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

Part 1: **Steel plant with blast furnace**

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

Partie 1: Usine sidérurgique avec fourneau

Reference number
ISO 14404-1:2013(E)

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Foreword

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ISO 14404-1 was prepared by Technical Committee ISO/TC 17, *Steel*.

ISO 14404 consists of the following parts, under the general title of *Calculation method of carbon dioxide emission intensity from iron and steel production:*

Part 1: Steel plant with blast furnace

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

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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.

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 wide range of steel products, by-products, waste materials and waste heat.

Steel plants manufacture various products including: sheet products, plate products, long products, pipe and tubes and many other types of products. In addition, steel plants produce unique speciality grade steel products with high-performance, which are achieved by various sub-processes including micro-alloying and applying surface treatments like galvanizing and coating that require additional heat treatments. Therefore, none of the steel plants in the world is exactly 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.

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

The World Steel Association (worldsteel), which consists of more than 130 major steel companies in 55 countries and regions of the world, has been working on the development of a calculation method for CO_2 emission intensity of steel plants to facilitate steel plant CO_2 emissions improvement by the objective comparison of the intensity among the member companies' steel plants located in various 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.

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 equipments 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 commonly used data in the management of plants. However, because different regions have different energy sources and raw materials available to them, the resulting calculations cannot be used to determine a benchmark or best in class across regions.

With this method, a steel company can calculate a single figure for the CO_2 emissions intensity of a plant as a whole. As was explained earlier, most steel plants manufacture vast range of products with various shapes and specifications. This calculation method ensures the simplicity and universal applicability by not accommodating the differences in the production processes of such diverse products, and treats

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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. Also, and for this reason, this method can be used neither for establishing caps or benchmarks for emissions under emissions trading scheme in any specific local or regional economic system, nor for the generation of CO_2 data that would allow a comparison of CO_2 intensities of production processes that are operated inside the site.

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

Part 1: Steel plant with blast furnace

1 Scope

This part of ISO 14404 specifies calculation methods for the carbon dioxide (CO_2) intensity of plant where steel is produced through a blast furnace.

NOTE The steel plant is generally called "the integrated steel works".

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 part of ISO 14404 supports the steel producer to establish CO_2 emissions attributable to a site. This part of ISO 14404 cannot be used to calculate benchmarks or to compare CO_2 intensities of production processes that are operated inside the site.

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

2 Terms and definitions

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

2.1 Emissions

2.1.1
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 part of ISO 14404 are given in 2.1.2, 2.1.3 and 2.1.4.

2.1.2
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.

2.1.3
upstream CO_2 emission
CO_2 emissions from imported material related to outsourced steel production activities outside the boundary and from imported electricity and steam into the boundary

Note 1 to entry: Possible outsourced activities are, for example, production of coke, burnt lime, burnt dolomite, pellet, sintered ore, hot metal, cold iron, direct reduced iron, oxygen, nitrogen and argon.

Note 2 to entry: CO_2 emissions from imported material in this term is categorized as "other indirect GHG emissions" in ISO 14064-1.

Note 3 to entry: CO_2 emissions from imported electricity and steam in this term are categorized as "energy indirect GHG emissions" in ISO 14064-1.

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2.1.4
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.

2.2 Gas fuel

2.2.1
natural gas
mixture of gaseous hydrocarbons, primarily methane, occurring naturally in the earth and used principally as a fuel

2.2.2
coke oven gas
COG
gas recovered from coke oven

2.2.3
blast furnace gas
BFG
gas recovered from blast furnace

2.2.4
BOF gas
LDG
gas recovered from basic oxygen furnace (Linze Donawitz converter)

Note 1 to entry: BOF: basic oxygen furnace

2.3 Liquid fuel

2.3.1
heavy oil
No. 4- No. 6 fuel oil defined by ASTM

Note 1 to entry: ASTM: American Society for Testing and Materials

2.3.2
light oil
No. 2- No. 3 fuel oil defined by ASTM

2.3.3
kerosene
paraffin (oil)

2.3.4
LPG
liquefied petroleum gas

2.4 Solid fuel

2.4.1
coking coal
coal for making coke, including anthracite

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2.4.2
BF injection coal
pulverized coal injection (PCI) coal, including anthracite

Note 1 to entry: BF: blast furnace

2.4.3
sinter coal
BOF coal
coal for sinter/BOF, including anthracite

2.4.4
steam coal
boiler coal for producing electricity and steam, including anthracite

2.4.5
coke
solid carbonaceous material

2.4.6
charcoal
devolatilized or coked carbon neutral materials

EXAMPLE Trees, plants.

2.5 Auxiliary material

2.5.1
limestone
calcium carbonate, $CaCO_3$

2.5.2
burnt lime
CaO

2.5.3
crude dolomite
calcium magnesium carbonate, $CaMg(CO_3)_2$

2.5.4
burnt dolomite
$CaMgO_2$

2.5.5
nitrogen
$\mathbf{N_2}$
inert gas separated from air at oxygen plant, imported from outside the boundary or exported to outside the boundary

2.5.6
argon
Ar
inert gas separated from air at oxygen plant, imported from outside the boundary or exported to outside the boundary

2.5.7
oxygen
$\mathbf{O_2}$
gas separated from air at oxygen plant, imported from outside the boundary or exported to outside the boundary

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2.6 Energy carriers

2.6.1
electricity
electricity imported from outside the boundary or exported to outside the boundary

2.6.2
steam
pressurized water vapour imported from/exported to outside the boundary

2.7 Ferrous containing materials

2.7.1
pellets
agglomerated spherical iron ore calcinated by rotary kiln

2.7.2
sinter
bulk iron ore sintered by baking mixture of fine iron ore, coke breeze and pulverized lime

2.7.3
hot metal
intermediate liquid iron products containing 3 % to 5 % by mass carbon produced by smelting iron ore with equipment such as blast furnace

2.7.4
cold iron
solidified hot metal as an intermediate solid iron products

2.7.5
gas-based DRI
direct reduced iron (DRI) reduced by a reducing gas such as reformed natural gas

2.7.6
coal-based DRI
direct reduced iron (DRI) reduced by coal

2.8 Alloys

2.8.1
ferro-nickel
alloy of iron and nickel

2.8.2
ferro-chromium
alloy of iron and chromium

2.8.3
ferro-molybdenum
alloy of iron and molybdenum

2.9 Product and by-product

2.9.1
CO_2 for external use
CO_2 exported to outside the boundary

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2.9.2
coal tar
by-products of the carbonization of coal to coke, containing complex and variable mixtures of phenols and polycyclic aromatic hydrocarbons

2.9.3
coal light oil
benzole
light oil recovered by COG gas purification, consisting mainly of benzene, toluene and xylene (BTX)

2.9.4
BF slag to cement
blast furnace slag supplied to cement industry

2.9.5
BOF slag to cement
BOF slag supplied to cement industry

2.10 Others

2.10.1
other emission source
other related emission sources such as plastics, scraps, desulfurization additives, graphite electrodes, alloys, fluxes for secondary metallurgy, dust, sludges, etc.

2.10.2
boundary
limit of activity used to calculate CO_2 emissions intensity for steel production activities

Note 1 to entry: Generally, the boundary is set to be the same as the site boundary.

Note 2 to entry: Major facilities in iron and steel production in boundaries are given in 2.10.2.1 to 2.10.2.13.

2.10.2.1
blast furnace
BF
vertical shaft furnace for producing hot metal from iron ore

2.10.2.2
basic oxygen furnace
BOF
vessel where hot metal from blast furnace and scrap is converted into molten steel using oxygen

2.10.2.3
casting
pouring steel directly from a ladle through a tundish into a mold shaped to form billets, blooms, or slabs, or pouring steel from a ladle into a mold shaped to form ingots

2.10.2.4
sinter plant
plant used to produce a fused clinker-like aggregate or sinter of fine iron-bearing materials suited for use in a blast furnace

2.10.2.5
pellet plant
plant for agglomeration and thermal treatment to convert the raw fine iron ore into spherical pellets with characteristics appropriate for use in a blast furnace

2.10.2.6
lime kiln
kiln used to produce burnt lime by the calcination of limestone (calcium carbonate)

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2.10.2.7
coke oven
oven for the conversion of coal into coke by heating the coal in the absence of air to distill the volatile ingredients

2.10.2.8
oxygen plant
cryogenic air separator to produce high-purity oxygen

2.10.2.9
steam boiler
boiler for production of steam

2.10.2.10
power plant
plant that generates electricity

2.10.2.11
hot rolling
rolling at elevated temperature

2.10.2.12
cold rolling
rolling at room temperature

2.10.2.13
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, etc.

3 Symbols

The symbols used in this part of ISO 14404 are given in Table 1.

Table 1 — Symbols

Symbol	Unit	Descriptions
$E_{\mathrm{d,CO2}}$	tons (or tonnes) of CO_2	Direct CO_2 emissions
$E_{\mathrm{u,CO2}}$	tons (or tonnes) of CO_2	Upstream CO_2 emissions
$E_{\mathrm{c,CO2}}$	tons (or tonnes) of CO_2	Credit CO_2 emissions
$E_{\mathrm{CO2,annual}}$	tons (or tonnes) of CO_2	Annual CO_2 emissions
I_{CO2}	tons (or tonnes)of CO_2 per ton (or tonne)	CO_2 intensity factor
$K_{t,\mathrm{d,CO2}}$	tons (or tonnes) of CO_2 per unit	Emission factor for calculation of direct CO_2 emissions
$K_{t,\mathrm{u,CO2}}$	tons (or tonnes) of CO_2 per unit	Emission factor for calculation of upstream CO_2 emissions
$K_{t,\mathrm{c,CO2}}$	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
$Q_{t,\mathrm{d,CO2}}$	—	Quantities of direct CO_2 emission sources
$Q_{t,\mathrm{u,CO2}}$	—	Quantities of upstream CO_2 emission sources
$Q_{t,\mathrm{c,CO2}}$	—	Quantities of credit CO_2 emission sources

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4 Principles

4.1 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.

4.2 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.

4.3 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.

4.4 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.

4.5 Accuracy

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

4.6 Transparency

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

5 Definition of boundary

5.1 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).

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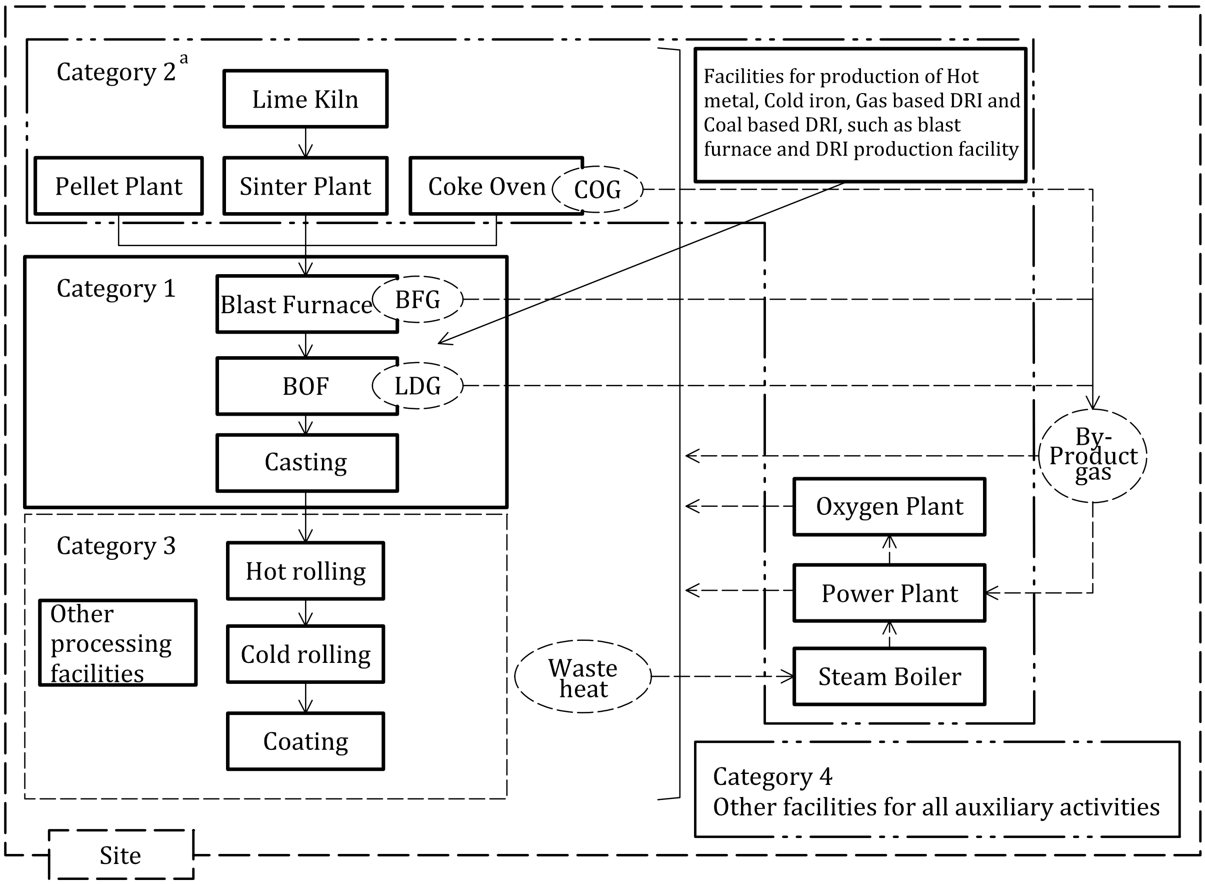

a Equipment that can be outsourced.

Figure 1 — Essential facilities in the site

5.2 Category 1

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

blast furnace;

BOF;

casting.

5.3 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.

sinter plant;

lime kiln;

pellet plant;

coke oven;

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facilities for production of hot metal, cold iron, gas-based DRI and coal-based DRI, such as blast furnace and DRI production facility;

oxygen plant;

steam boiler;

power plant.

5.4 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.

5.5 Category 4

Other facilities for all auxiliary activities are classified as category 4.

6 Calculation

6.1 General

A plant manufacturing crude steel performs its calculations as follows.

a) Step 1: Identify the categories.

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 imports to the plant.

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

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

6.2 Calculation procedure

6.2.1 Data collection of crude steel production

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

6.2.2 Data collection direct and/or upstream CO_2 emission sources

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

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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	Coke oven gas	$10^3 m^3$(stp)	$Q_{2,d,CO2}$	N/A
3	Blast furnace gas	$10^3 m^3$(stp)	$Q_{3,d,CO2}$	N/A
4	BOF gas	$10^3 m^3$(stp)	$Q_{4,d,CO2}$	N/A
Liquid fuel				
5	Heavy oil	m^3	$Q_{5,d,CO2}$	N/A
6	Light oil	m^3	$Q_{6,d,CO2}$	N/A
7	Kerosene	m^3	$Q_{7,d,CO2}$	N/A
8	LPG	t	$Q_{8,d,CO2}$	N/A
Solid fuel				
9	Coking coal	dry t	$Q_{9,d,CO2}$	N/A
10	BF injection coal	dry t	$Q_{10,d,CO2}$	N/A
11	Sinter/BOF coal	dry t	$Q_{11,d,CO2}$	N/A
12	Steam coal	dry t	$Q_{12,d,CO2}$	N/A
13	Coke	dry t	$Q_{13,d,CO2}$	$Q_{13,u,CO2}$
14	Charcoal	dry t	$Q_{14,d,CO2}$	N/A
Auxiliary material				
15	Limestone	dry t	$Q_{15,d,CO2}$	N/A
16	Burnt lime	t	N/A	$Q_{16,u,CO2}$
17	Crude dolomite	dry t	$Q_{17,d,CO2}$	N/A
18	Burnt dolomite	t	N/A	$Q_{18,u,CO2}$
19	Nitrogen	$10^3 m^3$(stp)	N/A	$Q_{19,u,CO2}$
20	Argon	$10^3 m^3$(stp)	N/A	$Q_{20,u,CO2}$
21	Oxygen	$10^3 m^3$(stp)	N/A	$Q_{21,u,CO2}$
Energy carriers				
22	Electricity	MWh	N/A	$Q_{22,u,CO2}$
23	Steam	t	N/A	$Q_{23,u,CO2}$
Ferrous containing material				
24	Pellets	t	N/A	$Q_{24,u,CO2}$
25	Sinter	t	N/A	$Q_{25,u,CO2}$
26	Hot metal	t	$Q_{26,d,CO2}$	$Q_{26,u,CO2}$
27	Cold iron	t	$Q_{27,d,CO2}$	$Q_{27,u,CO2}$
28	Gas-based DRI	t	$Q_{28,d,CO2}$	$Q_{28,u,CO2}$
29	Coal-based DRI	t	$Q_{29,d,CO2}$	$Q_{29,u,CO2}$
Alloys				
30	Ferro-nickel	t	$Q_{30,d,CO2}$	N/A
31	Ferro-chromium	t	$Q_{31,d,CO2}$	N/A
32	Ferro-molybdenum	t	$Q_{32,d,CO2}$	N/A
Product or by-product				

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Table 2 *(continued)*

Subscript designator for Q t	Emission sources	Unit	Quantities of direct emission source $Q_{t,\mathrm{d,CO2}}$	Quantities of upstream emission source $Q_{t,\mathrm{u,CO2}}$
33	CO_2 for external use	t	$Q_{33,\mathrm{d,CO2}}$	N/A
34	Coal tar	t	$Q_{34,\mathrm{d,CO2}}$	N/A
35	Benzole (coal light oil)	t	$Q_{35,\mathrm{d,CO2}}$	N/A
Others				
N	Other emission sources	—	$Q_{N,\mathrm{d,CO2}}$	$Q_{N,\mathrm{u,CO2}}$
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 emissions sources when calculating CO_2 emissions.				
[a] 10^3=1000				
[b] Standard temperature and pressure.				
[c] Not applicable.				

6.2.3 Data collection of credit CO_2 emission sources

A plant manufacturing steel records the quantities of raw materials, intermediate products and energy that are exported 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 $Q_{t,\mathrm{c,CO2}}$
Gas fuel			
1	Natural gas	10^3 [a] m^3(stp [b])	$Q_{1,\mathrm{c,CO2}}$
2	Coke oven gas	10^3m^3(stp)	$Q_{2,\mathrm{c,CO2}}$
3	Blast furnace gas	10^3m^3(stp)	$Q_{3,\mathrm{c,CO2}}$
4	BOF gas	10^3m^3(stp)	$Q_{4,\mathrm{c,CO2}}$
Liquid fuel			
5	Heavy oil	m^3	$Q_{5\mathrm{c\ CO2}}$
6	Light oil	m^3	$Q_{6,\mathrm{c,CO2}}$
7	Kerosene	m^3	$Q_{7,\mathrm{c,CO2}}$
8	LPG	t	$Q_{8,\mathrm{c,CO2}}$
Solid fuel			
9	Coking coal	dry t	$Q_{9,\mathrm{c,CO2}}$
10	BF injection coal	dry t	$Q_{10,\mathrm{c,CO2}}$
11	Sinter/BOF coal	dry t	$Q_{11,\mathrm{c,CO2}}$
12	Steam coal	dry t	$Q_{12,\mathrm{c,CO2}}$
13	Coke	dry t	$Q_{13,\mathrm{c,CO2}}$
14	Charcoal	dry t	$Q_{14,\mathrm{c,CO2}}$
Auxiliary material			
15	Limestone	dry t	$Q_{15\mathrm{c\ CO2}}$
16	Burnt lime	t	$Q_{16,\mathrm{c,CO2}}$
17	Crude dolomite	dry t	$Q_{17,\mathrm{c,CO2}}$
18	Burnt dolomite	t	$Q_{18,\mathrm{c,CO2}}$

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Table 3 *(continued)*

Subscript designator for Q t	Emission sources	Unit	Quantities of credit emission source $Q_{t,c,CO2}$
19	Nitrogen	10^3m^3(stp)	$Q_{19,c,CO2}$
20	Argon	10^3m^3(stp)	$Q_{20,c,CO2}$
21	Oxygen	10^3m^3(stp)	$Q_{21,c,CO2}$
Energy carriers			
22	Electricity	MWh	$Q_{22,c,CO2}$
23	Steam	t	$Q_{23,c,CO2}$
Ferrous-containing material			
24	Pellets	t	$Q_{24,c,CO2}$
25	Sinter	t	$Q_{25,c,CO2}$
26	Hot metal	t	$Q_{26,c,CO2}$
27	Cold iron	t	$Q_{27,c,CO2}$
28	Gas-based DRI	t	$Q_{28,c,CO2}$
29	Coal-based DRI	t	$Q_{29,c,CO2}$
Alloys			
30	Ferro-nickel	t	$Q_{30,c,CO2}$
31	Ferro-chromium	t	$Q_{31,c,CO2}$
32	Ferro-molybdenum	t	$Q_{32,c,CO2}$
Product and by-product			
33	CO_2 for external use	t	$Q_{33,c,CO2}$
34	Coal tar	t	$Q_{34,c,CO2}$
35	Benzole (coal light oil)	t	$Q_{35,c,CO2}$
Others			
N	Other emission sources	—	$Q_{N,c,CO2}$

[a] 10^3=1000

[b] Standard temperature and pressure.

6.2.4 Calculation

The annual CO_2 emissions ($E_{CO2,annual}$) and CO_2 intensity (I_{CO2}) of a site are calculated from Equations (1) and (2) using CO_2 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 6.2.2 and 6.2.3.

A calculation example in shown in Annex C.

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

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

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

Table 4 — Indicative emission factors for CO_2 emission sources

Subscript designator for K t	CO_2 emission sources	Direct emission factor ($K_{t,\mathrm{d,CO2}}$) t CO_2/unit	Upstream emission factor ($K_{t,\mathrm{u,CO2}}$) t CO_2/unit	Credit emission factor ($K_{t,\mathrm{c,CO2}}$) t CO_2/unit
Gas fuel				
1	Natural gas	2,014	N/A	2,014
2	Coke oven gas	0,836	N/A	0,977[a]
				0,952[b]
3	Blast furnace gas	0,891	N/A	0,170[a]
				0,185[b]
4	BOF gas	1,512	N/A	0,432[a]
				0,470[b]
Liquid fuel				
5	Heavy oil	2,907	N/A	2,907
6	Light oil	2,601	N/A	2,601
7	Kerosene	2,481	N/A	2,481
8	LPG	2,985	N/A	2,985
Solid fuel				
9	Coking coal	3,059	N/A	3,059
10	BF injection coal	2,955	N/A	2,955
11	Sinter/BOF coal	2,784	N/A	2,784
12	Steam coal	2,461	N/A	2,461
13	Coke	3,257	0,224	3,481
14	Charcoal	0,000	N/A	0,000
Auxiliary material				
15	Limestone	0,440	N/A	0,440
16	Burnt lime	N/A	0,950	0,950
17	Crude dolomite	0,471	N/A	0,471
18	Burnt dolomite	N/A	1,100	1,100
19	Nitrogen	N/A	0,103	0,103
20	Argon	N/A	0,103	0,103
21	Oxygen	N/A	0,355	0,355
Energy carriers				
22	Electricity	N/A	0,504	0,504
23	Steam	N/A	0,195	0,195
Ferrous-containing material				
24	Pellets	N/A	0,137	0,137
25	Sinter	N/A	0.262	0.262
26	Hot metal	0,172	1,855	2,027
27	Cold iron	0,172	1,855	2,027
28	Gas-based DRI	0,073	0,780	0,853
29	Coal-based DRI	0,073	1,210	1,283
Alloys				
30	Ferro-nickel	0,037	N/A	0,037
31	Ferro-chromium	0,275	N/A	0,275

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Table 4 *(continued)*

Subscript designator for K 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
32	Ferro-molybdenum	0,018	N/A	0,018
Product and by-product				
33	CO_2 for external use	1,000	N/A	1,000
34	Coal tar	3,389	N/A	3,389
35	Benzole (coal light oil)	3,382	N/A	3,382
Others				
N	Other emission sources	[c]	[c]	[c]
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 Annex B.				

[a] This credit emission factor is based on world average electricity equivalent based on worldsteel methodology.[1]

[b] This credit emission factor is based on natural gas equivalent.

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

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Annex A
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Calculation of energy consumption and intensity

The annual energy consumption, $C_{E,annual}$, and intensity, I_E, at a plant manufacturing steel using blast furnaces can be calculated from Equations (A.1) and (A.2) using $Q_{t,d,CO2}$, $Q_{t,u,CO2}$ and ,$Q_{t,c,CO2}$ collected as explained in 6.2.2 and 6.2.3 and the energy conversion factors ($K_{t,d,E}$, $K_{t,u,E}$, and $K_{t,c,E}$):

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

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

where

$Q_{t,d,CO2}$	are the quantities of direct CO_2 emission sources;
$Q_{t,u,CO2}$	are the quantities of upstream CO_2 emission sources;
$Q_{t,c,CO2}$	are the quantities of credit CO_2 emission sources;
$K_{t,d,E}$	is the energy conversion factor for calculation of direct energy consumption;
$K_{t,u,E}$	is the energy conversion factor for calculation of upstream energy consumption;
$K_{t,c,E}$	is the energy conversion factor for calculation of credit energy consumption;
I_E	is the energy intention factor;
$C_{E,annnual}$	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.[1]

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Annex B
(informative)

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

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

Subscript designator for K t	CO_2 emission source	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	Coke oven gas				
3	Blast furnace gas				
4	BOF gas				
Liquid fuel					
5	Heavy oil				
6	Light oil				
7	Kerosene				
8	LPG				
Solid fuel					
9	Coking coal				
10	BF injection coal				
11	Sinter/BOF coal				
12	Steam coal				
13	Coke				
14	Charcoal				
Auxiliary material					
15	Limestone				
16	Burnt lime				
17	Crude dolomite				
18	Burnt dolomite				
19	Nitrogen				
20	Argon				
21	Oxygen				
Energy carriers					
22	Electricity				
23	Steam				
Ferrous-containing material					
24	Pellets				
25	Sinter				
26	Hot metal				

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Table B.1 *(continued)*

Subscript designator for K t	CO_2 **emission source**	**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	Cold Iron				
28	Gas-based DRI				
29	Coal-based DRI				
Alloys					
30	Ferro-nickel				
31	Ferro-chromium				
32	Ferro-molybdenum				
Product and by-product					
33	CO_2 for external use				
34	Coal tar				
35	Benzole (coal light oil)				
Others					
N	Other emission sources				

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Annex C
(informative)

An example of CO_2 emission and intensity calculations for a steel plant

C.1 Data of a steel plant

For an annual crude steel production: 7 000 000 t, the following applies.

Table C.1 — Example of imports and exports of a steel plant

Subscript designator for K_t	Emission sources	Unit	Imports	Exports
Gas fuel				
1	Natural gas	10^3 [a] m^3(stp [b])	50 000	—
2	Coke oven gas	$10^3 m^3$(stp)	—	80 000
3	Blast furnace gas	$10^3 m^3$(stp)	—	100 000
4	BOF gas	$10^3 m^3$(stp)	—	10 000
Liquid fuel				
5	Heavy oil	m^3	5 000	—
6	Light oil	m^3	2 000	—
7	Kerosene	m^3	800	—
8	LPG	t	3 000	—
Solid fuel				
9	Coking coal	dry t	3 500 000	—
10	BF injection coal	dry t	1 000 000	—
11	Sinter/BOF coal	dry t	100 000	—
12	Steam coal	dry t	600 000	—
13	Coke	dry t	200 000	—
14	Charcoal	dry t	-—	—
Auxiliary material				
15	Limestone	dry t	1 500 000	-—
16	Burnt lime	t	500 000	-—
17	Crude dolomite	dry t	10 000	—
18	Burnt dolomite	t	20 000	—
19	Nitrogen	$10^3 m^3$(stp)	1 000 000	20 000
20	Argon	$10^3 m^3$(stp)	—	—
21	Oxygen	$10^3 m^3$(stp)	800 000	—
Energy carriers				
22	Electricity	MWh	100 000	1 500 000
23	Steam	t	—	50 000
Ferrous-containing material				

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Table C.1 *(continued)*

Subscript designator for K t	Emission sources	Unit	Imports	Exports
24	Pellets	t	1 000 000	—
25	Sinter	t	—	—
26	Hot metal	t	—	—
27	Cold iron	t	—	—
28	Gas-based DRI	t	—	—
29	Coal-based DRI	t	—	—
Alloys				
30	Ferro-Nickel	t	—	—
31	Ferro-Chromium	t	—	—
32	Ferro-Molybdenium	t	—	—
Product and by-product				
33	CO_2 for external use	t	—	—
34	Coal tar	t	—	90 000
35	Benzole (coal light oil)	t	—	30 000
Others				
N	Other emission sources	—	—	—
[a] 10^3=1000				
[b] Standard temperature and pressure.				

Table C.2 — Example of the calculation result of a steel plant[a]

Subscript designator for K t	Emission sources	Unit	Calculation results		
			Direct emissions tCO_2	Upstream emissions tCO_2	Credit emissions tCO_2
Gas fuel					
1	Natural gas	10^3 [b] m^3(stp[c])	100 700	—	—
2	Coke oven gas	$10^3 m^3$(stp)	—	—	78 128[d]
3	Blast furnace gas	$10^3 m^3$(stp)	—	—	16 962[d]
4	BOF gas	$10^3 m^3$(stp)	—	—	4 318[d]
Liquid fuel					
5	Heavy oil	m^3	14 533	—	—
6	Light oil	m^3	5 202	—	—
7	Kerosene	m^3	1 985	—	—
8	LPG	t	8 954	—	—
Solid fuel					
9	Coking coal	dry t	10 706 500	—	—
10	BF injection coal	dry t	2 954 500	—	—
11	Sinter/BOF coal	dry t	278 350	—	—
12	Steam coal	dry t	1 476 300	—	—
13	Coke	dry t	651 364	44 880	—
14	Charcoal	dry t	—	—	—
Auxiliary material					
15	Limestone	dry t	660 000	—	—

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Table C.2 *(continued)*

Subscript designator for K_t	Emission sources	Unit	Calculation results		
			Direct emissions tCO_2	Upstream emissions tCO_2	Credit emissions tCO_2
16	Burnt lime	t	—	475 000	—
17	Crude dolomite	t	4 710	—	—
18	Burnt dolomite	t	—	22 000	—
19	Nitrogen	10^3m^3(stp)	—	102 800	2 056
20	Argon	10^3m^3(stp)	—	—	—
21	Oxygen	10^3m^3(stp)	—	283 728	—
Energy carriers					
22	Electricity	MWh	—	50 372	755 580
23	Steam	t	—	—	9 776
Ferrous containing material					
24	Pellets	t	—	137 000	—
25	Sinter	t	—	—	—
26	Hot metal	t	—	—	—
27	Cold iron	t	—	—	—
28	Gas-based DRI	t	—	—	—
29	Coal-based DRI	t	—	—	—
Alloys					
30	Ferro-nickel	t	—	—	—
31	Ferro-chromium	t	—	—	—
32	Ferro-molybdenum	t	—	—	—
Product / By-product					
33	CO_2 for external use	t	—	—	—
34	Coal tar	t	—	—	305 040
35	Benzole (coal light oil)	t	—	—	101 460
Others					
N	Other emission sources	—	—	—	—
Total			16 863 098	1 115 780	1 273 310
Total CO_2 emission			16 705 568		
Intensity			2 387 kg/t crude steel		

a These calculation data and values use indicative factors in Table 4.

b 10^3=1000

c Standard temperature and pressure.

d These credit emission factors are based on worldsteel methodology.[1]

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Annex D
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Explanation of emission factors for by-product gases in Table 4

D.1 General

Coke oven gas, blast furnace gas and BOF gas, which are produced in blast furnace-BOF process in the integrated steel plants, are generically called by-product gas. Although they are burnable and used as fuel, the gases are selectively utilized depending on their chemical composition and generated volume which differs largely from gas to gas. Especially, blast furnace gas, called lean gas due to the low heat value, is generally used as fuel for electrical power generation. Coke oven gas has higher heat value and then is widely used as fuel for a reheating furnace and other heating processes. The generated volume of BOF gas is not large and then the gas is often used as the mixture with other by-product gases.

In an integrated steel plant, by-product gases are used for various heat sources inside the plants, but excess by-product gases are often exported and used outside of the boundary. These exported by-product gases are subject to credit emission. As the energy amount of these exported gases is relatively large, their evaluation is critical to calculate CO_2 intensity of the steel plant.

Two credit emission factors for by-product gases are given in Table 4. The first one is based on world average electricity equivalent (D.1) and the second one is based on natural gas equivalent (D.2).

D.2 Explanation of emission factors based on world average electricity equivalent

Table D.1 — Emission factors of by-product gases
(excerpted from Table 4)

CO_2 **emission sources**	**Direct** CO_2 **emission factor** t $CO_2/10^3$ [a] m^3(stp[b])	**Upstream** CO_2 **emission factor** t $CO_2/10^3$ m^3 (stp)	**Credit** CO_2 **emission factor** t $CO_2/10^3$ m^3 (stp)
Coke oven gas	0,836	N/A	0,977
Blast furnace gas	0,891	N/A	0,170
BOF gas	1,512	N/A	0,432

[a] 10^3=1000

[b] Standard temperature and pressure.

Credit emission factors for by-product gases can be calculated based on world average CO_2 emission intensity and efficiency for electricity generation of power plant.

When the plants do not have an industrial owned power generation, blast furnace gas is usually used in the adjacent power plant out of the plants. Therefore, worldsteel methodology sets credit CO_2 emission

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factor of by-product gas based on world average CO_2 emission intensity A, expressed in GJ/m^3, and efficiency for electricity generation of power plant D, expressed in GJ/MWh, as given in Equation (D.1):

$$A = B \times \frac{C}{D} \tag{D.1}$$

where

A is credit CO_2 conversion factor of by-product gas ($t\text{-}CO_2/10^3m^3$);

B is the world average CO_2 intensity of electricity ($t\text{-}CO_2$/MWh);

C is the heat value of by-product gas ($GJ/10^3m^3$);

D is the world average energy intensity of electricity (GJ/MWh).

The credit CO_2 emission factors in Table D.1 are calculated as follows.

coke oven gas: 0,977= 0,504 × 19/9,8

blast furnace gas: 0,170 = 0,504 × 3,31/9,8

BOF gas: 0,432 = 0,504 × 8,40/9,8

where

0,504 is the world average CO_2 intensity of electricity i.e. the CO_2 emission per MWh from electricity and heat generation (IEA global average 2006), ($t\text{-}CO_2$/MWh);

9,8 is the world average energy intensity of electricity i.e. the energy conversion coefficient for electricity on the premise of a power generation factor of 36,7 %, e.g. a typical efficiency for power generation (GJ/MWH);

19,0 is the heat value of COG, [$GJ/10^3m^3$ (stp)];

3,31 is the heat value of BFG, [$GJ/10^3m^3$ (stp)];

8,40 is the heat value of LDG, [$GJ/10^3m^3$ (stp)].

CO_2 emissions per MWh from electricity and heat generation and the power generation factor should be updated.

D.3 Explanation of emission factors based on natural gas equivalent

Table D.2 — Emission factors of by-product gases
(excerpted from Table 4)

CO_2 **emission sources**	**Direct** CO_2 **emission factor** $t\,CO_2/10^3$ [a] m^3(stp[b])	**Upstream** CO_2 **emission factor** $t\,CO_2/10^3\,m^3$ (stp)	**Credit** CO_2 **emission factor** $t\,CO_2/10^3\,m^3$ (stp)
Coke oven gas	0,836	N/A	0,952
Blast furnace gas	0,891	N/A	0,185
BOF gas	1,512	N/A	0,470

[a] 10^3=1000

[b] Standard temperature and pressure.

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Credit emission factors for by-product gases A_N, expressed in GJ/m^3, can be calculated based on CO_2 emission intensity of natural gas as given in Equation (D.2):

$$A_N = B_N \times \frac{C_N}{D_N} \tag{D.2}$$

where

A_N is credit CO_2 conversion factor of by-product gas (t-CO_2/m^3);

B_N is the CO_2 intensity of natural gas (t-CO_2/m^3);

C_N is the heat value of by-product gas (GJ/m^3);

D_N is the heat value of natural gas (GJ/m^3).

The calculation of the credit CO_2 emission factor is as follows:

Coke oven gas: 0,952 = 0,056 × 19

Blast furnace gas: 0,186 = 0,056 × 3,31

BOF gas: 0,470 = 0,056 × 8,40

where

0,056 is the direct emission factor of natural gas (tCO_2/GJ);

19,0 is the heat value of COG (GJ/10^{3}m^3 (stp));

3,31 is the heat value of BFG (GJ/10^{3}m^3 (stp));

8,40 is the heat value of LDG (GJ/10^{3}m^3 (stp)).

NOTE When steel plants imports by-product gas from other steel plant and/or coke plant, direct emission factors based on their carbon content are adopted.

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[2] ISO 14064-1, *Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*

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