produces primary steel. In the production of its products, the company uses scrap metal, both internal and external, in addition to primary materials. Internal scrap consists of cutting steel, defective products, etc. The company uses two types of external scrap, post-consumer and post-industrial. In the production to make open-hearth steel, the company uses secondary aluminum as an alloying additive. The production uses internal by-products, such as agglomeration, blast furnace and open-hearth slag and sludge, blast furnace gas, mill scale, aspiration dust, blast furnace dust, metal cutting, and scrap. As for energy materials - coke oven gas, which is a purchased material and a secondary product of the coal coke production process, was used as a fuel material for the production of agglomerate, pig iron, slabs and hot-rolled coils.

2.4.4 END-OF-WASTE STATE

No specification is needed.

2.4.5 CERTIFICATE OF GREEN ELECTRICITY

No certificate is considered.

2.4.6 IF APPLICABLE: REFERENCE TO THE CERTIFICATE OF THE OFFSETTING OF CO2

Not applicable.

2.5 A1 TO A3: ALLOCATION OF CO-PRODUCTS

2.5.1 SELECTION OF THE ALLOCATION FACTORS FOR CO-PRODUCT ALLOCATION

In the LCA study, we have allocated CO_2 emissions according to the investigated processes. The allocation of CO_2 emissions was based on a fuel consumption approach. The following principles from the PCR document for construction products were applied:

For CO_2 emissions from the combustion of gaseous fuels (natural gas and coke oven gas), the allocation was based on the amount of fuel consumed in the respective production processes. The emissions distribution was carried out using a proportional approach, taking into account the specific carbon content and combustion efficiency of each type of gas. For natural gas, the specific combustion value was taken as 39.5 MJ/m^3, while for coke oven gas, this value was 18 MJ/m^3.

For CO_2 emissions from carbon-containing solid materials (coke and coal), the allocation was based on the mass of material used in combustion processes. This approach considers the carbon content of each material, ensuring a fair distribution of emissions in accordance with their contribution.

The environmental impact assessment study also included a breakdown of the impact of scrap, using an economic approach. The environmental impacts of post-industry scrap and pig iron were attributed according to the ratio of the price of the main product and the scrap.

The economic allocation of post-consumer pig iron was calculated from average primary pig iron price for year 2023 what was 2000 USD/t and secondary pig iron price 285 USD/t. Based on this price ratio, 14,3 % of the impacts were allocated to the post-consumer pig iron.

2.5.2 JUSTIFICATION OF SPECIFIC ALLOCATION PROCESSES (E.G. IF DATA ARE NOT AVAILABLE TO ALLOCATE ACCORDING TO THE EN15804 RULES)

In regards to CO2 emissions, fuel consumption based allocation is used in this report and for the EPD. For other inputs and outputs only the general allocation rule is used.

2.5.3 PRESENTATION OF THE ENERGY AND MATERIAL FLOWS AS A RESULT OF DEVIATING ALLOCATION PROCESSES

No declaration of loads and benefits in Module D from the allocation in A1-A3.

2.6 A4 TO A5 (OPTIONAL MODULE):

Module A4 covers the transport of material from the site of production PJSC "ZAPORIZHSTAL" to the site of installation (the values for each product

are weighted averages and are presented in Table 2).

Table 5 Representation of distance according to module 4

Product name	Distance by truck (km)	Distance by train (km)
Pig iron	-	2975
Slab	-	1367
Hot-rolled coil	-	1733,08
Cold-rolled coil	137	1670,72

Generic DB processes with site-specific parameters for distance were used.

Module A5 covers the phase of treatment and disposal of waste generated from the unpacking and installation of pig iron, slab, hot-rolled coil and cold-rolled coil.

2.7 ACCOUNTING LOSSES IN THE MODULES IN WHICH THEY ARISE

Not applicable.

2.8 B1 TO B5 (OPTIONAL MODULE)

These modules are not covered in this study.

2.9 B6 AND B7 (OPTIONAL MODULE):

These modules are not covered in this study.

2.10 C1 TO C4

Module C1 covers the process of machine operation during the deconstruction of products made from construction steel. Estimated time for machine operation 10 hours.

Module C2 covers the transport of waste material into recycling facilities. Generic DB processes with estimated general distances were used. Estimated distance for the transport of material for recycling was set at 100 km.

Module C3 covers the process for sorting of used construction products made of pig iron, slab, hot-rolled coil or cold-rolled coil.

Module C4 covers the process for landfilling construction steel products (waste from pre-sorting for recycling).

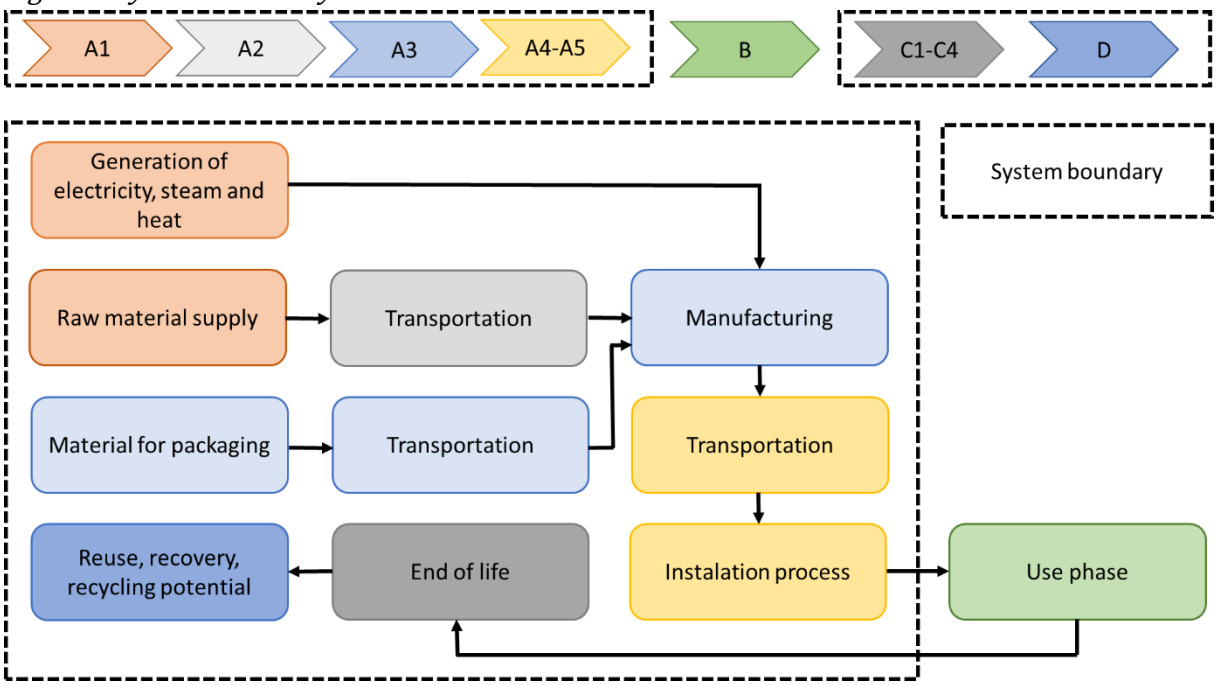
2.11 D

In **Module D** there are declared benefits and loads regarding to recycling potential of steel and energy recovery from incineration of packaging materials.

2.12 FLOW DIAGRAM OF MAIN PRODUCTION PROCESSES AND VISUALIZATION OF SYSTEM BOUNDARIES

In the following figure system, boundaries using modules included in the study are visualized.

Figure 2 System boundary



2.13 CRITERIA FOR EXCLUDING INPUTS AND OUTPUTS

2.13.1 SELECTION OF THE CUT-OFF CRITERIA, DESCRIPTION OF APPLICATION OF THE CRITERIA, AND ASSUMPTIONS

The cut-off criterion was chosen based on the used PCR. According to the used PCR, more than 99 % of flows were included.

2.13.2 LIST OF EXCLUDED PROCESSES

There are no excluded processes from the system boundary. All relevant processes are included in the LCA study.

2.13.3 DEVELOPMENT OF SCENARIOS AT PRODUCT LEVEL IN MODULES A4-A5-B-C-D

No scenarios within mentioned modules used.

2.13.4 STATEMENT THAT THE SCENARIOS INCLUDED ARE CURRENTLY IN USE AND ARE REPRESENTATIVE FOR ONE OF THE MOST LIKELY SCENARIO ALTERNATIVES.

No scenarios within mentioned modules used.

2.13.5 DOCUMENTATION OF THE RELEVANT TECHNICAL INFORMATION

This scenario is modelled using data from generic processes from the Sphera and ecoinvent databases.

LIFE CYCLE INVENTORY (LCI)

3 LIFE CYCLE INVENTORY (LCI)

3.1 DATA COLLECTION

All data used for this LCA study was collected in PJSC "ZAPORIZHSTAL"

Data was collected and provided by:

Kholina Inna, inna.kholina@zaporizhstal.com, +38 (059) 4561932.

The following assumptions were accepted in this LCA study:

1. The transportation distance for waste generated from used construction steel was selected at a level of 100 km.
2. The average transportation distance across Ukraine was calculated as 552 km by truck.
3. The largest source of CO_2 in the studied processes is the combustion of gas (natural and coke oven gas) and the combustion of carbon-containing fuels (coal, pulverized coal fuel and coke).
4. One cubic meter of coke oven gas contains 18 MJ.
5. One cubic meter of blast furnace gas contains 3 MJ.
6. The density of oxygen was taken as 1.43 kg/m^3.
7. The input material MZS-1 in the study was represented as slag.
8. The consumed electricity consists of 70% purchased electricity and 30% self-generated electricity.
9. Internal scrap is a by-product of production that is returned to the process stream.
10. Slag, sludge, aspiration dust, and scale are by-products of production that are returned to the process stream.
11. Blast furnace gas is a by-product of production that is returned to the process stream.
12. In the production of open-hearth steel, input post-consumer scrap represents 50% of the total input steel scrap. This input is without environmental burden.
13. The input material mixture containing iron in the study was represented as scrap.
14. The basis of the purchased steel scrap is hot-rolled coil scrap.
15. The purchased material, which is a metal by-product from steelmaking - MFA-1 and Mixture containing iron, is taken as scrap.

3.1.1 SELECTION AND USE OF GENERIC DATA AND BACKGROUND DATA

Sphera database and ecoinvent database are used as a source of generic and background data.

The specific data were used for modelling of processes, which can be operated by the producer (manufacturing of products). Also, specific parameters for some generic processes were considered (site-specific distance in transport processes).

Generic data were used for modelling of other processes (production of raw materials, components, generation of electricity and heat, general transport processes, processes in modules C1-C4, D).

The geographical scope of the study is Global, Ukraina.

The technological scope is from cradle to gate with modules C1-C4, module D and optional modules A4 and A5.

Accuracy of the data is determined by the operating documentation of the manufacturer and no variability is available.

Completeness is reached due to considered flow, which is accounted for according to cut-off rules.

The following rules for time scope of data were applied:

< 10 years for background data,

< 2 years for manufacturer's data.

3.1.2 DOCUMENTATION ON DATA / BACKGROUND DATA

Based on the operational data provided by PJSC "ZAPORIZHSTAL", product system models were created. All relevant data were used. Generic data from Sphera databases and ecoinvent databases were used. Both databases are internationally used with process data-sets validated at European level.

3.2 VALIDITY OF DATA

Site specific data from producer are based on 1 year average for process data (reference year 2023). The integrity of generic data records is ensured by Sphera (LCA software provider).

3.3 POWER MIX

3.3.1 SELECTION OF THE POWER MIX UNDER THE LOCATION OF THE PRODUCTION SITE(S)

Production of electricity spent within PJSC "ZAPORIZHSTAL" production was based on the Ukrainian electricity product mix from Sphera database. Zaporizhstal, in addition to purchased electricity, also uses electricity of its own production in a proportion of 7:3.

3.3.2 IF APPLICABLE: VALIDITY OF THE CERTIFICATES FOR GREEN POWER

Not applicable.

3.4 GREEN ELECTRICITY

Not applicable.

3.5 ALLOCATIONS

3.5.1 GENERAL ALLOCATION PRINCIPLES APPLIED

In the LCA study, we have allocated CO_2 emissions according to the investigated processes. The allocation of CO_2 emissions was based on a fuel consumption approach. The following principles from the PCR document for construction products were applied:

For CO_2 emissions from the combustion of gaseous fuels (natural gas and coke oven gas), the allocation was based on the amount of fuel consumed in the respective production processes. The emissions distribution was carried out using a proportional approach, taking into account the specific carbon content and combustion efficiency of each type of gas. For natural gas, the specific combustion value was taken as 39.5 MJ/m^3, while for coke oven gas, this value was 18 MJ/m^3 [1].

For CO_2 emissions from carbon-containing solid materials (coke and coal), the allocation was based on the mass of material used in combustion processes. This approach considers the carbon content of each material, ensuring a fair distribution of emissions in accordance with their contribution.

The environmental impact assessment study also included a breakdown of the impact of scrap, using an economic approach. The environmental impacts of post-industry scrap and pig iron were attributed according to the ratio of the price of the main product and the scrap.

The economic allocation of post-consumer pig iron was calculated from average primary pig iron price for year 2023 what was 2000 USD/t [2] and secondary pig iron price 285 USD/t. Based on this price ratio, 14,3 % of the impacts were allocated to the post-consumer pig iron.

Table 6 Result of CO2 allocation according to the studied processes

	Agglomerate	Pig iron	Open-Hearth Steel	Slab	HRC	CRC
Kg CO_2/t	205,28	1764,08	262,81	7,36	2,70	45,20

At the system boundary, cut-off allocation shall be applied, i.e., all unit processes before the point of end-of-waste shall be assigned to the product system generating the waste and all unit processes after the point of end-of-waste shall be assigned to the subsequent product system (except outputs from modules A1-A3, which shall be allocated as co-products, see Section 4.5.1).

3.5.2 PRESENTATION AND JUSTIFICATION OF ALLOCATIONS IN THE USE OF SECONDARY MATERIALS OR SECONDARY FUELS AS RAW MATERIALS

PJSC “ZAPORIZHSTAL” produces primary steel. In the production of its products, the company uses scrap metal, both internal and external, in addition to primary materials.

Internal scrap consists of cutting steel, defective products, etc. The company uses two types of external scrap, post-consumer and post-industrial, in. In the production to make open-hearth steel, the company uses secondary aluminum as an alloying additive. The production uses internal by-products, such as agglomeration, blast furnace and open-hearth slag and sludge, blast furnace gas, mill scale, aspiration dust, blast furnace dust, metal cutting, and scrap. As for energy materials - coke oven gas, which is a purchased material and a secondary product of the coal coke production process, was used as a fuel material for the production of agglomerate, pig iron, slabs and hot-rolled coils.

3.5.3 PRESENTATION AND JUSTIFICATION OF ALLOCATIONS IN THE PLANT

In this LCA study, allocation based on the amount of fuel consumed and the use of carbon-containing materials was used.

3.5.4 PRESENTATION AND JUSTIFICATION OF ALLOCATION OF MULTI-INPUT PROCESSES

Not applicable.

3.5.5 CO-PRODUCT ALLOCATION CORRECTLY APPLIED

The by-products are recycled and reintroduced into the flow as raw material.

3.5.6 DOCUMENTATION OF ALLOCATION FACTORS USED AND THEIR (INDEPENDENT) SOURCES

Only previously described general allocation rule was used.

3.5.7 ALLOCATION PROCESS FOR REUSE, RECYCLING, AND RECOVERY CHECK SPECIFICALLY

Not applicable.

3.5.8 IS THERE ANY PRESENTATION OR EXPERT GUESS OF DATASETS WHICH DO NOT COMPLY WITH THE ALLOCATION PRINCIPLES AND DESCRIPTION OF CONSEQUENCES FOR THE LCA RESULTS?

Not applicable.

3.6 LIFE CYCLE MODELING INFORMATION

3.6.1 CLEAR DESCRIPTION HOW COMPANY DATA ARE USED IN WHICH DATA RECORDS IN LIFE CYCLE ASSESSMENT SOFTWARE PROGRAMS

Generic and specific process data were used for the study. Specific data was obtained directly from the company and was used in relevant production processes. If there was no specific data available, then generic data from the Sphera database and ecoinvent database were used in calculations as is summarized below.

The following generic and specific process data were used in calculations:

Table 7 Generic processes

Generic process	Produced material/component
GLO: market for coal gas ecoinvent 3.9.1	Coke gas
GLO: iron scrap, sorted, pressed, Recycled Content cut-off ecoinvent 3.9.1	Iron scrap
RER: Hydrated Lime EuLa	Quicklime
GLO: market for iron ore, crude ore, 46% Fe ecoinvent 3.9.1	Iron Ore
DE: Metallurgical coke Sphera	Coke
UA: Natural gas mix Sphera	Natural gas
DE: Limestone (CaCO3; washed) Sphera	Limestone
DE: Lubricants at refinery Sphera	Lubricating oil
RoW: refractory production, fireclay, packed ecoinvent 3.9.1	Refractory
UA: Sand 0/2 Sphera	Sand
CA-QC: iron pellet production ecoinvent 3.9.1	Iron pellet
IN: iron ore mine operation, 63% Fe ecoinvent 3.9.1	Iron ore
DE: Aluminium foil primary Sphera	Aluminum primary
GLO: Ferro silicon mix (90% Si) Sphera	Ferro silicon
RER: ferromanganese production, high-coal, 74.5% Mn ecoinvent 3.9.1	Ferromanganese
RNA: Secondary aluminum ingot (95% recycled content) AA	Secondary aluminum
RER: Stainless steel product (430&409)- value of scrap Eurofer	Steel scrap
RER: Timber beech (12% moisture; 10.7% H2O content) (EN15804 A1-A3) 1kg Sphera	Wood packaging
RER: Process steam from hard coal 85% Sphera	Steam for own electricity production
RER: Kraft paper (EN15804 A1-A3) Sphera	Paper packaging
RER: Polyethylene low density granulate (LDPE/PE-LD) Sphera	Plastic packaging
DE: Steel sheet (EN 15804 A1-A3) Sphera	Metal Packaging
RER: Hard coal mix Sphera	Hard Coal

Generic process	Description of transport processes
GLO: Truck, Euro VI A-C, more than 32t gross weight / 24.7t payload capacity Sphera	Truck
GLO: machine operation, diesel, < 18.64 kW, high load factor ecoinvent 3.9.1	Machine operation of construction steel
RER: Residual grid mix Sphera	Electricity for train
RER: Diesel mix at refinery (EPD) Sphera	Fuel for trucks and train

Generic process	Description of background process
RER: Residual grid mix Sphera	European residual grid mix
RER: Thermal energy from natural gas Sphera	Thermal energy production
RER: Thermal energy from light fuel oil (LFO) Sphera	Thermal energy production
UA: Electricity grid mix Sphera	Electricity
RER: Light fuel oil at refinery Sphera	Light fuel

RER: Tap water from groundwater Sphera	Water for blast furnace gas operations

Generic process	**Description of waste processes**
RER: Hazardous waste (statistical average composition) treatment mix (incineration and landfill) Sphera	Disposal of used bag filters
RER: Municipal wastewater treatment (mix) Sphera	Wastewater treatment
DE: Recycling potential steel profile (D) Sphera	Recycling potential for steel
RER: Recyclable waste sorting facility (single flow) Sphera	Recyclable waste sorting facility
DE: Recycling potential steel profile (C4) Sphera	Recycling potential for steel
RER: Inert matter (Unspecific construction waste) on landfill Sphera	Refractory waste
DE: Used oil in waste incineration plant (15% H2O content) Sphera	Used lubricant oil
Paper recycling (for EPD)	Paper recycling
Metal recycling (for EPD)	Metal recycling
Wood recycling (for EPD)	Wood recycling
RER: Plastic packaging in municipal waste incineration plant (0% H2O content) Sphera	Incineration of plastics packaging

Table 8 Specific processes

Specific processes	
BF gas (plan)	Blast furnace gas
Compressed air (plan)	Compressed air
Water MPS (plan)	Water MPS
Electricity Mix (plan)	Electricity
A5- Pig iron	Installation phase for pig iron
A5- CRC	Installation phase for CRC
A5- HRC	Installation phase for HRC
A5 Slab	Installation phase for slab
GLO: Product Sphera	Auxiliary process
Agglomerate (plan)	Agglomerate
Argon (plan)	Argon
GLO: Exported Electrical Energy (EEE) Sphera-EPD	Auxiliary process
GLO: Exported Thermal Energy (EET) Sphera-EPD	Auxiliary process
GLO: Materials for Recycling (MFR) Sphera-EPD	Auxiliary process
GLO: Materials for Energy Recovery (MER) Sphera-EPD	Auxiliary process
GLO: Use of Secondary Materials (SM) Sphera-EPD	Auxiliary process
GLO: Use of Secondary Materials (SM, Steel sheet (EN 15804 A1-A3)) Sphera-EPD	Auxiliary process
Blast air (plan)	Blast air
Pig iron production (plan)	Pig iron production

Pig iron products demolition	Pig iron products demolition
CRC production (plan)	CRC production
CRC products demolition	CRC products demolition
Electricity (own) (plan)	Electricity own
EoL Pig iron	EOL phase
EoL CRC	EOL phase
EoL HRC	EOL phase
EoL Slab	EOL phase
HRC production (plan)	HRC production
HRC products demolition	HRC products demolition
Nitrogen (plan)	Nitrogen
Oxygen technological (plan)	Oxygen technological
Packaging Pig iron (plan)	Packaging pig iron
Packaging CRC (plan)	Packaging CRC
Packaging HRC (plan)	Packaging HRC
Packaging Slab (plan)	Packaging Slab
Pulverized Coal Injection (plan)	Pulverized coal fuel
Slab production (plan)	Slab production
Steam own (plan)	Steam
Steel products demolition	Steel products demolition
Open-Hearth Steel (plan)	Steel
Water recycled (plan)	Water (processed)
Pig iron A1 - A3 (plan)	Pig iron phase A1 - A3
HRC A1 - A3 (plan)	HRC phase A1 - A3
Slab A1-A3 (plan)	Slab phase A1 - A3

The composition of the products is shown in the section 1.5.2. The following tables illustrate the data relating to transport, packaging, inputs and outputs.

Table 9 Packaging of construction steel per declared unit 1 t

Material	**Agglomerate**	**Pig iron**	**Open-Hearth Steel**	**Slab**	**HRC**	**CRC**
Metal packaging (kg)	-	-	-	-	1,39	13,78
Wood beech (kg)	-	-	-	-	-	0,09
Plastic packaging - PP (kg)	-	-	-	-	-	5,97
Paper packaging (kg)	-	-	-	-	0,0001	1,34

Table 10 Transportation of construction steel production inputs

Upstream inputs	Agglo merate	Pig iron	Open-Hearth Steel	Slab	HRC	CRC	Unit	Transport mode
Material	**Distance**							
Iron ore	297,62	297,62	-	-	-	-	km	Train
Quicklime	451,6	-	-	-	-	-	km	Train
Limestone	988,4	988,4	-	-	-	-	km	Train
Mixture containing iron (kg)	173	-	-	-	-	-	km	Train
Coke (kg)	549,33	549,33	-	-	-	-	km	Train
Iron pellets	-	552	-	-	-	-	km	Truck
Pig iron (kg)	-	-	0	-	-	-	km	Train
Scrap (kg)	-	-	552	-	-	-	km	Truck
Ferromanganese (kg)	-	-	552	-	-	-	km	Truck
Ferrosilicon manganese (kg)	-	-	552	-	-	-	km	Truck
Primary aluminum (kg)	-	-	552	-	-	-	km	Truck
Secondary aluminum (kg)	-	-	552	-	-	-	km	Truck
Ferrosilicon (kg)	-	-	552	-	-	-	km	Truck
Steel ingot (kg)	-	-	-	0	-	-	km	Truck
HRC (kg)	-	-	-	-	-	0	km	Truck
Refractoty (kg)	-	552	552	552	-	-	km	Truck
Lubricating oil (kg)	-	552	552	552	552	552	km	Truck
Sand (kg)	-	552					km	Truck
Slab (kg)	-	-	-	-	0	-	km	Truck

Table 11 Transportation of waste from production

Upstream inputs	Agglo merate	Pig iron	Open-Hearth Steel	Slab	HRC	CRC	Unit	Transport mode
Material	**Distance**							
Used bag filters	556	556	-	-	-	-	km	Truck
Mill crankcase sludge	-	-	-	-	-	309	km	Truck
Refractory waste	-	552	552	552	-	-	km	Truck
Used lubricant oil	-	552	552	-	552	552	km	Truck

Table 12 Inputs and outputs related to production phase of different type of construction steel per declared unit 1 t

Inputs	Agglomerate	Pig iron	Open-Hearth Steel	Slab	HRC	CRC	Unit
Iron ore	828,35	19,24	-	-	-	-	kg
MFA-1	31,54	27,15	-	-	-	-	kg
Quicklime	16,84	-	-	-	-	-	kg
Limestone	154,7	0,96	-	-	-	-	kg
Agglomerate sludge	6,6	-	-	-	-	-	kg
Blast furnace sludge	18,37	-	-	-	-	-	kg
Open-hearth furnace sludge	8,39	-	-	-	-	-	kg
Mixture containing iron	3,82	-	-	-	-	-	kg
Blast furnace dust	13,11	-	-	-	-	-	kg
Aspiration dust	4,66	-	-	-	-	-	kg
Iron pellets	17,26	260,325	-	-	-	-	kg
Sinter pellets	50,21	-	-	-	-	-	kg
Coke	82,16	478,64	-	-	-	-	kg
Electricity	120,23	68,28	24,28	52,57	242,28	288,84	MJ
Natural gas	1,04	55,92	24,77	2,21	0,49	25,24	m3
Blast furnace gas	16,63	1,47	-	613,98	41,71	-	MJ
Coke gas	108,14	127,3	-	75,11	40,1	-	MJ
Water MPS	0,04	22,05	6,65	1,18	7,94	6,94	m3
Compressed air	19,52	29,24	145,74	9,82	43,33	100,61	m3
Steam	1,93	86,8	9,27	1,18	1,27	104,86	MJ
Agglomerate	-	1 434,99	-	-	-	-	kg
Slag	-	8,65	-	-	-	-	kg
Pulverized coal fuel	-	23,31	-	-	-	-	kg
Oxygen	-	2,25	64,41	-	-	-	m3
Nitrogen	-	25,61	-	-	-	-	m3
Argon	-	-	0,12	-	-	-	m3
Blast air	-	1425,07	-	-	-	-	m3
Pig iron	-	-	882,23	-	-	-	kg
Scrap	-	-	210,62	-	-	-	kg
Scrap (defective product)	-	-	8,2	-	0,45	-	kg
Waste (scrap, incomplete ingots, open-hearth sludge, ingot scrap)	-	-	99,8	-	-	-	kg
Recycled water	-	-	10,06	-	19,55	-	m3

Ferromanganese	-	-	1,1	-	-	-	kg
Ferrosilicon manganese	-	-	1,1	-	-	-	kg
Primary aluminum	-	-	1,1	-	-	-	kg
Secondary aluminum	-	-	3,29	-	-	-	kg
Ferrosilicon	-	-	1,1	-	-	-	kg
Steel ingot	-	-	-	1121,8	-	-	kg
Cutting for remelting	-	-	-	105,1	29,01	-	kg
Iron in slag	-	-	-	13,07	-	-	kg
Slag from slab prod.	-	-	-	7,69	-	-	kg
Mill scale	8,55	-	130,13	23,99	20,54	12,03	kg
Sludge	-	-	-	1,12	-	-	kg
Cutting	-	-	-	-	1,24	58,76	kg
HRC	-	-	-	-	-	1093,18	kg
Refractoty	-	1,29	4,68	1,19	-	-	kg
Lubricating oil	-	0,015	0,0017	-	0,359	2,6	kg
Sand	-	2,53	-	-	-	-	kg
Slab	-	-	-	-	1039,23	-	kg
Outputs							
Waste water	0,23	1,16	0,91	1,14	15,41	11,65	m3
Filter materials	0,01	0,007	-	-	-	-	kg
Agglomerate sludge	6,60	-	-	-	-	-	kg
Aspiration dust	4,66	-	-	-	-	-	kg
BF slag	-	290,63	-	-	-	-	kg
BF sludge	-	18,373	-	-	-	-	kg
Used oil waste	-	0,002	0,002	-	0,07	0,05	kg
Refractory waste	-	0,04	1,20	0,859	-	-	kg
Open-hearth furnace slag	-	-	125,41	-	-	-	kg
Open-hearth furnace sludge	-	-	8,4	-	-	-	kg
Slag from slab production	-	-	-	7,69	-	-	kg
Mill scale from slab production	-	-	-	13,79	-	-	kg
Mill scale	-	-	-	-	8,37	-	kg
Cutting	-	-	-	-	47,87	-	kg
Mill crankcase sludge	-	-	-	-	-	0,55	kg

Table 13 Inorganic emissions to air per production process per declared unit 1 t

Material	Agglomerate	Pig iron	Open-Hearth Steel	Slab	HRC	CRC	Unit
Carbon monoxide	8,75E+00	9,79E-01	2,47E-01	5,16E-01	1,47E-02	1,56E-01	kg
Nitrogen oxides	2,98E-05	5,15E-04	-	-	3,40E-08	7,87E-08	kg
Nitrogen dioxides	2,63E-01	7,89E-02	3,15E-01	2,50E-02	2,39E-02	2,86E-02	kg
Methan	7,28E-05	2,69E-04	-	-	3,40E-07	7,87E-07	kg
Sulphur dioxide	8,99E-01	9,15E-03	1,48E-03	3,24E-03	5,57E-03	-	kg
Particulate matter	1,81E-01	1,88E-01	2,62E-01	5,75E-03	2,64E-02	9,12E-03	kg
Benzo(a)ypren	4,83E-06	6,51E-08	2,49E-07	3,63E-08	1,79E-09	1,71E-08	kg
Mineral oil	2,40E-12	-	-	-	-	5,95E-03	kg
Fluoride	8,39E-08	8,11E-06	-	-	-	5,09E-08	kg
Hydrogen fluoride	2,11E-08	2,04E-06	-	-	-	1,28E-08	kg
Cadmium	4,88E-05	-	3,38E-05	-	-	-	kg
Copper	1,22E-05	3,24E-07	6,13E-05	-	-	-	kg
Iron	1,97E-05	7,13E-05	3,76E-05	6,41E-03	2,37E-05	4,60E-03	kg
Nickel	6,11E-05	2,00E-08	1,38E-05	-	7,69E-09	4,05E-07	kg
Lead	7,33E-06	1,00E-07	1,44E-03	-	-	-	kg
Chrom	5,02E-06	9,74E-07	-	-	-	-	kg
Manganese	1,28E-04	1,37E-07	9,95E-04	-	3,50E-07	1,20E-07	kg
Zinc	3,30E-04	2,00E-07	2,12E-03	-	-	-	kg
Arsen	-	2,06E-10	-	-	-	-	kg
Mercury	-	3,82E-10	-	-	3,40E-10	5,61E-11	kg
Aluminum	-	-	1,13E-08	-	-	-	kg
Hydrochloric acid	-	-	-	-	-	2,48E-03	kg
Sulfuric acid	-	-	-	-	-	1,34E-06	kg

Table 14 Inorganic emissions to water per production process per declared unit 1 t

Material	Agglomerate	Pig iron	Open-Hearth Steel	Slab	HRC	CRC	Unit
Suspended solids	1,67E-03	7,86E-03	2,21E-03	-	-	-	kg
Iron	4,10E-04	1,85E-03	7,53E-04	2,91E-04	4,28E-03	2,84E-03	kg
Chlorides	5,41E-02	2,64E-01	4,39E-03	6,89E-04	7,96E-03	6,27E-03	kg
Oil products	4,37E-05	2,02E-04	5,72E-05	1,45E-04	2,02E-03	1,47E-03	kg
Nitrogen amonium	5,70E-03	2,54E-02	2,32E-05	3,80E-05	5,04E-04	3,58E-04	kg
Nitrites	2,08E-03	1,08E-02	6,77E-04	6,35E-04	8,74E-03	6,50E-03	kg

Nitrates	1,28E-03	5,28E-03	1,61E-02	5,58E-03	7,26E-02	5,66E-02	kg
Thiocyanates	5,36E-05	2,05E-04	-	-	-	-	kg
Fenol	4,76E-06	1,99E-05	-	-	-	-	kg
Fluorides	6,74E-04	3,00E-03	1,30E-03	1,09E-04	1,33E-03	9,82E-04	kg
BOD5	2,85E-04	1,35E-03	1,04E-03	9,56E-04	1,26E-02	9,92E-03	kg
COD	2,18E-03	1,08E-02	6,51E-03	6,81E-03	9,23E-02	6,82E-02	kg
Calcium	-	6,93E-05	-	-	-	-	kg
Magnesium	-	1,41E-05	-	-	-	-	kg
Sulphides	-	2,89E-04	-	-	-	-	kg
Phosphates	-	6,11E-06	-	-	-	-	kg
Nickel	-	-	-	5,91E-07	7,00E-06	5,48E-06	kg
Manganese	-	-	-	5,04E-06	5,46E-05	4,83E-05	kg

3.6.2 ASSIGNMENT OF PROCESS DATA TO THE LIFE CYCLE ASSESSMENT MODULES

The LCA study evaluates the life cycle of the product "from cradle to gate, modules C1–C4, module D and with optional modules A4-A5". The studied system contains upstream processes as raw material supply (A1) through core processes as transportation (A2) and manufacturing itself (A3), transport from the gate to the site (A4) and construction installation processes (A5). Also, this system includes "End of life" of construction steel, which includes, machine operation (C1), transport (C2), sorting and waste processing (C3) and disposal (C4).

3.6.3 FOR SEVERAL LOCATIONS/PRODUCTS

Production from one location is the subject of this study.

Plant: PJSC "ZAPORIZHSTAL", 72 Pivdenne Highway, Zaporizhzhia, Ukraine, 69005.

3.6.4 PLAUSIBILITY AND CONSISTENCY OF DATA AND RESULTS OF INVENTORY ANALYSIS

The input data were gained from continuous records of evidence from the central register of the producer. The results of inventory analysis are a summarization of elementary flows - the inputs from the environment and emissions of substances that are emitted into the environment during the product´s lifecycle.

LIFE CYCLE IMPACT ASSESSMENT (LCIA)

4 LIFE CYCLE IMPACT ASSESSMENT (LCIA)

4.1 PARAMETERS OF THE LIFE CYCLE INVENTORY ANALYSIS AND LIFE CYCLE IMPACT ASSESSMENT

4.1.1 PRESENTATION OF THE PARAMETERS IN TABULAR FORM

Presentation of parameters for all modules declared in the study in paragraph 2.3.2 is shown.

4.1.2 PRESENTATION OF THE PARAMETERS

For each set of inventory data by using characterization factors were defined the results of indicators of impact categories. Characterizations of environmental impacts were performed using characterization factors specified in the PCR specifically.

As it is an extensive set of data that is widely available, the values of each characterization factors are not listed. The calculation of characterization was carried out by LCA for Experts (Sphera).

According to EN 15804+A2:2019/AC:2021 the environmental impact per declared unit is reported for the following impact categories:

Table 15 List of impact categories according to EN 15804:2012+A2:2019/AC:2021

Impact category	Indicator	Unit
Climate change - total	Global Warming Potential total (GWP-total)	kg CO2 eq.
Climate change - fossil	Global Warming Potential total (GWP-fossil)	kg CO2 eq.
Climate change - biogenic	Global Warming Potential total (GWP-biogenic)	kg CO2 eq.
Climate change - land use and land use change	Global Warming Potential total (GWP-luluc)	kg CO2 eq.
Ozone Depletion	Depletion potential of the stratospheric ozone layer (ODP)	kg CFC 11 eq.
Acidification	Acidification potential, Accumulated Exceedance (AP)	mol H+ eq.
Eutrophication aquatic freshwater	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater)	kg P eq.
Eutrophication aquatic marine	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-marine)	kg N eq.
Eutrophication terrestrial	Eutrophication potential, Accumulated Exceedance (EP-terrestrial)	mol N eq.
Photochemical ozone formation	Formation potential of tropospheric ozone (POCP);	kg NMVOC eq.
Depletion of abiotic resources - minerals and metals	Abiotic depletion potential (ADPminerals& metals) for non-fossil resources	kg Sb eq.
Depletion of abiotic resources - fossil fuels	Abiotic depletion potential (ADP-fossil) for fossil resources	MJ, net calorific value
Water use	Water (user) deprivation potential, deprivation weighted water consumption (WDP)	m3 world eq. deprived
Particulate matter emissions	Potential incidence of disease due to PM emissions (PM)	Disease incidence

Impact category	Indicator	Unit
Ionising radiation, human health	Potential Human exposure efficiency relative to U235 (IR)	kBq U235 eq.
Ecotoxicity (freshwater)	Potential Comparative Toxic Unit for ecosystems (ETP-fw)	CTUe
Human toxicity, cancer effects	Potential Comparative Toxic Unit for humans (HTP-c)	CTUh
Human toxicity, noncancer effects	Potential Comparative Toxic Unit for humans (HTP-nc)	CTUh
Land use related impacts / soil quality	Potential Soil quality index (SQP)	dimensionless

The use of resource is described by the other parameters:

- Use of renewable primary energy excluding renewable primary energy resources used as raw materials (MJ),
- Use of renewable primary energy resources used as raw materials (MJ),
- Total use of renewable primary energy resources (MJ),
- Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (MJ),
- Use of non-renewable primary energy resources used as raw materials (MJ),
- Total use of non-renewable primary energy resources (MJ),
- Use of secondary material (kg),
- Use of renewable secondary fuels (MJ),
- Use of non-renewable secondary fuels (MJ),
- and Net use of freshwater (m^3).

The indicators describing waste categories are also reported by 3 parameters:

- Non-hazardous waste disposed (kg),
- Hazardous waste disposed (kg),
- Radioactive waste disposed (kg).

The following tables provide results for each product according to defined indicators.

Table 16 Pig iron: Parameters describing environmental impact, resource use, waste and outputs and optional indicators

Potential environmental impact – mandatory indicators according to EN 15804									
Results per 1t of pig iron									
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-fossil	kg CO_2 eq.	2,88E+03	5,25E+01	0,00E+00	6,29E+01	1,01E+01	2,07E+01	7,49E-01	-4,08E+02
GWP-biogenic	kg CO_2 eq.	5,96E-01	1,53E-01	0,00E+00	2,10E-02	1,22E-01	9,01E-03	0,00E+00	6,60E-01
GWP-luluc	kg CO_2 eq.	7,18E-01	1,90E-01	0,00E+00	6,23E-03	1,67E-01	2,46E-03	4,49E-03	-1,99E-01
GWP-total	kg CO_2 eq.	2,88E+03	5,28E+01	0,00E+00	6,29E+01	1,04E+01	2,08E+01	7,53E-01	-4,08E+02
ODP	kg CFC 11 eq.	5,50E-06	4,55E-10	0,00E+00	1,35E-05	1,00E-12	1,66E-10	2,04E-12	1,29E-09
AP	mol H^+ eq.	4,79E+00	2,05E-01	0,00E+00	3,93E-01	1,29E-02	4,83E-02	5,31E-03	-9,36E-01
EP-freshwater	kg P eq.	6,64E-02	6,84E-05	0,00E+00	1,95E-03	4,24E-05	8,96E-06	1,71E-06	-3,90E-05
EP-marine	kg N eq.	1,07E+00	7,11E-02	0,00E+00	1,64E-01	4,58E-03	1,12E-02	1,37E-03	-2,27E-01
EP-terrestrial	mol N eq.	1,14E+01	7,79E-01	0,00E+00	1,79E+00	5,50E-02	1,21E-01	1,51E-02	-2,46E+00
POCP	kg NMVOC eq.	4,07E+00	-4,88E-03	0,00E+00	5,03E-01	-1,78E-01	3,31E-02	4,19E-03	-7,54E-01
ADP-minerals& metals*	kg Sb eq.	1,96E-04	2,89E-06	0,00E+00	3,24E-05	8,46E-07	8,49E-07	4,86E-08	-4,54E-06
ADP-fossil*	MJ	2,70E+04	9,09E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03
WDP	m^3	1,03E+03	2,52E+00	0,00E+00	2,12E+00	1,48E-01	8,75E-01	8,54E-02	-3,41E+00

Acronyms	GWP-fossil = Global Warming Potential fossil fuels; GWP-biogenic = Global Warming Potential biogenic; GWP-luluc = Global Warming Potential land use and land use change; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential, Accumulated Exceedance; EP-freshwater = Eutrophication potential, fraction of nutrients reaching freshwater end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals&metals = Abiotic depletion potential for non-fossil resources; ADP-fossil = Abiotic depletion for fossil resources potential; WDP = Water (user) deprivation potential, deprivation-weighted water consumption

Potential environmental impact – additional mandatory and voluntary indicators

Results per 1t of pig iron

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
GWP-GHG	kg CO2 eq.	2,88E+03	5,27E+01	0,00E+00	6,29E+01	1,03E+01	2,08E+01	7,55E-01	-4,08E+02
Particulate matter	Disease incidences	5,02E-05	2,07E-06	0,00E+00	6,77E-06	1,16E-07	4,03E-07	6,67E-08	-1,37E-05
Ionising radiation, human health	kBq U235 eq.	2,08E+01	1,48E+01	0,00E+00	3,89E+00	2,34E-02	5,39E+00	1,16E-02	5,49E+00
Ecotoxicity fresh water	CTUe	3,28E+03	1,82E+02	0,00E+00	2,30E+02	9,55E+01	8,28E+01	6,55E+00	-4,71E+02
Human toxicity, cancer	CTUh	1,42E-06	6,17E-09	0,00E+00	8,05E-08	1,91E-09	2,90E-09	1,34E-10	-6,38E-07
Human toxicity, non-cancer	CTUh	5,06E-06	2,41E-07	0,00E+00	1,98E-07	8,53E-08	8,51E-08	5,19E-09	5,57E-07
Land Use	Pt	9,19E+02	1,26E+02	0,00E+00	1,08E+02	4,75E+01	2,70E+01	2,81E+00	2,84E+02

Use of resources

Results per 1t of pig iron

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
PERE	MJ	5,41E+02	1,21E+02	0,00E+00	4,87E+00	1,10E+01	4,01E+01	1,73E+00	5,42E+02
PERM	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PERT	MJ	5,41E+02	1,21E+02	0,00E+00	4,87E+00	1,10E+01	4,01E+01	1,73E+00	5,42E+02
PENRE	MJ	2,70E+04	9,09E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03

PENRM	MJ.	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PENRT	MJ	2,70E+04	9,09E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03
SM	kg	3,26E+01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
RSF	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
NRSF	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
FW	m^3	3,61E+01	1,67E-01	0,00E+00	4,93E-02	1,23E-02	5,66E-02	2,61E-03	-2,74E-01
Acronyms	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water								

Waste production

Results per 1t of pig iron

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Hazardous waste disposed	kg	4,51E-03	1,13E-07	0,00E+00	0,00E+00	4,20E-09	4,18E-08	2,48E-09	1,38E-06
Non-hazardous waste disposed	kg	4,21E+00	2,12E-01	0,00E+00	0,00E+00	2,02E-02	8,46E-02	5,00E+01	-6,14E+00
Radioactive waste disposed	kg	2,33E-01	9,91E-02	0,00E+00	0,00E+00	1,68E-04	3,61E-02	1,02E-04	4,91E-02

Output flows

Results per 1t of pig iron

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Components for re-use	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Material for recycling	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,00E+03	0,00E+00	0,00E+00
Materials for energy recovery	kg	2,08E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Exported energy, electricity	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy, thermal	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Table 17 Slab: Parameters describing environmental impact, resource use, waste and outputs and optional indicators

Potential environmental impact – mandatory indicators according to EN 15804									
Results per 1t of slab									
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-fossil	kg CO_2 eq.	3,27E+03	2,41E+01	0,00E+00	6,29E+01	1,01E+01	2,07E+01	7,49E-01	-4,08E+02
GWP-biogenic	kg CO_2 eq.	2,05E+00	7,03E-02	0,00E+00	2,10E-02	1,22E-01	9,01E-03	0,00E+00	6,60E-01
GWP-luluc	kg CO_2 eq.	9,07E-01	8,75E-02	0,00E+00	6,23E-03	1,67E-01	2,46E-03	4,49E-03	-1,99E-01
GWP-total	kg CO_2 eq.	3,27E+03	2,43E+01	0,00E+00	6,29E+01	1,04E+01	2,08E+01	7,53E-01	-4,08E+02
ODP	kg CFC 11 eq.	6,15E-06	2,09E-10	0,00E+00	1,35E-05	1,00E-12	1,66E-10	2,04E-12	1,29E-09
AP	mol H^+ eq.	5,61E+00	9,44E-02	0,00E+00	3,93E-01	1,29E-02	4,83E-02	5,31E-03	-9,36E-01
EP-freshwater	kg P eq.	7,88E-02	3,14E-05	0,00E+00	1,95E-03	4,24E-05	8,96E-06	1,71E-06	-3,90E-05
EP-marine	kg N eq.	1,32E+00	3,27E-02	0,00E+00	1,64E-01	4,58E-03	1,12E-02	1,37E-03	-2,27E-01
EP-terrestrial	mol N eq.	1,40E+01	3,58E-01	0,00E+00	1,79E+00	5,50E-02	1,21E-01	1,51E-02	-2,46E+00
POCP	kg NMVOC eq.	4,61E+00	-2,24E-03	0,00E+00	5,03E-01	-1,78E-01	3,31E-02	4,19E-03	-7,54E-01
ADP-minerals& metals*	kg Sb eq.	3,06E-04	1,33E-06	0,00E+00	3,24E-05	8,46E-07	8,49E-07	4,86E-08	-4,54E-06
ADP-fossil*	MJ	2,96E+04	4,18E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03

WDP	m^3	1,80E+03	1,16E+00	0,00E+00	2,12E+00	1,48E-01	8,75E-01	8,54E-02	-3,41E+00
Acronyms	GWP-fossil = Global Warming Potential fossil fuels; GWP-biogenic = Global Warming Potential biogenic; GWP-luluc = Global Warming Potential land use and land use change; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential, Accumulated Exceedance; EP-freshwater = Eutrophication potential, fraction of nutrients reaching freshwater end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals&metals = Abiotic depletion potential for non-fossil resources; ADP-fossil = Abiotic depletion for fossil resources potential; WDP = Water (user) deprivation potential, deprivation-weighted water consumption								

Potential environmental impact – additional mandatory and voluntary indicators

Results per 1t of slab

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
GWP-GHG	kg CO2 eq.	3,27E+03	2,42E+01	0,00E+00	6,29E+01	1,03E+01	2,08E+01	7,55E-01	-4,08E+02
Particulate matter	Disease incidences	1,47E-04	9,49E-07	0,00E+00	6,77E-06	1,16E-07	4,03E-07	6,67E-08	-1,37E-05
Ionising radiation, human health	kBq U235 eq.	3,30E+01	6,80E+00	0,00E+00	3,89E+00	2,34E-02	5,39E+00	1,16E-02	5,49E+00
Ecotoxicity fresh water	CTUe	4,01E+03	8,35E+01	0,00E+00	2,30E+02	9,55E+01	8,28E+01	6,55E+00	-4,71E+02
Human toxicity, cancer	CTUh	2,27E-06	2,84E-09	0,00E+00	8,05E-08	1,91E-09	2,90E-09	1,34E-10	-6,38E-07
Human toxicity, non-cancer	CTUh	1,06E-05	1,11E-07	0,00E+00	1,98E-07	8,53E-08	8,51E-08	5,19E-09	5,57E-07
Land Use	Pt	1,32E+03	5,77E+01	0,00E+00	1,08E+02	4,75E+01	2,70E+01	2,81E+00	2,84E+02

Use of resources

Results per 1t of slab

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
PERE	MJ	1,09E+03	5,57E+01	0,00E+00	4,87E+00	1,10E+01	4,01E+01	1,73E+00	5,42E+02
PERM	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PERT	MJ	1,09E+03	5,57E+01	0,00E+00	4,87E+00	1,10E+01	4,01E+01	1,73E+00	5,42E+02

PENRE	MJ	2,96E+04	4,18E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03
PENRM	MJ.	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PENRT	MJ	2,96E+04	4,18E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03
SM	kg	2,72E+02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
RSF	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
NRSF	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
FW	m^3	6,51E+01	7,69E-02	0,00E+00	4,93E-02	1,23E-02	5,66E-02	2,61E-03	-2,74E-01
Acronyms	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water								

Waste production

Results per 1t of slab

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Hazardous waste disposed	kg	4,38E-03	5,19E-08	0,00E+00	0,00E+00	4,20E-09	4,18E-08	2,48E-09	1,38E-06
Non-hazardous waste disposed	kg	1,46E+01	9,73E-02	0,00E+00	0,00E+00	2,02E-02	8,46E-02	5,00E+01	-6,14E+00
Radioactive waste disposed	kg	3,84E-01	4,55E-02	0,00E+00	0,00E+00	1,68E-04	3,61E-02	1,02E-04	4,91E-02

Output flows

Results per 1t of slab

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Components for re-use	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Material for recycling	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,00E+03	0,00E+00	0,00E+00

Materials for energy recovery	kg	2,02E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy, electricity	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy, thermal	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Table 18 HRC: Parameters describing environmental impact, resource use, waste and outputs and optional indicators

Potential environmental impact – mandatory indicators according to EN 15804									
Results per 1t of HRC									
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-fossil	kg CO_2 eq.	3,43E+03	3,12E+01	0,00E+00	6,29E+01	1,01E+01	2,07E+01	7,49E-01	-4,08E+02
GWP-biogenic	kg CO_2 eq.	9,64E+00	9,10E-02	0,00E+00	2,10E-02	1,22E-01	9,01E-03	0,00E+00	6,60E-01
GWP-luluc	kg CO_2 eq.	9,44E-01	1,13E-01	0,00E+00	6,23E-03	1,67E-01	2,46E-03	4,49E-03	-1,99E-01
GWP-total	kg CO_2 eq.	3,44E+03	3,14E+01	0,00E+00	6,29E+01	1,04E+01	2,08E+01	7,53E-01	-4,08E+02
ODP	kg CFC 11 eq.	6,60E-06	2,70E-10	0,00E+00	1,35E-05	1,00E-12	1,66E-10	2,04E-12	1,29E-09
AP	mol H^+ eq.	6,22E+00	1,22E-01	0,00E+00	3,93E-01	1,29E-02	4,83E-02	5,31E-03	-9,36E-01
EP-freshwater	kg P eq.	9,39E-02	4,07E-05	0,00E+00	1,95E-03	4,24E-05	8,96E-06	1,71E-06	-3,90E-05
EP-marine	kg N eq.	1,47E+00	4,23E-02	0,00E+00	1,64E-01	4,58E-03	1,12E-02	1,37E-03	-2,27E-01
EP-terrestrial	mol N eq.	1,51E+01	4,63E-01	0,00E+00	1,79E+00	5,50E-02	1,21E-01	1,51E-02	-2,46E+00
POCP	kg NMVOC eq.	4,96E+00	-2,90E-03	0,00E+00	5,03E-01	-1,78E-01	3,31E-02	4,19E-03	-7,54E-01
ADP-minerals& metals*	kg Sb eq.	3,16E-04	1,72E-06	0,00E+00	3,24E-05	8,46E-07	8,49E-07	4,86E-08	-4,54E-06
ADP-fossil*	MJ	3,16E+04	5,41E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03
WDP	m^3	2,04E+03	1,50E+00	0,00E+00	2,12E+00	1,48E-01	8,75E-01	8,54E-02	-3,41E+00

Acronyms	GWP-fossil = Global Warming Potential fossil fuels; GWP-biogenic = Global Warming Potential biogenic; GWP-luluc = Global Warming Potential land use and land use change; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential, Accumulated Exceedance; EP-freshwater = Eutrophication potential, fraction of nutrients reaching freshwater end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals&metals = Abiotic depletion potential for non-fossil resources; ADP-fossil = Abiotic depletion for fossil resources potential; WDP = Water (user) deprivation potential, deprivation-weighted water consumption

Potential environmental impact – additional mandatory and voluntary indicators

Results per 1t of HRC

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
GWP-GHG	kg CO2 eq.	3,43E+03	3,14E+01	0,00E+00	6,29E+01	1,03E+01	2,08E+01	7,55E-01	-4,08E+02
Particulate matter	Disease incidences	1,56E-04	1,23E-06	0,00E+00	6,77E-06	1,16E-07	4,03E-07	6,67E-08	-1,37E-05
Ionising radiation, human health	kBq U235 eq.	4,43E+01	8,80E+00	0,00E+00	3,89E+00	2,34E-02	5,39E+00	1,16E-02	5,49E+00
Ecotoxicity fresh water	CTUe	4,62E+03	1,08E+02	0,00E+00	2,30E+02	9,55E+01	8,28E+01	6,55E+00	-4,71E+02
Human toxicity, cancer	CTUh	2,45E-06	3,67E-09	0,00E+00	8,05E-08	1,91E-09	2,90E-09	1,34E-10	-6,38E-07
Human toxicity, non-cancer	CTUh	1,60E-05	1,44E-07	0,00E+00	1,98E-07	8,53E-08	8,51E-08	5,19E-09	5,57E-07
Land Use	Pt	1,42E+03	7,47E+01	0,00E+00	1,08E+02	4,75E+01	2,70E+01	2,81E+00	2,84E+02

Use of resources

Results per 1t of HRC

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
PERE	MJ	1,25E+03	7,21E+01	0,00E+00	4,87E+00	1,10E+01	4,01E+01	1,73E+00	5,42E+02
PERM	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PERT	MJ	1,25E+03	7,21E+01	0,00E+00	4,87E+00	1,10E+01	4,01E+01	1,73E+00	5,42E+02
PENRE	MJ	3,16E+04	5,41E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03

PENRM	MJ.	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PENRT	MJ	3,16E+04	5,41E+02	0,00E+00	8,60E+02	1,30E+02	3,53E+02	9,87E+00	-3,11E+03
SM	kg	2,77E+02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
RSF	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
NRSF	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
FW	m^3	8,32E+01	9,95E-02	0,00E+00	4,93E-02	1,23E-02	5,66E-02	2,61E-03	-2,74E-01
Acronyms	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water								

Waste production

Results per 1t of HRC

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Hazardous waste disposed	kg	4,47E-03	6,72E-08	0,00E+00	0,00E+00	4,20E-09	4,18E-08	2,48E-09	1,38E-06
Non-hazardous waste disposed	kg	2,59E+01	1,26E-01	0,00E+00	0,00E+00	2,02E-02	8,46E-02	5,00E+01	-6,14E+00
Radioactive waste disposed	kg	5,46E-01	5,90E-02	0,00E+00	0,00E+00	1,68E-04	3,61E-02	1,02E-04	4,91E-02

Output flows

Results per 1t of HRC

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Components for re-use	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Material for recycling	kg	0,00E+00	0,00E+00	1,51E+01	0,00E+00	0,00E+00	1,00E+03	0,00E+00	0,00E+00
Materials for energy recovery	kg	7,51E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Exported energy, electricity	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy, thermal	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Table 19 CHC: Parameters describing environmental impact, resource use, waste and outputs and optional indicators

Potential environmental impact – mandatory indicators according to EN 15804									
Results per 1t of CRC									
Indicator	**Unit**	**A1-A3**	**A4**	**A5**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-fossil	kg CO_2 eq.	3,86E+03	4,42E+01	1,49E+01	6,29E+01	5,29E+01	2,07E+01	7,49E-01	-4,15E+02
GWP-biogenic	kg CO_2 eq.	1,40E+01	2,58E-01	1,02E-04	2,10E-02	6,38E-01	9,01E-03	0,00E+00	6,55E-01
GWP-luluc	kg CO_2 eq.	1,07E+00	3,43E-01	7,05E-04	6,23E-03	8,77E-01	2,46E-03	4,49E-03	-2,00E-01
GWP-total	kg CO_2 eq.	3,87E+03	4,48E+01	1,49E+01	6,29E+01	5,44E+01	2,08E+01	7,53E-01	-4,15E+02
ODP	kg CFC 11 eq.	7,27E-06	2,62E-10	3,16E-12	1,35E-05	5,26E-12	1,66E-10	2,04E-12	1,25E-09
AP	mol H^+ eq.	7,32E+00	1,36E-01	1,87E-03	3,93E-01	6,78E-02	4,83E-02	5,31E-03	-9,46E-01
EP-freshwater	kg P eq.	1,10E-01	9,86E-05	7,70E-07	1,95E-03	2,23E-04	8,96E-06	1,71E-06	-4,11E-05
EP-marine	kg N eq.	1,72E+00	4,72E-02	5,16E-04	1,64E-01	2,41E-02	1,12E-02	1,37E-03	-2,29E-01
EP-terrestrial	mol N eq.	1,73E+01	5,24E-01	8,65E-03	1,79E+00	2,89E-01	1,21E-01	1,51E-02	-2,49E+00
POCP	kg NMVOC eq.	5,66E+00	-2,52E-01	1,49E-03	5,03E-01	-9,36E-01	3,31E-02	4,19E-03	-7,61E-01
ADP-minerals& metals*	kg Sb eq.	3,47E-04	2,84E-06	3,28E-08	3,24E-05	4,44E-06	8,49E-07	4,86E-08	-4,79E-06
ADP-fossil*	MJ	3,70E+04	7,03E+02	6,51E+00	8,60E+02	6,81E+02	3,53E+02	9,87E+00	-3,23E+03
WDP	m^3	1,99E+03	1,65E+00	1,42E+00	2,12E+00	7,77E-01	8,75E-01	8,54E-02	-3,63E+00
Acronyms	GWP-fossil = Global Warming Potential fossil fuels; GWP-biogenic = Global Warming Potential biogenic; GWP-luluc = Global Warming Potential land use and land use change; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification								

potential, Accumulated Exceedance; EP-freshwater = Eutrophication potential, fraction of nutrients reaching freshwater end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals&metals = Abiotic depletion potential for non-fossil resources; ADP-fossil = Abiotic depletion for fossil resources potential; WDP = Water (user) deprivation potential, deprivation-weighted water consumption

Potential environmental impact – additional mandatory and voluntary indicators

Results per 1t of CRC

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
GWP-GHG	kg CO2 eq.	3,87E+03	4,46E+01	1,49E+01	6,29E+01	5,39E+01	2,08E+01	7,55E-01	-4,15E+02
Particulate matter	Disease incidences	1,75E-04	1,35E-06	2,29E-08	6,77E-06	6,10E-07	4,03E-07	6,67E-08	-1,38E-05
Ionising radiation, human health	kBq U235 eq.	6,00E+01	8,52E+00	3,01E-02	3,89E+00	1,23E-01	5,39E+00	1,16E-02	4,14E+00
Ecotoxicity fresh water	CTUe	5,79E+03	2,38E+02	4,38E+00	2,30E+02	5,01E+02	8,28E+01	6,55E+00	-4,78E+02
Human toxicity, cancer	CTUh	2,78E-06	6,22E-09	2,16E-10	8,05E-08	1,01E-08	2,90E-09	1,34E-10	-6,39E-07
Human toxicity, non-cancer	CTUh	2,22E-05	2,58E-07	1,72E-08	1,98E-07	4,48E-07	8,51E-08	5,19E-09	5,28E-07
Land Use	Pt	1,88E+03	1,38E+02	1,71E+00	1,08E+02	2,49E+02	2,70E+01	2,81E+00	2,77E+02

Use of resources

Results per 1t of CRC

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
PERE	MJ	1,57E+03	8,48E+01	1,73E+00	4,87E+00	5,76E+01	4,01E+01	1,73E+00	5,32E+02
PERM	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PERT	MJ	1,57E+03	8,48E+01	1,73E+00	4,87E+00	5,76E+01	4,01E+01	1,73E+00	5,32E+02
PENRE	MJ	3,70E+04	7,03E+02	6,51E+00	8,60E+02	6,81E+02	3,53E+02	9,87E+00	-3,23E+03
PENRM	MJ.	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

PENRT	MJ	3,70E+04	7,03E+02	6,51E+00	8,60E+02	6,81E+02	3,53E+02	9,87E+00	-3,23E+03
SM	kg	2,97E+02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
RSF	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
NRSF	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
FW	m^3	8,87E+01	1,13E-01	3,37E-02	4,93E-02	6,47E-02	5,66E-02	2,61E-03	-2,88E-01
Acronyms	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water								

Waste production

Results per 1t of CRC

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Hazardous waste disposed	kg	4,79E-03	7,07E-08	3,73E-09	0,00E+00	2,20E-08	4,18E-08	2,48E-09	1,37E-06
Non-hazardous waste disposed	kg	3,87E+01	1,50E-01	1,35E+00	0,00E+00	1,06E-01	8,46E-02	5,00E+01	-6,17E+00
Radioactive waste disposed	kg	7,59E-01	5,71E-02	2,19E-04	0,00E+00	8,81E-04	3,61E-02	1,02E-04	4,00E-02

Output flows

Results per 1t of CRC

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Components for re-use	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Material for recycling	kg	0,00E+00	0,00E+00	1,52E+01	0,00E+00	0,00E+00	1,00E+03	0,00E+00	0,00E+00
Materials for energy recovery	kg	8,04E-02	0,00E+00	5,97E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy, electricity	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	-2,71E+01

Exported energy, thermal	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	-4,84E+01

4.2 SELECTION OF CHARACTERISATION FACTORS

The characterization of Environmental Footprint (EF 3.1), was used based on EN 15804+A2.

4.3 JUSTIFICATION OF CHARACTERISATION FACTORS

Not to be applied. All input/output flows are on the list of characterization factors of the EN15804+A2.

4.4 INFORMATION ON THE ENVIRONMENTAL IMPACTS IN THE PROJECT REPORT

4.4.1 REFERENCE TO CHARACTERISATION MODELS AND FACTOR

Table 20 List of impact categories according to EN 15804+A2 and their models

Impact category	Unit	Model
Climate change - total	kg CO2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change - fossil	kg CO2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change - biogenic	kg CO2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change - land use and land use change	kg CO2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
Ozone Depletion	kg CFC 11 eq.	Steady-state ODPs, WMO 2014
Acidification	mol H+ eq.	Accumulated Exceedance, Seppälä et al. 2006, Posch et al., 2008
Eutrophication aquatic freshwater	kg P eq.	EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe
Eutrophication aquatic marine	kg N eq.	EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe
Eutrophication terrestrial	mol N eq.	Accumulated Exceedance, Seppälä et al. 2006, Posch et al.
Photochemical ozone formation	kg NMVOC eq.	LOTOS-EUROS ,Van Zelm et al., 2008, as applied in ReCiPe
Depletion of abiotic resources – minerals and metals	kg Sb eq.	CML 2002, Guinée et al., 2002, and van Oers et al. 2002.
Depletion of abiotic resources – fossil fuels	MJ, net calorific value	CML 2002, Guinée et al., 2002, and van Oers et al. 2002.
Water use	m3 world eq. deprived	Available WAter REmaining (AWARE) Boulay et al., 2016
Particulate matter emissions	Disease incidence	SETAC-UNEP, Fantke et al. 2016
Ionising radiation,human health	kBq U235 eq.	Human health effect model as developed by Dreicer et al. 1995, update by Frischknecht et al., 2000
Ecotoxicity (freshwater)	CTUe	Usetox version 2
Human toxicity, cancer effects	CTUh	Usetox version 2
Human toxicity, noncancer effects	CTUh	Usetox version 2
Land use related impacts / soil quality	dimensionless	Soil quality index based on LANCA

4.4.2 STATEMENT THAT THE ESTIMATED IMPACT RESULTS ARE ONLY RELATIVE STATEMENTS WHICH DO NOT INDICATE THE ENDPOINTS OF THE IMPACT CATEGORIES, EXCEEDING THRESHOLD VALUES, SAFETY MARGINS, OR RISKS

Estimated results of impact category indicators are relative, indicating no endpoints of impact categories.

INTERPRETATION

5 INTERPRETATION

5.1 INTERPRETATION OF THE RESULTS BASED ON A DOMINANCE/CONTRIBUTION ANALYSIS OF SELECTED INDICATORS

The results of each module were related to the sum of impacts for each indicator. Relative impacts are shown in the following figures and tables.

As it is visible from figures, the stages A1-A3 (raw material production (A1), transport stage (A2), manufacturing stage (A3)) are dominant across the considered system for all indicators except Climate Change, biogenic and Ozone depletion.

Figure 3 Relative impacts of LCA stages for each environmental indicator for pig iron

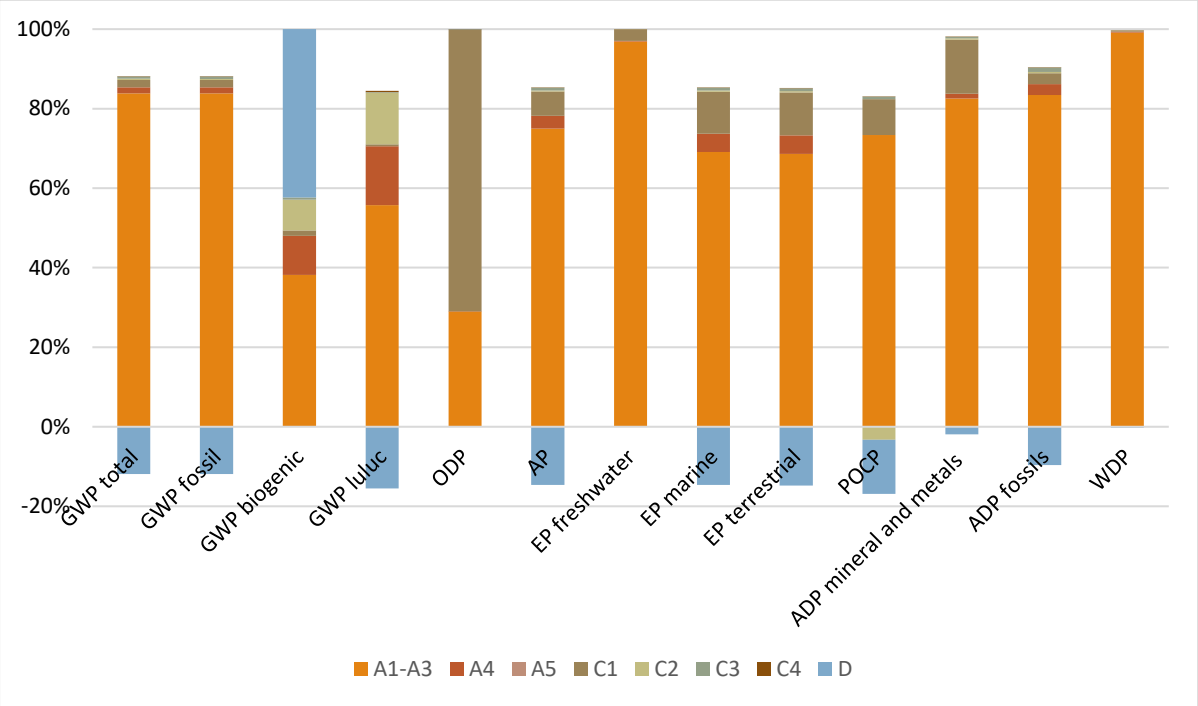


Figure 4 Relative impacts of LCA stages for each environmental indicator for slab

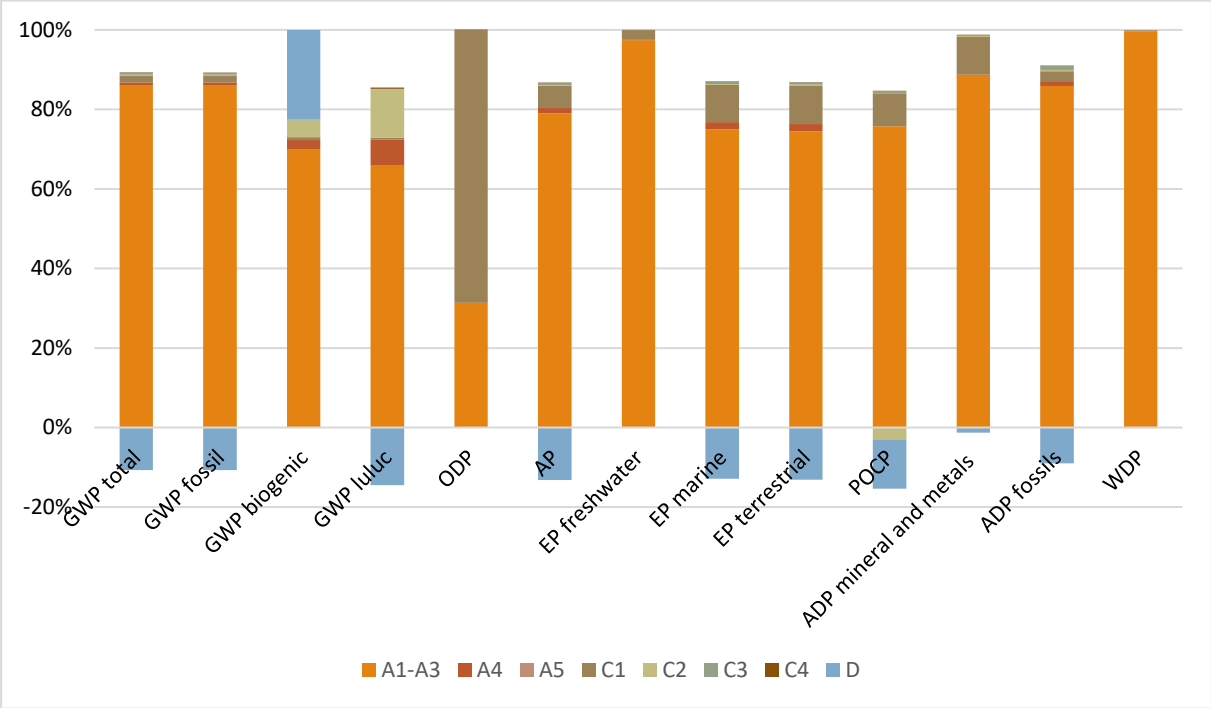


Figure 5 Relative impacts of LCA stages for each environmental indicator for HRC

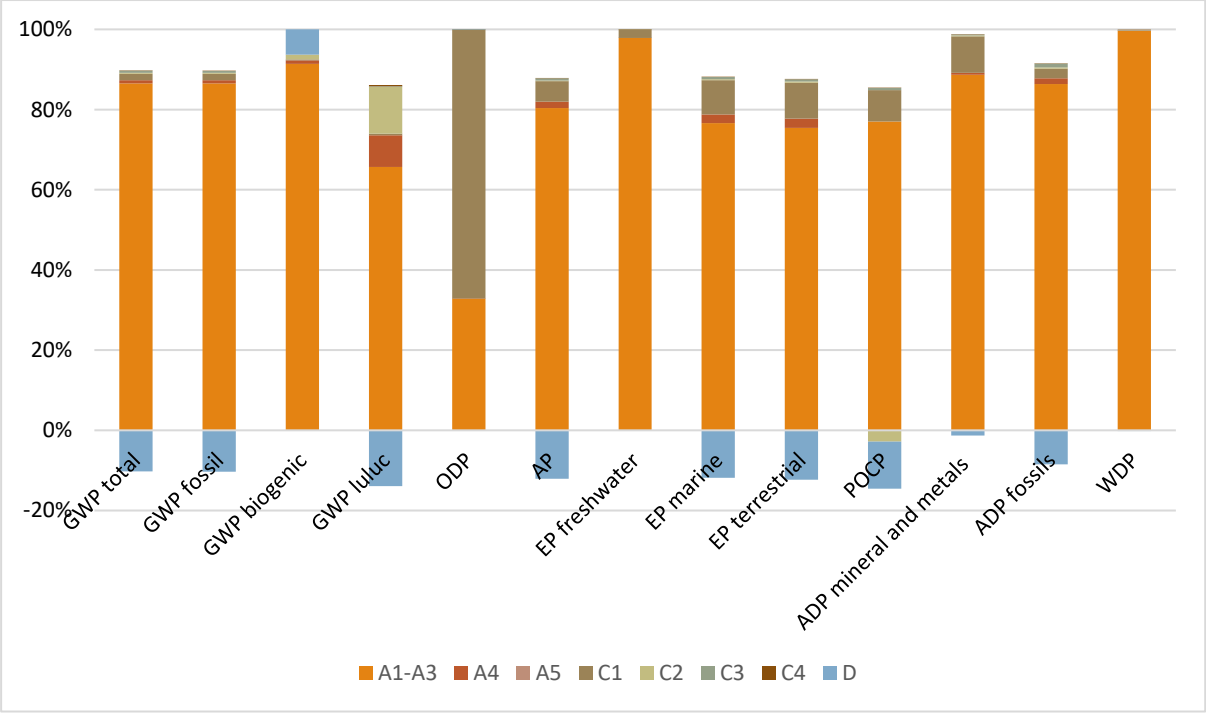
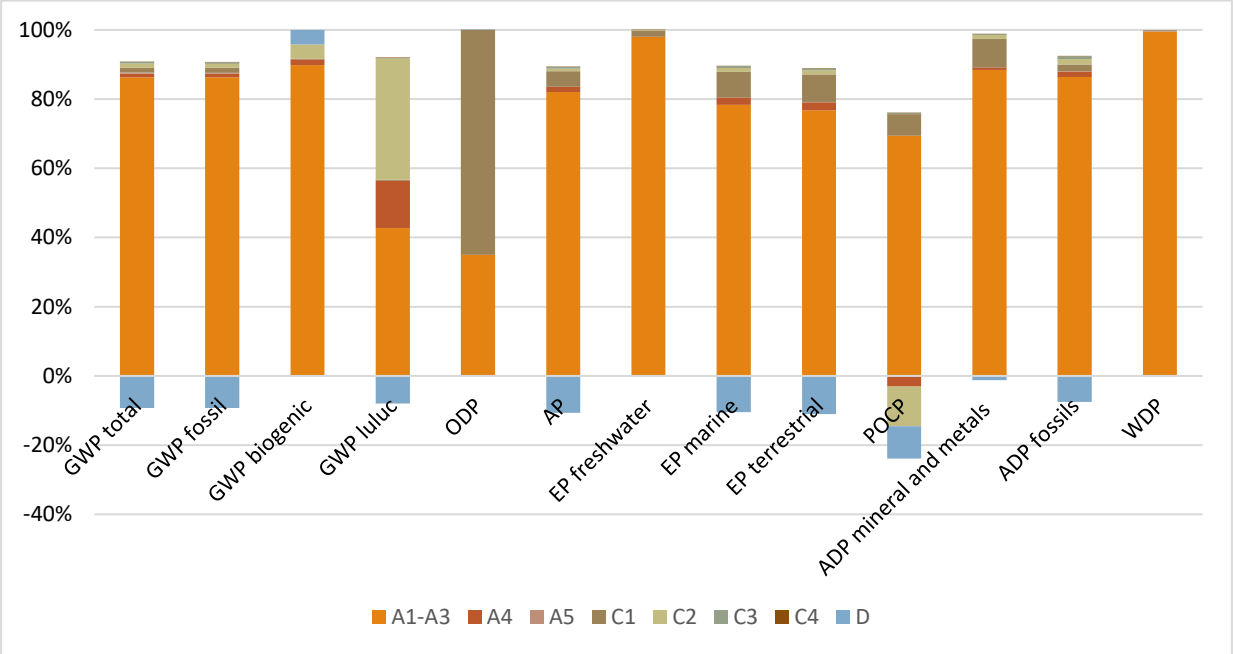


Figure 6 Relative impacts of LCA stages for each environmental indicator for CRC



Tables 21-26 show the relative impact of individual processes to each impact category. In tables, only processes with a relative impact higher than 10 % in at least one indicator are shown.

For agglomerate, processes with the highest relative impact on all categories are:

- Agglomerate production (in categories Climate change total, Acidification, Eutrophication terrestrial, Eutrophication marine, Photochemical ozone formation, human health),
- DE: Metallurgical coke Sphera (in categories Climate change total, Eutrophication marine and terrestrial, Photochemical ozone formation, human healt, Water use),
- GLO: market for coal gas ecoinvent 3.9.1 (in categories Ozone depletion, Eutrophication fresh water, Water use),
- GLO: market for iron ore, crude ore, 46% Fe ecoinvent 3.9.1 (in categories Eutrophication fresh water, marine, terrestrial, POCP, Resource use – mineral and metals, Water use),
- CA-QC: iron pellet production ecoinvent 3.9.1 (in categories Resource use – mineral and metals, Water use),
- Electricity Mix (in categories Resource use - fossil, Water use),
- Compressed air (in categorie Water use),
- BF gas (in categorie Water use),
- Water MPS (in categorie Water use).

For pig iron, processes with the highest relative impact on all categories are:

- Cast Iron production (in categories Climate change total),
- Aglomerat (in all categories except Ozone depletion),

- DE: Metallurgical coke Sphera (in categories Climate change total, Eutrophication terrestrial, marine, POCP, Resource use - fossil, Water use),
- GLO: machine operation, diesel (in categories Ozone depletion, Eutrophication terrestrial, marine, POCP, Resource use - mineral and metals),
- Blast air (in categories Ozone depletion, Eutrophication fresh water),
- GLO: market for coal gas ecoinvent 3.9.1 (in categories Eutrophication fresh water),
- CA-QC: iron pellet production ecoinvent 3.9.1 (in categories Eutrophication fresh water, Resource use – mineral and metals),
- Water MPS (in categories Water use).

For open-hearth steel, processes with the highest relative impact on all categories are:

- Cast Iron A1 - A3 (in all categories),
- Open-Hearth Steel (in categories Eutrophication marine and terrestrial),
- RoW: refractory production, basic, packed ecoinvent 3.9.1 (in categories Resource use – mineral and metals),
- Water recycled (in categorie Water use),
- Water MPS (in categorie Water use).

For slab, processes with the highest relative impact on all categories are:

- Open-Hearth Steel (in all categories),
- GLO: machine operation, diesel, < 18.64 kW, high load factor ecoinvent 3.8 (in categories Ozone depletion, Eutrophication marine and terrestrial, Photochemical ozone formation).

For HRC, processes with the highest relative impact on all categories are:

- Slab A1-A3 (in all categories),
- GLO: machine operation, diesel, < 18.64 kW, high load factor ecoinvent 3.8 (in categories Ozone depletion, Eutrophication marine, terrestrial, POCP),
- Water recycled (in categorie Water use).

For CRC, processes with the highest relative impact on all categories are:

- HRC A1 - A3 (in all categories),
- GLO: machine operation, diesel, < 18.64 kW, high load factor ecoinvent 3.8 (in categories Ozone depletion, POCP),
- Water MPS 8 (in categorie Water use).

Table 21 Relative impact of each process for agglomerate

	GWP total	ODP	AP	EP fresh-water	EP marine	EP terres-trial	POCP	ADP mineral and metals	ADP fossils	WDP
Agglomerate	57,79%	0,00%	68,55%	0,00%	37,34%	34,31%	55,22%	0,00%	0,00%	0,00%
DE: Metallurgical coke Sphera	21,72%	0,00%	8,91%	0,26%	26,12%	25,70%	16,09%	2,57%	69,41%	9,75%
GLO: market for coal gas ecoinvent 3.9.1	1,75%	82,62%	2,41%	83,63%	3,40%%	2,80%	8,50%	5,95%	9,20%	10,82%
GLO: market for iron ore, crude ore, 46% Fe ecoinvent 3.9.1	2,07%	9,73%	7,51%	8,00%	17,87%	22,55%	11,93%	74,43%	2,46%	10,93%
CA-QC: iron pellet production ecoinvent 3.9.1	0,77%	4,59%	0,95%	4,19%	1,18%	1,08%	1,06%	12,80%	0,72%	19,31%
Electricity Mix	8,25%	0,01%	8,63%	0,06%	7,52%	7,32%	5,11%	1,35%	10,96%	21,17%
Compressed air	0,50%	0,00%	0,54%	0,00%	0,45%	0,44%	0,31%	0,09%	0,68%	84,67%
BF gas	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	15,55%
Water MPS	0,00%	0,00%	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%	0,01%	14,06%

Table 22 Relative impact of each process for input pig iron

	GWP total	ODP	AP	EP fresh-water	EP marine	EP terres-trial	POCP	ADP mineral and metals	ADP fossils	WDP

Cast Iron production	67,37%	0,00%	1,56	0,00%	5,51%	2,87%	3,38%	0,00%	0,00%	0,00%
Aglomerat	19,47%	7,88%	63,54%	26,07%	38,14%	39,97%	52,00%	31,20%	21,56%	1,39%
DE: Metallurgical coke Sphera	17,17%	0,00%	22,97%	0,27%	40,45%	41,70%	33,97%	3,26%	60,75%	0,55%
GLO: machine operation, diesel	2,40%	70,96%	8,70%	2,85%	14,90%	15,29%	13,70%	14,17%	3,29%	0,20%
Blast air	1,51%	11,02%	3,73%	36,93%	2,66%	2,36%	7,97%	3,60%	4,26%	8,60%
GLO: market for coal gas ecoinvent 3.9.1	0,28%	5,34%	1,26%	17,88%	1,06%	0,92%	3,63%	1,52%	1,63%	0,12%
CA-QC: iron pellet production ecoinvent 3.9.1	1,58%	3,80%	6,31%	11,46%	4,71%	4,55%	5,77%	41,97%	1,63%	2,82%
Water MPS	0,23	0,00	1,37	0,00	0,34	0,35	0,38	0,15	0,55	74,91%

Table 23 Relative impact of each process for open-hearth steel

	GWP total	ODP	AP	EP fresh-water	EP marine	EP terres-trial	POCP	ADP mineral and metals	ADP fossils	WDP
Cast Iron A1 - A3	86,26%	96,65%	85,36%	91,30%	81,12%	81,16%	88,96%	63,10%	90,24%	57,59%
Open-Hearth Steel	9,08%	0,00%	4,83%	0,00%	11,03%	11,00%	8,23%	0,00%	0,00%	0,00%
RoW: refractory production, basic, packed ecoinvent 3.9.1	0,44%	2,07%	0,77%	1,79%	0,77%	0,79%	0,84%	26,30%	0,41%	0,07%

Water recycled	0,07%	0,00%	0,45%	0,00%	0,12%	0,12%	0,12%	0,05%	0,20%	19,63%
Water MPS	0,06%	0,00%	0,38%	0,00%	0,10%	0,10%	0,11%	0,04%	0,17%	15,03%

Table 24 Relative impact of each process for input slab

	GWP total	ODP	AP	EP fresh-water	EP marine	EP terres-trial	POCP	ADP mineral and metals	ADP fossils	WDP
Open-Hearth Steel	108,68%	28,24%	104,47%	87,51%	98,49%	98,63%	105,42%	89,67%	102,71%	96,83%
GLO: machine operation, diesel, < 18.64 kW, high load factor ecoinvent 3.8	2,11%	68,62%	7,53%	2,41%	12,52%	12,92%	11,92%	9,61%	3,04%	0,12%

Table 25 Relative impact of each process for input HRC

	GWP total	ODP	AP	EP fresh-water	EP marine	EP terres-trial	POCP	ADP mineral and metals	ADP fossils	WDP
Slab A1-A3	106,01%	31,31%	97,50%	83,89%	91,73%	95,02%	103,29%	89,98%	99,62%	90,06%
GLO: machine operation, diesel, < 18.64 kW, high load factor ecoinvent 3.8	1,99%	67,08%	6,70%	2,03%	11,13%	11,92%	11,02%	9,33%	2,83%	0,10%
Water recycled	0,18%	0,00%	1,02%	0,00%	0,25%	0,26%	0,30%	0,10%	0,46%	40,87%

Table 26 Relative impact of each process for input CRC

	GWP total	ODP	AP	EP fresh-water	EP marine	EP terres-trial	POCP	ADP mineral and metals	ADP fossils	WDP
HRC A1 - A3	100,58%	34,10%	94,82%	89,37%	90,63%	91,70%	124,78%	88,48%	92,88%	109,64%
GLO: machine operation, diesel, < 18.64 kW, high load factor ecoinvent 3.8	1,72%	64,93%	5,60%	1,73%	9,40%	10,20%	11,83%	8,47%	2,36%	0,11%
Water MPS	0,05%	0,00%	0,28%	0,00%	0,07%	0,07%	0,10%	0,03%	0,12%	12,26%

5.2 RELATIONSHIP BETWEEN THE RESULTS OF THE LIFE CYCLE INVENTORY ASSESSMENT AND THE RESULTS OF THE LIFE CYCLE IMPACT ASSESSMENT (LCIA)

The results of the life cycle impact assessment were calculated using the characterization methods according to EN 15 804 + A2. Regarding the characterization methods, the calculation is based on multiplying the life cycle inventory results by characterization factors.

5.3 ASSUMPTIONS AND RESTRICTIONS

No specific assumptions and restrictions are applied.

5.4 VARIANCE FROM THE MEANS OF LCIA RESULTS

No variance from the means.

5.5 DATA QUALITY ASSESSMENT

Data quality is assessed by independent verification.

5.6 COMPREHENSIVE TRANSPARENCY AS REGARDS VALUE DECISIONS, JUSTIFICATIONS, AND EXPERT OPINIONS

No specific value decision, justification, and/or expert opinions are applied.

5.7 DOCUMENTATION OF ADDITIONAL INFORMATION

No additional information.

5.8 DOCUMENTATION FOR CALCULATING THE REFERENCE SERVICE LIFE (RSL)

Not relevant.

6 REFERENCE

ISO 14020:2000 Environmental labels and declarations — General principles, 2000-09

ISO 14025: EN ISO 14025:2006-11: Environmental labels and declarations - Type III environmental declarations — Principles and procedures

ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework, 2006-07

ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines, 2006-07

EN 15804:2012 +A2:2019/AC:2021 European Committee for Standardization: Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products, 2021.

Product Category Rules (PCR) document for Construction Products (PCR 2019:14 Version 1.3.4, 2024-04-30)

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