International Standard

ISO 14404-2

Second edition
2024-09

Calculation method of carbon dioxide emission intensity from iron and steel production —

Part 2: Steel plant with electric arc furnace (EAF)

Méthode de calcul de l'intensité de l'émission de dioxyde de carbone de la production de la fonte et de l'acier —

Partie 2: Usine sidérurgique équipée d'un four électrique à arc (FEA)

Reference number
ISO 14404-2:2024(en)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 21, *Environment related to climate change in the iron and steel industry*.

This second edition cancels and replaces the first edition (ISO 14404-2:2013), which has been technically revised.

The main changes are as follows:

— revision of Introduction, Terms and Definitions, and default emission factors;

— addition and revision of some emissions sources;

— clarification of the difference between "Boundary" and "Site boundary";

— addition a new informative annex, Annex D on “Decarbonization strategies and its impact in CO_2 Calculation Method” to give guidance on future relevant emission source categories as new materials and processes become widely applicable at industrial level.

A list of all parts in the ISO 14404 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The steel industry recognizes the urgent need to take actions concerning climate change. Slowing and halting global warming requires reductions in GHG emissions on a global scale. To play a part in achieving these reductions, it is necessary for steel plants to identify the amount of CO_2 emitted during the production of steel products, in order to identify next opportunities for reduction of CO_2 on their pathway to decarbonization.

The production process of steel involves complex chemical reactions, various heating cycles, and the recycling of various by-products. This variety of imports, including raw materials, reactive agents, fuel and heat sources are transformed into a wide range of steel products, by-products, waste materials and waste heat.

Steel plants manufacture a vast range of products with various shapes and specifications including: flat items, long items, pipes, tubes and many others. In addition, they produce unique specialty-grade steel products with high-performance. These are achieved using a number of sub-processes including micro-alloying and applying surface treatments like galvanizing and coating, which require additional heat treatments. The variety of products manufactured, and processes used means no two steel plants are identical.

Climate regulations in each country require steel companies to devise methods to lower CO_2 emissions from steel plants while continuing to produce steel products by these diverse and complex steelmaking processes. To accomplish this, it is desirable to have universally common indicators for determining steel plant CO_2 emissions.

Additionally, there are other aspects related to the heterogeneous nature of the steel industry around the globe other than assets characteristics, that should be taken into account (inputs availability; market and business environment, innovation), when looking for commonalities in calculation methodologies to ensure consistency and comprehensiveness.

There are many methods for calculating CO_2 emission intensity from steel plants and specific processes. Each method was created to meet the objectives of a particular country or region. In some cases, a single country can have several calculation methods in order to fulfil different objectives. Each one of these methods reflects the unique local characteristics of a particular country or region. Therefore, these methods cannot be used for comparisons of CO_2 emission intensity from steel plants located in different countries and regions.

To overcome this methodological fragmentation, the World Steel Association (worldsteel), has developed a calculation method for CO_2 emission intensity of steel plants. This calculation method was developed to facilitate the improvement of steel plant CO_2 emissions. It helps members keep track of their CO_2 emissions intensity relative to the other member steel companies located in different places in the world. An agreement was reached among members, and worldsteel has issued the method as a guideline called "CO_2 Emissions Data Collection User Guide." Actual data collection among worldsteel members based upon the guide started in 2007. Furthermore, worldsteel is encouraging even non-member steel companies to begin using the guide to calculate CO_2 emission intensity of their steel plants.

The present ISO 14404-1 revision is based on worldsteel's CO_2 Data Collection Users Guide, version 11[4], reviewed in 2022 and follows ISO14404-4.

This calculation method establishes clear boundaries for collection of CO_2 emissions data. The net CO_2 emissions and production from a steel plant are calculated using all parameters within the boundaries. The CO_2 emission intensity of the steel plant is calculated by the net CO_2 emission from the plant using the boundaries divided by the amount of crude steel production of the plant. With this methodology, the CO_2 emission intensity of steel plants is calculated irrespective of the variance in the type of process used, products manufactured and geographic characteristics.

This calculation method only uses basic imports and exports that are commonly measured and recorded by the plants; thus, the method requires neither the measurement of the specific efficiency of individual equipment or processes nor dedicated measurements of the complex flow and recycling of materials and waste heat. In this way, the calculation method ensures its simplicity and universal applicability without requiring steel plants to install additional dedicated measuring devices or to collect additional dedicated data other than those commonly used data in the management. Even though, the use of measured carbon content and net calorific values are highly recommended to obtain more accurate emissions accounting for

each material considered. Any home metrics needs to be referenced with link to a transparent and accessible source, including indirect emission factors. To ensure transparency in communicating results to interested parties, these distinctions should be clearly stated.

With this method, a steel company can calculate a single figure for the CO_2 emissions intensity of a steel plant as a whole. By observing changes in CO_2 emissions intensity over time using this methodology, steel companies can evaluate whether their efforts to reduce CO_2 emissions are being properly implemented. As was explained earlier, most steel plants manufacture a vast range of products with various shapes and specifications. This calculation method is simple and universally applicable because it is not affected by the differences in the production processes of such diverse products, and treats a whole steel plant as one unit with one CO_2 emission intensity. Therefore, this calculation method is not applicable for calculating and determining the carbon footprint of any specific steel product.

When comparing CO_2 emission intensity between different steel plants, it should be kept in mind that each steel plant has a different composition of manufacturing products and that the energy sources and raw materials available varies among countries and regions. In addition, since the ISO 14404 series strictly defines the boundary of the target process route for each part, only steel plants using the same part of the ISO 14404 series (i.e., ISO 14404-1, ISO 14404-2, ISO 14404-3) can be compared with each other. Note that the default emission factors provided in the ISO 14404 series are global averages and is not adjusted to reflect regional differences in energy sources and raw materials. When calculating total CO_2 emissions or CO_2 emission intensity for inventory or benchmarking purposes, the emission factors applicable to the conditions of the target country or region should be selected.

In order to give guidance to users on which areas of interest will be dealt with as future sources for direct and indirect CO_2 emission factors in programmed revisions of this document, a tentative list is provided in Annex D.

Calculation method of carbon dioxide emission intensity from iron and steel production —

Part 2:
Steel plant with electric arc furnace (EAF)

1 Scope

This document specifies calculation methods to evaluate the total annual carbon dioxide (CO_2) emissions, and the emission factor of CO_2 per unit of steel production of the entire steel production process. This document applies to plants that produce mainly carbon steel. It can be used by companies using EAF to manufacture steel.

It includes boundary definition, material and energy flow definition, and emission factor of CO_2. Besides direct source import to the boundary, upstream and credit concept is applied to exhibit the plant CO_2 intensity.

This document supports steel producers to establish CO_2 emissions attributable to a site.

Conversion to energy consumption and to consumption efficiency can be obtained using Annex A.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Emissions

3.1.1
emission source
process emitting CO_2 during production of steel products

Note 1 to entry: There are three categories of CO_2 emission sources: direct, upstream and credit. Examples of emission sources that are subject to this document are given in 3.1.2, 3.1.3 and 3.1.4.

3.1.2
direct CO_2 emission
CO_2 emissions from steel production activity inside the boundary

Note 1 to entry: Direct CO_2 emission is categorized as “direct GHG emissions” in ISO 14064-1.

3.1.3
upstream CO_2 emission
CO_2 emissions from imported material related to outsourced steel production activities outside the site boundary and from imported electricity and steam into the site boundary

Note 1 to entry: CO_2 emissions from imported material in this term is categorized as "other indirect GHG emissions" in ISO 14064-1.

Note 2 to entry: CO_2 emissions from imported electricity and steam in this term is categorized as "energy indirect GHG emissions" in ISO 14064-1.

3.1.4
credit CO_2 emission
CO_2 emission that corresponds to exported material and electricity or steam

Note 1 to entry: Credit CO_2 emission is categorized as "direct GHG emissions" in ISO 14064-1.

3.2 Gas fuel

3.2.1
natural gas
mixture of gaseous hydrocarbons, primarily methane, occurring naturally on earth, and used in metallurgic plants either as a fuel or as raw material

3.2.2
town gas
fuel gas manufactured for domestic and industrial use

3.3 Liquid fuel

3.3.1
heavy oil
No. 4 and No.6 fuel oil defined by the American Society for Testing and Materials (ASTM)

Note 1 to entry: For No.4 and No.6 fuel oil, see ASTM Fuel Oils Standard Specification.

3.3.2
light oil
No. 2 and No.3 fuel oil defined by the American Society for Testing and Materials (ASTM)

Note 1 to entry: For No.2 and No.3 fuel oil, see ASTM Fuel Oils Standard Specification.

3.3.3
kerosene
light petroleum distillate that has maximum distillation temperature of 204 °C and a final boiling point of 300 °C

Note 1 to entry: Also known as paraffin (oil).

Note 2 to entry: U.S. Energy Information Administration, Petroleum and other liquids, units are modified.

3.3.4
LPG
liquefied petroleum gas
liquid composed predominantly of any of the following hydrocarbons or mixtures thereof: propane, propene, butanes and butene

[SOURCE: ISO 6578:2017, 3.1.4]

3.3.5
LNG
liquefied natural gas
liquids composed predominantly of methane

[SOURCE: ISO 8943:2007, 3.10]

3.4 Solid fuel

3.4.1
EAF coal
solid fuel for *EAF* (3.10.4), including anthracite

Note 1 to entry: Coal can be either fossil coal derived from geological deposits or biocoal derived from biomass.

3.4.2
steam coal
boiler coal for producing electricity and steam, including anthracite

Note 1 to entry: Coal can be either fossil coal derived from geological deposits or biocoal derived from biomass.

3.4.3
coke
solid carbonaceous material

3.4.4
charcoal
devolatilized or coked carbon neutral materials

EXAMPLE Trees, plants.

3.5 Auxiliary material

3.5.1
limestone
calcium carbonate
$CaCO_3$
mineral used in metallurgic plants as slag former or as raw material for *burnt lime* (3.5.2)

3.5.2
burnt lime
calcium oxide
CaO
limestone (3.5.1) calcinated in blast furnaces or in lime kiln

Note 1 to entry: Usually used as slag former.

3.5.3
crude dolomite
calcium magnesium carbonate
$CaMg(CO_3)_2$
mineral used in metallurgic plants as raw material for *burnt dolomite* (3.5.4)

3.5.4
burnt dolomite
$CaMgO_2$
crude dolomite (3.5.3) calcinated in lime kilns

Note 1 to entry: Usually used as slag former.

3.5.5
electric arc furnace graphite electrode
EAF graphite electrode
net use of EAF graphite electrodes or attrition loss

3.5.6
nitrogen
N_2
inert gas separated from air at oxygen plant, imported from outside the boundary or exported to outside the boundary

3.5.7
argon
Ar
inert gas separated from air at oxygen plant, imported from outside the boundary or exported to outside the boundary

3.5.8
oxygen
O_2
gas separated from air at oxygen plant, imported from outside the boundary or exported to outside the boundary

3.6 Energy carriers

3.6.1
electricity
electrical power imported from outside the boundary or exported to outside the boundary

3.6.2
steam
pressurized water vapour imported from/exported to outside the boundary

3.6.3
waste heat
any heat that can be collected economically and re-used for low grade heating or even low pressure steam generation for social heating or process heating or cleaning, within the industry or other industries

3.7 Ferrous containing materials

3.7.1
pellets
agglomerated spherical iron ore calcinated by rotary kiln or other equipment

3.7.2
pig iron
hot metal, intermediate liquid iron products produced by smelting iron ore with equipment such as blast furnace

Note 1 to entry: Many companies report emissions from purchased pig iron in solid state as metallic charge under this product category, for this specific process route.

Note 2 to entry: According to International Iron Metals Association, (IIMA) on average, pig iron makes up between 5-10 percent of the global EAF metallics charge. In some parts of the world where scrap is scarce, pig iron can be used at up to 60 percent of the charge.

3.7.3
cold iron
solidified hot metal as an intermediate solid iron products

3.7.4
scrap
used steel available for reprocessing

3.7.5
gas-based DRI
direct reduced iron (DRI) reduced by a reducing gas such as reformed *natural gas* (3.2.1)

3.7.6
coal-based DRI
direct reduced iron (DRI) reduced by coal

3.8 Alloys

3.8.1
ferro-nickel
alloy of iron and nickel

3.8.2
ferro-chromium
alloy of iron and chromium

3.8.3
ferro-molybdenum
alloy of iron and molybdenum

3.8.4
ferro-manganese
alloy of iron and manganese

3.8.5
ferro-silicon
alloy of iron and silicon

3.8.6
silico-manganese
alloy of silicon and manganese

3.9 Other imported/exported materials

3.9.1
crude steel
steel in its first solid (or usable) form

Note 1 to entry: Crude steel is the normalization unit for this calculation methodology.

Note 2 to entry: Crude steel examples are ingots and semi-finished products (billets, blooms, slabs) defined by Steel Statistical Yearbook.

3.9.2
CO_2 for external use
CO_2 exported to outside the boundary

3.10 Others

3.10.1
other emission source
other related *emission sources* (3.1.1) such as plastics, scraps, desulfurization additives, alloys, fluxes for secondary metallurgy, dust, sludges, etc., that can be used if not covered by any other specific source

3.10.2
boundary
limit of activity used to calculate CO_2 emissions intensity for steel production activities

Note 1 to entry: Boundary may be different from site boundary.

Note 2 to entry: Major facilities in iron and steel production in boundaries are given in 3.10.4 to 3.10.12.

3.10.3
site boundary
boundary defined by the target steel production site for the calculation of CO_2 emission and intensity

3.10.4
electric arc furnace
EAF
furnace that melts and refines iron-bearing material into steel

Note 1 to entry: It can include ladle furnace; degassing; alloying station, as minor related emission sources. It should not be assimilated to an EAF steel plant defined as a comprehensive production unit.

3.10.5
casting
pouring steel directly from a ladle through a tundish into a mould shaped to form billets, blooms, or slabs, or pouring steel from a ladle into a mould shaped to form ingots

3.10.6
lime kiln
kiln used to produce *burnt lime* (3.5.2) by the calcination of *limestone* (3.5.1)

3.10.7
oxygen plant
cryogenic air separator to produce high-purity oxygen or other alternative technologies, such as hydrogen electrolysis plants

3.10.8
steam boiler
boiler for production of steam device to generate pressurized water vapour from heat

3.10.9
power plant
plant that generates electricity

3.10.10
hot rolling
rolling at temperatures above the recrystallisation temperature, normally above 500 °C

3.10.11
cold rolling
rolling at temperatures below the recrystallisation temperature, normally below 500 °C

3.10.12
coating
covering steel with another material (tin, chrome, zinc, etc.), primarily for corrosion resistance

Note 1 to entry: Coating materials may include tin, chrome, zinc, and other non-metallic materials, such as paints, etc.

4 Symbols

The symbols used in this document are given in Table 1.

Table 1 — Symbols

Symbols	Unit	Description
$E_{d,CO2}$	tons (or tonnes) of CO_2	Direct CO_2 emissions
$E_{u,CO2}$	tons (or tonnes) of CO_2	Upstream CO_2 emissions
$E_{c,CO2}$	tons (or tonnes) of CO_2	Credit CO_2 emissions
$E_{CO2,annual}$	tons (or tonnes) of CO_2	Annual CO_2 emissions
I_{CO2}	tons (or tonnes) of CO_2 per ton	CO_2 intensity factor
$K_{t,d,CO2}$	tons (or tonnes) of CO_2 per unit	Emission factor for calculation of direct CO_2 emissions
$K_{t,u,CO2}$	tons (or tonnes) of CO_2 per unit	Emission factor for calculation of upstream CO_2 emissions
$K_{t,c,CO2}$	tons (or tonnes) of CO_2 per unit	Emission factor for calculation of credit CO_2 emissions
P	tons (or tonnes)	Annual crude steel production
$Q_{t,d,CO2}$	—	Quantities of direct CO_2 emission sources
$Q_{t,u,CO2}$	—	Quantities of upstream CO_2 emission sources
$Q_{t,c,CO2}$	—	Quantities of credit CO_2 emission sources

5 Principles

5.1 General

The application of principles is a base to ensure that calculated CO_2 intensity is effectively usable for steel producers to assess their production site efficiency universally without specificity of product configurations, location of site, and individual facility used in the site.

5.2 Relevance

Select all the direct source, upstream source and credits into and out of the boundary of steel production site, data and methodologies appropriate to the need of intended purpose.

5.3 Completeness

Include all the relevant imports to, exports from sources and credits to steel production site to calculate CO_2 intensity of steel production site.

5.4 Consistency

Enable universally meaningful assessment in CO_2 intensity of steel production site regardless of the product configurations, location of the site, and individual facilities used in the site.

5.5 Accuracy

Reduce bias and uncertainties of the data being collected and used for the calculation and methodologies of the calculations as much as appropriate.

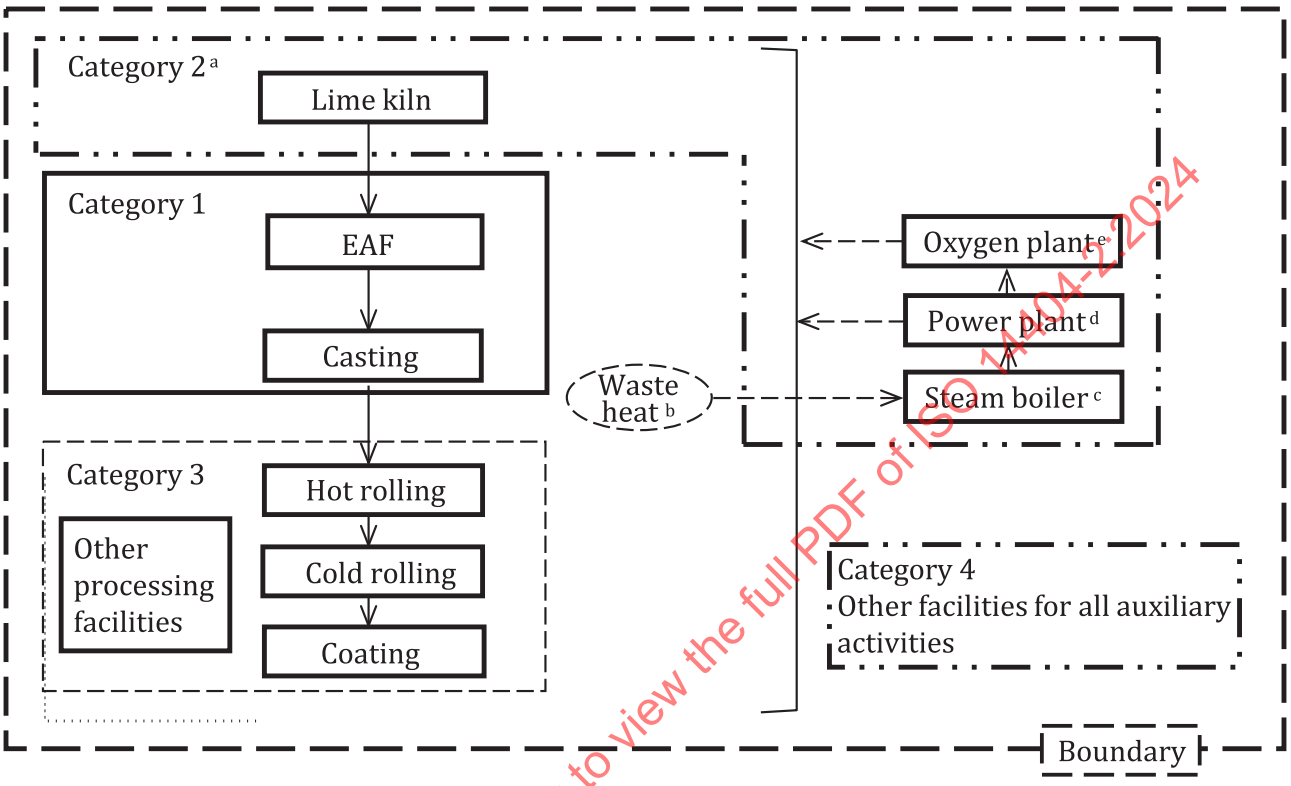
5.6 Transparency

Disclose CO_2 calculation method, including emission factors to allow every steel producer assess its CO_2 intensity of steel production site universally.

6 Boundary

6.1 General

This calculation method defines the boundary applied to the calculation of CO_2 emissions of the steel production as the following essential facilities. These essential facilities are categorized into four groups. (See Figure 1)



a Equipment that can be outsourced.

b The materials in the dotted circles are by-products, and the dotted arrows show the flow of by-product reuse.

c Steam boilers reuse waste heat from the production facilities to produce steam.

d Power plants use steam and by-product gas to generate electricity to supply power to oxygen plants and Category 1~3 facilities

e Oxygen plants supply oxygen to Category 1~3 facilities.

Figure 1 — Essential facilities within the boundary

6.2 Category 1

The following essential facilities are classified as category 1. These facilities shall be included in the site.

— EAF;

— casting.

NOTE EAF can include ladle furnace, degassing, alloying station, etc.

6.3 Category 2

The following facilities are classified as category 2. These facilities are operated in the site or operations of these facilities are outsourced. In the case where operations of these facilities are outsourced, intermediate products from these operations are imported and these upstream CO_2 emissions shall be calculated.

— lime kiln;

— oxygen plant;

— steam boiler;

— power plant.

6.4 Category 3

The following processing facilities are classified as category 3. CO_2 emission from these facilities in the site shall be calculated.

— hot rolling;

— cold rolling;

— coating;

— other processing facilities, such as pipe manufacturing facility.

6.5 Category 4

Other facilities for all auxiliary activities are classified as category 4. CO_2 emission from these facilities in the site, if any, shall be calculated.

EXAMPLE Office, on-site transport, etc.

7 Calculation

7.1 General

A plant producing crude steel performs its calculations as follows.

a) Step 1: Identify the categories of processing facilities.

b) Step 2: Clarify the quantity of annual crude steel production at the plant.

c) Step 3: Clarify the annual direct CO_2 emission sources and upstream CO_2 emission sources based on raw materials, intermediate products and energy import to the plant.

d) Step 4: Clarify the annual credit CO_2 emission sources based on raw materials, intermediate products, and energy which the plant exports to outside users.

e) Step 5: Calculate the annual CO_2 emissions and CO_2 factor using the emission factors.

7.2 Calculation procedure

7.2.1 Data collection of crude steel production

A plant producing steel records its annual production of crude steel (P).

7.2.2 Data collection direct and/or upstream CO_2 emission sources

A plant producing steel records the quantities of raw materials, intermediate products, and energy that are imported from outside suppliers as the direct or upstream CO_2 emission sources based on Table 2.

Table 2 — Direct and/or upstream CO_2 emission sources

Subscript designator for Q t	Emission sources	Unit	Quantities of direct emission source $Q_{t,d,CO2}$	Quantities of upstream emission source $Q_{t,u,CO2}$
Gas fuel				
1	Natural gas	10^3[a] m^3(stp[b])	$Q_{1,d,CO2}$	N/A[c]
2	Town gas	10^3m^3(stp)	$Q_{2,d,CO2}$	N/A
Liquid fuel				
3	Heavy oil	m^3	$Q_{3,d,CO2}$	N/A
4	Light oil	m^3	Q_{4dCO2}	N/A
5	Kerosene	m^3	$Q_{5,d,CO2}$	N/A
6	LPG	t	$Q_{6,d,CO2}$	N/A
7	LNG	10^3m^3(stp)	$Q_{7,d,CO2}$	N/A
Solid fuel				
8	EAF coal	dry t	$Q_{8,d,CO2}$	N/A
9	Steam coal	dry t	$Q_{9,d,CO2}$	N/A
10	Coke	dry t	$Q_{10,d,CO2}$	N/A
11	Charcoal	dry t	$Q_{11,d,CO2}$	N/A
Auxiliary materials				
12	Limestone	dry t	$Q_{12,d,CO2}$	N/A
13	Burnt lime	t	N/A	Q_{13uCO2}
14	Crude dolomite	dry t	$Q_{14,d,CO2}$	N/A
15	Burnt dolomite	t	N/A	$Q_{15,u,CO2}$
16	EAF graphite electrodes	t	$Q_{16,d,CO2}$	N/A
17	Nitrogen	10^3m^3(stp)	N/A	$Q_{17,u,CO2}$
18	Argon	10^3m^3(stp)	N/A	$Q_{18,u,CO2}$
19	Oxygen	10^3m^3(stp)	N/A	$Q_{19,u,CO2}$
Energy carriers				
20	Electricity	MWh	N/A	$Q_{20,u,CO2}$
21	Steam	t	N/A	$Q_{21,u,CO2}$
Ferrous-containing material				
22	Pellets	t	N/A	N/A
23	Pig iron	t	$Q_{23,d,CO2}$	N/A
24	Cold iron	t	$Q_{24,d,CO2}$	N/A
25	Gas-based DRI	t	$Q_{25,d,CO2}$	N/A
26	Coal-based DRI	t	$Q_{26,d,CO2}$	N/A
Alloys				

NOTE Raw materials that are recorded as both direct and upstream CO_2 emission sources are handled similarly as both direct and upstream CO_2 emission sources when calculating CO_2 emissions.

[a] 10^3=1 000

[b] Standard temperature and pressure.

[c] Not applicable.

Table 2 *(continued)*

Subscript designator for Q t	Emission sources	Unit	Quantities of direct emission source $Q_{t,d,CO2}$	Quantities of upstream emission source $Q_{t,u,CO2}$
27	Ferro-nickel	t	$Q_{27,d,CO2}$	N/A
28	Ferro-chromium	t	$Q_{28,d,CO2}$	N/A
29	Ferro-molybdenum	t	$Q_{29,d,CO2}$	N/A
30	Ferro-manganese	t	$Q_{30,d,CO2}$	N/A
31	Ferro-silicon	t	$Q_{31,d,CO2}$	N/A
32	Silico-manganese	t	$Q_{32,d,CO2}$	N/A
Other imported material				
33	CO_2 for internal use	t	$Q_{33,d,CO2}$	N/A
N	Other emission sources	—	$Q_{N,d,CO2}$	$Q_{N,u,CO2}$

NOTE Raw materials that are recorded as both direct and upstream CO_2 emission sources are handled similarly as both direct and upstream CO_2 emission sources when calculating CO_2 emissions.

[a] 10^3=1 000

[b] Standard temperature and pressure.

[c] Not applicable.

7.2.3 Data collection of credit CO_2 emission sources

A plant producing steel records the quantities of raw materials, intermediate products, and energy that it exports to outside users as the credit CO_2 emission sources based on Table 3.

Table 3 — Credit CO_2 emission sources

Subscript designator for Q t	Emission sources	Unit	Quantities of credit emission source $Q_{t,c,CO2}$
Gas fuel			
1	Natural gas	10^{3a} m^3(stp[b])	$Q_{1,c,CO2}$
2	Town gas	10^3m^3(stp)	$Q_{2,c,CO2}$
Liquid fuel			
3	Heavy oil	m^3	$Q_{3,c,CO2}$
4	Light oil	m^3	$Q_{4,c,CO2}$
5	Kerosene	m^3	$Q_{5,c,CO2}$
6	LPG	t	$Q_{6,c,CO2}$
7	LNG	10^3m^3(stp)	$Q_{7,c,CO2}$
Solid fuel			
8	EAF coal	dry t	$Q_{8,c,CO2}$
9	Steam coal	dry t	$Q_{9,c,CO2}$
10	Coke	dry t	$Q_{10,c,CO2}$
11	Charcoal	dry t	$Q_{11,c,CO2}$
Auxiliary materials			
12	Limestone	dry t	$Q_{12,c,CO2}$
13	Burnt lime	t	$Q_{13,c,CO2}$

[a] 10^3=1 000

[b] Standard temperature and pressure.

Table 3 *(continued)*

Subscript designator for Q t	Emission sources	Unit	Quantities of credit emission source $Q_{t,c,CO2}$
14	Crude dolomite	dry t	$Q_{14,c,CO2}$
15	Burnt dolomite	t	$Q_{15,c,CO2}$
16	EAF graphite electrodes	t	$Q_{16,c,CO2}$
17	Nitrogen	$10^3 m^3$(stp)	$Q_{17,c,CO2}$
18	Argon	$10^3 m^3$(stp)	$Q_{18,c,CO2}$
19	Oxygen	$10^3 m^3$(stp)	$Q_{19,c,CO2}$
Energy carriers			
20	Electricity	MWh	$Q_{20,c,CO2}$
21	Steam	t	$Q_{21,c,CO2}$
Ferrous-containing material			
22	Pellets	t	$Q_{22,c,CO2}$
23	Pig iron	t	$Q_{23,c,CO2}$
24	Cold iron	t	$Q_{24,c,CO2}$
25	Gas-based DRI	t	$Q_{25,c,CO2}$
26	Coal-based DRI	t	$Q_{26,c,CO2}$
Alloys			
27	Ferro-nickel	t	$Q_{27,c,CO2}$
28	Ferro-chromium	t	$Q_{28,c,CO2}$
29	Ferro-molybdenum	t	$Q_{29,c,CO2}$
30	Ferro-manganese	t	$Q_{30,c,CO2}$
31	Ferro-silicon	t	$Q_{31,c,CO2}$
32	Silico-manganese	t	$Q_{32,c,CO2}$
Other exported materials			
33	CO_2 for external use	t	$Q_{33,c,CO2}$
N	Other emission sources	—	$Q_{N,c,CO2}$

[a] 10^3=1 000

[b] Standard temperature and pressure.

7.2.4 Calculation

The annual CO_2 emissions ($E_{CO2,annual}$) and CO_2 intensity (I_{CO2}) of a site are calculated from Formula (1) and (2) using emission factors that correspond to the direct CO_2 emission sources, upstream CO_2 emission sources, and credit CO_2 emission sources recorded as specified in 7.2.2 and 7.2.3:

Calculation example is shown in Annex C. See Tables C.1 and C.2.

$$E_{CO2,annual} = \sum_{t=1}^{N} K_{t,d,CO2} \times Q_{t,d,CO2} + \sum_{t=1}^{N} K_{t,u,CO2} \times Q_{t,u,CO2} - \sum_{t=1}^{N} K_{t,c,CO2} \times Q_{t,c,CO2} \quad (1)$$

$$I_{CO2} = E_{CO2,annual}/P \quad (2)$$

Table 4 gives an indication of emission factors that can be used if no other reliable data are available.

It is considered that the emissions associated with the carbon content of steel scrap, the final recarburants used to match the final composition of the steel are equivalent to the final steel grades produced and the

carbon which is contained in the slag and dust. Therefore, steel scrap is considered to have an emission factor of zero and has been left out of the table.

Table 4 — Indicative CO_2 emission factors for CO_2 emission sources

Subscript designator for Q t	CO_2 emission sources	Direct emission factor ($K_{t,d,CO2}$) t CO_2/unit	Upstream emission factor ($K_{t,u,CO2}$) t CO_2/unit	Credit emission factor ($K_{t,c,CO2}$) t CO_2/unit
Gas fuel				
1	Natural gas	2,015	N/A	2,015
2	Town gas	2,014	N/A	2,014
Liquid fuel				
3	Heavy oil	2,907	N/A	2,907
4	Light oil	2,601	N/A	2,601
5	Kerosene	2,481	N/A	2,481
6	LPG	2,985	N/A	2,985
7	LNG	2,015	N/A	2,015
Solid fuel				
8	EAF coal	3,257	N/A	3,257
9	Steam coal	2,462	N/A	2,462
10	Coke	3,257	N/A	3,257
11	Charcoal	0,000	N/A	0,000
Auxiliary materials				
12	Limestone	0,440	N/A	0,440
13	Burnt lime	N/A	0,950	0,950
14	Crude dolomite	0,476	N/A	0,476
15	Burnt dolomite	N/A	1,100	1,100
16	EAF graphite electrodes	3,663	N/A	3,663
17	Nitrogen	N/A	0,103	0,103
18	Argon	N/A	0,103	0,103
19	Oxygen	N/A	0,355	0,355
Energy carriers				
20	Electricity	N/A	0,504	0,504
21	Steam	N/A	0,195	0,195
Ferrous-containing materials				
22	Pellets	0	N/A	0
23	Pig iron	0,172	N/A	0,172
24	Cold iron	0,172	N/A	0,172
25	Gas-based DRI	0,073	N/A	0,073
26	Coal-based DRI	0,073	N/A	0,073
Alloys				
27	Ferro-nickel	0,037	N/A	0,037
28	Ferro-chromium	0,275	N/A	0,275
29	Ferro-molybdenum	0,018	N/A	0,018

If different emission factors or simplifications from Table 4 are applied, such emission factors or simplifications should be clearly identified and justified. If other emission sources specified in No. *N* of Table 4 are applied, such sources should be clearly identified with their emission factors. An example of a template is available in Table B.1 of Annex B.

[a] The value shall be determined by using available data backed by reliable evidence.

Table 4 *(continued)*

Subscript designator for Q t	**CO_2 emission sources**	**Direct emission factor ($K_{t,d,CO2}$)** t CO_2/unit	**Upstream emission factor ($K_{t,u,CO2}$)** t CO_2/unit	**Credit emission factor ($K_{t,c,CO2}$)** t CO_2/unit
30	Ferro-manganese	0,183	N/A	0,183
31	Ferro-silicon	0,004	N/A	0,004
32	Silico-manganese	0,018	N/A	0,018
Other imported/exported materials				
33	CO_2 for internal/external use	1,000	N/A	1,000
N	Other emission sources	[a]	[a]	[a]

If different emission factors or simplifications from Table 4 are applied, such emission factors or simplifications should be clearly identified and justified. If other emission sources specified in No. *N* of Table 4 are applied, such sources should be clearly identified with their emission factors. An example of a template is available in Table B.1 of Annex B.

[a] The value shall be determined by using available data backed by reliable evidence.

Annex A
(informative)

Calculation of energy consumption and intensity

The annual energy consumption, $C_{\mathrm{E,annual}}$, and intensity, I_E, at a plant manufacturing steel using electric arc furnace can be calculated from Formula (A.1) and (A.2) using $Q_{t,\mathrm{d,CO2}}$, $Q_{t,\mathrm{u,CO2}}$ and $Q_{t,\mathrm{c,CO2}}$ collected as explained in 7.2.2 and 7.2.3, and the energy conversion factors ($K_{t,\mathrm{d,E}}$, $K_{t,\mathrm{u,E}}$, and $K_{t,\mathrm{c,E}}$):

$$C_{\mathrm{E,annual}} = \sum_{t=1}^{N} K_{t,\mathrm{d,E}} \times Q_{t,\mathrm{d,CO2}} + \sum_{t=1}^{N} K_{t,\mathrm{u,E}} \times Q_{t,\mathrm{u,CO2}} - \sum_{t=1}^{N} K_{t,\mathrm{c,E}} \times Q_{t,\mathrm{c,CO2}} \quad \text{(A.1)}$$

$$I_{\mathrm{E}} = C_{\mathrm{E,annual}}/P \quad \text{(A.2)}$$

where

$Q_{t,\mathrm{d,CO2}}$ are the quantities of direct CO_2 emission sources;

$Q_{t,\mathrm{u,CO2}}$ are the quantities of upstream CO_2 emission sources;

$Q_{t,\mathrm{c,CO2}}$ are the quantities of credit CO_2 emission sources;

$K_{t,\mathrm{d,E}}$ is the energy conversion factor for calculation of direct energy consumption;

$K_{t,\mathrm{u,E}}$ is the energy conversion factor for calculation of upstream energy consumption;

$K_{t,\mathrm{c,E}}$ is the energy conversion factor for calculation of credit energy consumption;

I_{E} is the energy intention factor;

$C_{\mathrm{E,annnual}}$ is the annual energy consumption;

P is the annual crude steel production.

NOTE Energy conversion factors for CO_2 emission sources are referred in worldsteel CO_2 emissions data collection[4].

Additionally, upstream/credits factors for some materials should be dependent of electricity grid mix factor. The following formula guiding this assumption is provided by worldsteel.

For CO_2 emission sources:

— steam;

— oxygen;

— nitrogen;

— argon;

— waste heat.

Upstream $K_{t,\mathrm{u,CO2}}$ and Credit $K_{t,\mathrm{c,CO2}}$ emission factors are a function of the applicable Upstream emission factor for Electricity.

$$K_{t,c,CO_2} = K_{t,c,E}\ x \frac{K_{20,c,CO_2}}{K_{20,c,E}}$$

$$K_{t,u,CO_2} = K_{t,u,E}\ x \frac{K_{20,u,CO_2}}{K_{20,u,E}}$$

Annex B
(informative)

Example of template for using different emission factors or emission sources from Table 4

Table B.1 — Indicative emission factors for CO_2 emission sources

Subscript designator for Q t	CO_2 emission sources	Direct emission factor ($K_{t,d,CO2}$) t CO_2/unit	Upstream emission factor ($K_{t,u,CO2}$) t CO_2/unit	Credit emission factor ($K_{t,c,CO2}$) t CO_2/unit	Justification
Gas fuel					
1	Natural gas				
2	Town gas				
Liquid fuel					
3	Heavy oil				
4	Light oil				
5	Kerosene				
6	LPG				
7	LNG				
Solid fuel					
8	EAF coal				
9	Steam coal				
10	Coke				
11	Charcoal				
Auxiliary materials					
12	Limestone				
13	Burnt lime				
14	Crude dolomite				
15	Burnt dolomite				
16	EAF graphite electrodes				
17	Nitrogen				
18	Argon				
19	Oxygen				
Energy carriers					
20	Electricity				
21	Steam				
Ferrous-containing material					
22	Pellets				
23	Pig iron				
24	Cold iron				
25	Gas-based DRI				
26	Coal-based DRI				
Alloys					

Table B.1 *(continued)*

Subscript designator for Q t	CO_2 **emission sources**	**Direct emission factor** ($K_{t,d,CO2}$) t CO_2/unit	**Upstream emission factor** ($K_{t,u,CO2}$) t CO_2/unit	**Credit emission factor** ($K_{t,c,CO2}$) t CO_2/unit	**Justification**
27	Ferro-nickel				
28	Ferro-chromium				
29	Ferro-molybdenum				
30	Ferro-manganese				
31	Ferro-silicon				
32	Silico-manganese				
Other imported/exported materials					
33	CO_2 for internal/external use				
N	Other emission sources				