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Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries —

Part 6:
Ferroalloys and silicon industry

Émissions de sources fixes — Détermination des émissions des gaz à effet de serre dans les industries à forte intensité énergétique —

Partie 6: Industrie des ferro-alliages et du silicium

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 1, *Stationary source emissions.*

A list of all parts in the ISO 19694 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

0.1   Overview of the ferro-alloy manufacturing process

Ferroalloy production involves a metallurgical reduction process that results in significant carbon dioxide emissions. These emissions are the results of a carbothermic reaction which is intrinsic to the process. In ferroalloy production, ore, carbon materials and slag forming materials are mixed and heated to high temperatures for smelting.

Smelting in an electric arc furnace is accomplished by conversion of electrical energy to heat. An alternating current applied to the electrodes creates current to flow through the charge between the electrode tips. The heat is produced by the electric arcs and by the resistance in the charge materials. Emissions from the smelting process are therefore not to combustion emissions. The furnaces can be open, semi-closed or closed. Submerged electric arc furnaces with graphite electrodes or self-baking Søderberg electrodes are used (see Figure 1).

The reduction process is the main source of direct CO_2 emissions. Other CO_2 sources include direct emissions from calcination of calcium, magnesium and other carbonates (e.g. limestone) in some processes and from non-smelting fuels (e.g. dryers for ladles and refractory linings), room heating and indirect emissions from, for example, external power production.
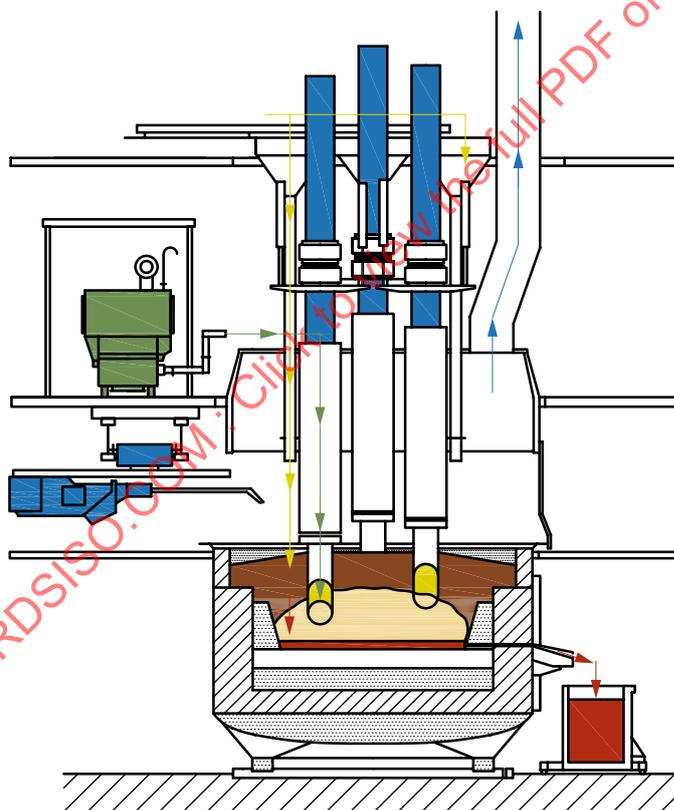
Figure 1 — Submerged electric arc furnace

0.2 CO_2 from the smelting of raw materials

In the smelting process, CO_2 is released due to the carbothermic reduction of the metallic oxides occurring with the consumption of both carbonaceous reductants and carbon-based electrodes. The carbon in the reductants reacts with oxygen from the metal oxides to form CO and then CO_2 (in different ways depending on the process), and the ores are reduced to molten base metals. For the calculation, the assumption is that all CO is assumed to be converted in the furnace to CO_2.

The reductant carbon is used in the form of coke, coal, pet coke, anthracite, charcoal and wood chips. The first four are fossil-based and the charcoal and wood chips are bio-carbon.

In the carbothermic process, only the fixed carbon content is used as a reducing agent, which means that volatile matter, ashes and moisture mostly leave the furnace with the off-gas and slag.

The nature of reducing agents, price and electrodes depends on the localization of the plant, the raw material availability and it is presented in Table 1. It is variable from one site to another and from one year to another and also from one ferro-alloy to another.

Table 1 — Type of reducing agents and electrodes used in the electrometallurgy sector

Reducing agents	Electrodes
Crude petroleum coke	Graphite electrode
Calcinated petroleum coke	Prebaked electrodes
Coal coke	Søderberg paste
Coke from coal	Composite electrode
Wood	—
Calcinated wood	—
Charcoal	—
Graphite powder	—
Anthracite	—

CO_2 emissions are estimated with and calculated from the consumption of the reducing agents and electrodes, their carbon content, and the carbon content of the final products.

NOTE   The basic calculation methods used in this document are compatible with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories issued by the Intergovernmental Panel on Climate Change (IPCC)[1].

Ores and reducing agent react to form ferro-alloys or metal, CO_2 and dust and other by-product (i.e. slags); amount of carbon can be found in the products

Default emission factors suggested in these documents are used, except where more recent, industry-specific data has become available.

Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries —

Part 6:
Ferroalloys and silicon industry

1 Scope

This document provides a harmonized methodology for calculating GHG emissions from the ferro-alloys industry based on the mass balance approach. This document also provides key performance indicators over time for ferro-alloys plants. This document covers the following direct and indirect sources of GHG:

— direct GHG emissions [see ISO 14064-1:2018, 5.2.4 a)] from sources that are owned or controlled by the company, such as emissions resulting from the following sources:

  — smelting (reduction) process;

  — decomposition of carbonates inside the furnace;

  — auxiliaries operation related to the smelting operation (i.e. aggregates, drying processes, heating of ladles, etc.);

— indirect GHG emissions [see ISO 14064-1:2018, 5.2.4 b)] from the generation of purchased electricity consumed in the company's owned or controlled equipment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14064-1:2018, *Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*

ISO/IEC 17025, 2005, *General requirements for the competence of testing and calibration laboratories*

ISO 19694-1:2021, *Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries — Part 1: General aspects*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19694-1:2021 and the following 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/

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

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

3.1
auxiliary
equipment consuming electricity/power related to the *smelting* (3.5) process

EXAMPLE   Fans, pumps, gas abatement systems (filter bags, venture scrubbers, etc.).

3.2
silica fume
amorphous silicon dioxide particles from the volatilization and vaporization of furnace feed materials in the manufacture of ferrosilicon and *silicon* (3.4)

Note 1 to entry: The process off-gas that contains silica fumes beings cleaned in a baghouse using fabric filters of the open or semi-closed *SEAF* (3.8).

3.3
ferro-alloy
alloy of iron and one or more metals such as *silicon* (3.4), manganese, chromium, molybdenum, vanadium and tungsten

3.4
silicon
metalloid produced by carbo-thermic reduction of quartz in an electric submerged arc furnace

3.5
smelting
industrial process where one or more ores or ore concentrates are heated and reduced (i.e. chemically modified) by, for example, aluminino-carbo-silico thermic reduction, to manufacture and mix the metals in one step

Note 1 to entry: Examples of smelted alloys are *ferro-alloys* (3.3).

3.6
gross GHG emission
absolute fossil direct GHG emission excluding GHG emissions from on-site power production

3.7
absolute gross GHG emission
total direct emission of GHGs within the boundaries excluding GHG emissions from biogenic CO_2 from biomass (i.e. wood chips and charcoal)

3.8
submerged electric arc furnace
SEAF
electric arc-heating furnace in which the arcs are completely submerged under the charge

Note 1 to entry: The arc forms between the electrode [graphite electrodes or self-baking *Søderberg electrodes* (3.12)] and metal surface or bottom lining. The heat being produced by the electric arcs and by the resistance in the charge materials initiates the reduction process. The furnaces can be open, semi-closed or closed, which can depend upon the *ferro-alloy* (3.3) to be produced.

3.9
biomass fuel
fuel with only biogenic carbon

3.10
petroleum coke
petcoke
carbon-based solid fuel derived from oil refineries

3.11
sinter
sintering
process to form a coherent mass by heating without melting

3.12
Søderberg electrode
continuously self-baking carbon electrode used in electro-metallurgical furnaces for production of ferroalloys and *silicon* ([3.4](#))

Note 1 to entry: The "Søderberg paste" is a preparation of coal tar pitch and carbonaceous dry aggregate.

3.13
composite electrode
electrode where the core is composed of graphite while the exterior is a self-baking carbon paste (which is a "Søderberg paste")

3.14
prebaked electrode
carbonaceous paste baked so as to carbonize coal tar pitch in order to form a solid pitch coke binder phase

Note 1 to entry: A carbonaceous paste is a mixing of coal tar pitch with a dry carbonaceous aggregate.

4   Abbreviated terms

For the purposes of this document, the following abbreviations apply.

CO   Carbon monoxide

CO_2 Carbon dioxide

EF   Emission factor

FA   Ferro-alloys

GHG   Greenhouse gases

HCV   High calorific value

IEA   International Energy Agency

IPCC   Intergovernmental Panel on Climate Change

KPI   Key performance indicator

SEAF   Submerged electric arc furnace

UNFCCC   United Nations Framework Convention on Climate Change

5   Determination of GHGs — Principles

5.1   Introduction

This document shall be used in conjunction with ISO 19694-1:2021 which contains generic, overall requirements, definitions and rules applicable to the determination of GHG emissions for all energy-intensive sectors, provides common methodological issues and specifies the details for applying the rules. The application of this document to the sector-specific standards ensures accuracy, precision and reproducibility of the results and is for this reason a normative reference standard.

5.2   General

The determination of CO_2 emissions can be in principle done either through calculation (mass balance method) or through stack emission measurement.

The methodology described in this document for GHG emissions determination is based on the mass balance method (see 7.1).

CO_2 is the only GHG relevant for the ferro-alloys industry. The emissions of CH_4 and of N_2O are extremely low. Therefore, they are both neglected in the calculation of carbon emissions.

The measurements of the concentrations of CH_4 and N_2O have been demonstrated to be near or below the detection limits during the field tests performed to develop this document with independent laboratories[7].

5.3   Determination based on mass balance

In installations where carbon stemming from input materials used remains in the products or other outputs of the production, for example, for the reduction of metal ores, a mass balance approach is applied. In installations where this is not the case, combustion emissions and process emissions are calculated separately.

Emissions from source streams are calculated from input or production data, obtained by means of measurement systems and additional parameters from laboratory analyses including calorific factor, carbon content and biomass content. Standard factors can also be used; references to these factors are provided in ISO 19694-1:2021.

5.4   Use of waste gas/heat recovery

GHG emissions related to waste gas and heat recovery are reported as direct GHG emissions. Waste gas including CO and CO_2 can be subtracted from the direct emission, when exported outside the boundaries of the location, as a negative carbon flow in the mass balance (e.g. when exporting waste gas to another installation).

6   Boundaries

6.1   General

Drawing appropriate boundaries is one of the key tasks in an emissions inventory process.

6.2 Operational boundaries

Operational boundaries refer to the types of sources covered by an inventory. A key distinction between direct and indirect emissions is the following.

a) Direct emissions [see ISO 14064-1:2018, 5.2.4 a)] are emissions from sources that are owned or controlled by the reporting company. For example, emissions from smelting are direct emissions of the company owning (or controlling) the furnace.

b) Indirect emissions [see ISO 14064-1:2018, 5.2.4 b) to f)] are emissions that result as a consequence of the activities of the reporting company but occur at sources owned or controlled by another company. For example, emissions from the generation of grid electricity consumed by a ferro-alloy company qualify as indirect.

Clause 7 provides detailed guidance on the different sources of direct emissions occurring in ferro-alloys plants. Indirect emissions are addressed in Clause 8.

Companies shall use the operational boundaries outlined in Table 2 and the relevant process steps in Table 3, for the determination of the GHG emissions for the smelting/carbo-thermic reduction operations part of the ferro-alloy plant. Any deviation from these boundaries shall be reported and explained.

Table 2 — Operational boundaries

Included within boundaries	Excluded
Smelting (carbo-thermic reduction):	Mobile transport
— electrodes	
— reducing agents	
— non-furnace fuels	
Electricity consumption for whole production process	Room heating / cooling (negligible)
Onsite power production: waste heat recovery	Mobile transport in plant
Stock inventories carbon materials	—

Table 3 — Process steps

Process step	Scope	Inclusion	GHG emission category ISO 14064-1:2018, 5.2.4 a)
Smelting	Scope 1	Yes	a
Electricity consumption for whole production process	Scope 2	Yes	b
Onsite power production	Scope 1	Yes	a
Waste heat recovery	Scope 1	Yes	a
Room heating / cooling	Scope 1	Yes, but negligible	a
Stock changes	Scope 1	Yes	a

6.3 Organizational boundaries

The major source of GHG emissions in the ferroalloys sector is the process-related emissions from the submerged electric arc furnaces operations, the reduction of the metallic oxides and the consumption of the electrodes during the process. There are practically no fuel related process emissions and heat is a negligible input factor in the production. The operational boundaries for this document GHG emissions cover only the smelting/carbo-thermic reduction operations considered as core activities and the related auxiliaries.

7 Direct emissions and their determination

7.1 General

Direct emissions are emissions from sources of the respective plant. In ferro-alloys plants, direct GHG emissions can result from the following sources:

a) CO_2 emissions from reducing agents and electrode use in the smelting process,

b) raw materials (e.g. decomposition of limestone, dolomite, and carbon containing metal ores and concentrates),

c) combustion of conventional fuels (e.g. natural gas, coal and coke, or fuel oil), and

d) combustion of biomass fuels.

In installations where carbon stemming from fuels or input materials used at this installation remains in the products or other outputs of the production, for example, for the reduction of metal ores, a mass balance approach is applied.

Generally, companies are encouraged to measure the required parameters at plant level for specific raw materials. Where plant- or company-specific data are not available, standard or default factors should be used.

7.2 Mass balance approach

7.2.1 Generic approach

In the mass balance approach, the CO_2 quantity corresponding to each source stream included in the mass balance has to be calculated by multiplying the activity data related to the amount of material entering or leaving the boundaries of the mass balance, with the emission factor for each material.

The methodologies for determining activity data and emission factors are referred to as tiers. The increasing numbering of tiers from one upwards reflects increasing levels of accuracy, with the highest numbered tier as the preferred tier.

For emission sources which emit more than 10 % of the total annual emissions of the installation the operator shall preferably apply the highest tier given the less uncertainty. For all other emission sources, the operator shall apply at least one tier lower than the highest tier.

In case the application of the highest tier is technically not feasible or incurs unreasonable costs, a next lower tier shall be used for the relevant emission source, with a minimum of tier 1.

For marginal flows, which jointly emit 1,000 t CO_2,eq or less, or less than 2 % of the "total of all monitored items" (whichever is highest and not exceeding 20,000 t CO_2,eq), it is allowed to calculate activity data and emission factors using a conservative estimation, instead of using tiers (unless it is possible to use tiers without additional effort or costs) with:

a) Activity data: The operator shall analyse and report the mass flows into and from the installation and respective stock changes for all relevant fuels and materials separately (generally in GJ for energy, in t for mass or m^3_n for volume).

— Tier 1: Activity data over the reporting period are determined with a maximum uncertainty of less than ±7,5 %.

— Tier 2: Activity data over the reporting period are determined with a maximum uncertainty of less than ±5 %.

— Tier 3: Activity data over the reporting period are determined with a maximum uncertainty of less than ±2,5 %.

— Tier 4: Activity data over the reporting period are determined with a maximum uncertainty of less than ±1,5 %.

b) Emission factors: Emission factors are expressed as tCO_2eq/GJ, tCO_2eq/t or as tCO_2eq/m^3_n.

— Tier 1 International reference for emission factors (IPCC data): The emission factor of input or output streams shall be derived from reference emission factors for fuels or materials named in Annex A.

— Tier 2 National reference: The operator applies country-specific emission factors for the respective fuel or material as reported by the respective country in its latest national inventory submitted to the Secretariat of the United Nations Framework Convention on Climate Change.

— Tier 3 Industry specific reference: The emission factor of input or output stream shall be derived following the provisions of this document in respect to representative sampling of fuels, products and by-products, the determination of their carbon contents and biomass fraction. These emission factors are usually determined by analysis of the carbon content. For the conversion of carbon content into the respective emission factor for CO_2, a factor of 3,664 t CO_2/t C shall be used.

Requirements for analysis should retain the preference for the use of laboratories meeting the requirements of ISO/IEC 17025. Company measurements are carried out by applying methods based on suitable ISO standards (e.g. ISO 9001) or national standards, or on industrial best practices, limiting sampling and measurement bias.

7.2.2 Sampling

The operator shall provide evidence that the derived samples are representative and free of bias. The respective value shall be used only for the delivery period or batch of fuel or material for which it was intended to be representative.

Generally, the analysis will be carried out on a sample which is the mixture of a larger number (e.g. 10 to 100) of samples collected over a period of time (e.g. from a day to several months) provided that the sampled fuel or material can be stored without changes of its composition.

The sampling procedure and frequency of analyses shall be designed to ensure that the annual average of the relevant parameter is determined with a maximum uncertainty of less than 1/3 of the maximum uncertainty which is required by the approved tier level for the activity data for the same source stream.

If the operator is not able to meet the allowed maximum uncertainty for the annual value or unable to demonstrate compliance with the thresholds, the operator shall apply the frequency of analyses as laid down in Annex B as a minimum, if applicable.

7.2.3 Alternate approach

The alternate approach for the Tier 3 method is to use emission factors for the reducing agents only, which is adopted in this subclause. The simplified adopted formula given in Formula (1):

$$E_{CO2} = U_{RA/E} \times EF_{RA/E} \tag{1}$$

where

E_{CO2} is the emissions of CO_2, in t;

$U_{RA/E}$ is the total consumption of reducing agents/electrodes, in t;

$EF_{RA/E}$ is the emission factor of reducing agents of electrodes, in t CO_2/t.

The emission factor of the reducing agent is based on its carbon content (see Formula (2)]:

$$EF_{RA/E} = C_{C,RA,i} \times 3,664 \qquad (2)$$

The total C-contents of reducing agents is calculated by Formula (3):

$$C_{C,RA,i} = F_{Fix\ C,i} + F_{volatiles,i} \times C_v \qquad (3)$$

where

$C_{C,RA,i}$	is the carbon content in reducing agent i, in tonne C/tonne reducing agent;
$F_{Fix\ C,i}$	is the mass fraction of Fix C in reducing agent i, in tonne C/ tonne reducing agent;
$F_{volatiles,i}$	is the mass fraction of volatiles in reducing agent i, in tonne volatiles/ tonne reducing agent;
C_v	is the carbon content in volatiles, in tonnes C/tonne volatiles.

NOTE   Unless other information is available, $C_v = 0,65$ is used for coal and 0,80 for coke.

Instead of calculating the carbon content using Formula (3), it is also possible to analyse the total carbon content directly using ISO 29541[5].

In case of humidity, H, in the reducing agent, Formulae (2) and (3) become Formulae (4) and (5):

$$C_{C,RA,i} = \frac{(1-w_H)}{1} \times \left(F_{Fix\ C,i} + F_{volatiles,i} \times C_v \right) \qquad (4)$$

$$EF_{RA} = \frac{(1-w_H)}{1} \times \left(F_{Fix\ C,i} + F_{volatiles,i} \times C_v \right) \times 3,664 \qquad (5)$$

where w_H is the mass fraction of humidity contained in the reducing agent or electrode.

Therefore, for the tier 3 method, it is necessary to determine the carbon contents of the reducing agents used in the production processes. But most ferroalloys producers analyse only on the basis of percentage of ash and volatiles, and calculate (dry basis calculation (db)) Formula (6):

$$w_{Fix\ C} = 1 - w_{ash} - w_{volatiles} \qquad (6)$$

where

$w_{Fix\ C}$	is the mass fraction of fixed carbon in reducing agent;
w_{ash}	is the mass fraction of ash contained product (reducing agent);
$W_{volatiles}$	is the mass fraction of volatiles contained product (reducing agent);

as received basis calculation (ar) [see Formula (7)]

$$w_{Fix\ C} = 1 - w_H - w_{ash} - w_{volatiles} \qquad (7)$$

where

$w_{Fix\ C}$	is the mass fraction of fixed carbon in reducing agent;
w_{ash}	is the mass fraction of ash contained product (reducing agent);
$w_{volatiles}$	is the mass fraction of volatiles contained product (reducing agent);

w_H is the mass fraction of humidity contained in reducing agent or electrode.

The frequency of analyses of the raw materials/products for determining the emission factors are made as a minimum according to Annex B. They are determined based on internal analysis and suppliers to calculate their carbon content, except for wood.

An option is also to use certificates issued by independent laboratories at loading ports. Such certificates are supplied by the producer or trader of raw materials.

In the absence of data analysis for one year and for the installation concerned, the factors used are from the average of measurements made on the site or sites in the corresponding year. When the number of analyses is insufficient (not shown), the factors used are from the average of the analyses conducted from 2005 to 2008 for the whole or the sites.

Requirements for analysis should retain the preference for the use of laboratories meeting the requirements of ISO/IEC 17025. Company measurements are carried out by applying methods based on on suitable ISO standards (e.g. ISO/IEC 9001) or national standards, or on industrial best practices, limiting sampling and measurement bias (see Table 4).

Table 4 — Relevant standards for analysis

	Standards
Moisture	ISO 579:2013[9], ISO 589:2008[10], ISO 687:2010[12], ISO 11722:2013[13]
Ash	ISO 1171:2010[12]
Volatile matter	ISO 562:2010[8]
Fixed carbon	NA
Total carbon	ISO 29541[5]
Key	
NA : not available	

7.3 Process emissions

7.3.1 Overview

The calcination of limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$ is considered under the process emission. These processes are used for the production of Mn and CaSi alloys.

7.3.2 Methods

For each type of input material used, the amount of CO_2 shall be calculated as follows:

$$E_{CO2} = \Sigma_{AD} \times EF \times CF$$

where

AD is the activity data:

— Tier 1: Amounts (t) of input material and process residues used as input material in the process over the reporting period are determined with a maximum uncertainty of less than ±5,0 %;

— Tier 2: Amounts (t) of input material and process residues used as input material in the process over the reporting period are determined with a maximum uncertainty of less than ±2,5 %;

EF is the emission factor tier 1; for carbonates, use of stoichiometric ratios given in Table 5;

CF is the conversion factor:

— Tier 1: Conversion factor: 1. Based on the principle that process emissions are coming from reducing agents, therefore the total carbon of the raw materials is converted to CO_2.

— Tier 2: The amount of non-carbonate compounds of the relevant metals in the raw materials, including return dust or fly ash or other already calcined materials, shall be reflected by means of conversion factors with a value between 0 and 1 with a value of 1 corresponding to a full conversion of raw material carbonates into oxides.

Table 5 — Stoichiometric emission factors

Carbonate	Ratio t CO_2 /t Ca-, Mg- or other carbonate	Remarks
$CaCO_3$: limestone	0,440	—
$MgCO_3$: Mg carbonate	0,522	Does not exist as natural carbonate
$MgCO_3$-$CaCO_3$: dolomite		Intermediate between $CaCO_3$ and $MgCO_3$ that typically contains 30 % of Mg and 20 % of CaO
General: X Y (CO_3) Z	$EF = M_{CO2} / (Y * M_X + Z * M_{CO_3^{2-}})$	where X is the metal; M_X is the molecular weight of X, g/mol; M_{CO2} is the molecular weight of CO_2, g/mol; $M_{CO_3^{2-}}$ is the molecular weight of CO_3^{2-}, g/mol; Y is the stoichiometric number of X Z is the stoichiometric number of CO_3^{2-}.

These values shall be adjusted for the respective moisture and gangue content of the applied carbonate material.

The carbon content of sinter, slag or other relevant output as well as in filtered dust shall be derived following the provisions of this document in respect to representative sampling and the determination of the carbon contents. In case filtered dust is re-employed in the process, the amount of carbon (t) contained shall not be accounted for in order to avoid double counting.

7.4 Combustion emissions

7.4.1 Overview

Combustion emissions concern auxiliaries' operations to the smelting/carbo-reduction process such as:

— mobile gas burner,

— radiators (heat),

— drying of granules, and

— hooding.

7.4.2 Methods

7.4.2.1 General

The uncertainty thresholds in Table 6 shall apply to tiers relevant to activity data requirements for which the operator shall use metering results based on measurement systems under its own control at

the installation and carry out an uncertainty assessment so as to ensure that the uncertainty threshold of the relevant tier level is met.

The uncertainty thresholds shall be interpreted as maximum permissible uncertainties for the determination of source streams over a reporting period.

7.4.2.2 Production or processing of ferro-alloys

Table 6 — TIER overview activity data

	Source	Tier 1	Tier 2	Tier 3	Tier 4
Process emissions	Each input material or process residue used as input material in the process, t	±5 %	±2,5 %	—	—
Mass balance methodology	Each input and output material, t	±7,5 %	±5 %	±2,5 %	±1,5 %

Tier 2 for the carbon content is used by the operator by deriving it from country specific emission factors (standard factors used by a country for its national inventory submission to the UNFCCC) for the respective fuel or material.

Activity data are based on fuel consumption. The quantity of fuel consumed is expressed as energy content, i.e. in TJ. The emission factor is expressed as tCO_2/TJ. When a fuel is consumed, all the carbon in the fuel is oxidized to CO_2. The imperfections of the combustion process result in incomplete oxidation. Some carbon is burned or partly oxidized as soot or ash. The carbon not oxidized or partially oxidized is reflected in the oxidation factor, which is expressed as a fraction.

CO_2 emissions (E_{CO2}) from combustion plants are calculated using Formula (8). The calculation shall be performed for each fuel and for each activity.

$$E_{CO2} = CC \times LCV * \times EF \times OF \tag{8}$$

where

CC is the quantity of fuel consumed during the reporting period (t or m^3_n);

LCV is the lower calorific value (TJ/t or TJ/ m^3_n);

EF is the fuel emission factor (tCO_2/TJ tCO_2/MW.h HCV for natural gas/ LCV);

OF is the oxidation factor of fuel.

NOTE   For natural gas, the HCV can be used instead of LCV, expressed in MW·h/ m^3_n.

7.4.3 Calculation of the quantity of fuel

The quantification method of the fuel consumed, made on the basis of the charged amount of fuel as well as the variation of storage according to Formula (9):

$$F_C = F_A + (F_D - F_F) \tag{9}$$

where

F_C is the fuel consumed during the reporting period under review;

F_A is the fuel purchased during the reporting period under review;

F_D is the fuel stock at the beginning of the reporting period under review;

F_F is the fuel stock at the end of the reporting period in question.

7.4.4   Determination of the lower calorific value and the emission factor

Tier 2 for the lower calorific value and the emission factor is used by the operator by deriving them from country specific emission factors for the respective fuel or material.

The LCV and EF apply to fuels regardless of moisture, ash content and sulfur content.

7.4.5   Determination of the oxidation factor

The proportion of carbon is not oxidized or converted in the process is represented by means of an oxidation factor for the emissions of combustion or conversion factor for the process emissions. For oxidation factors, it is exempted from the requirement to apply the highest level possible. If different fuels are used in a facility and specific oxidation factors are calculated, the operator may determine an aggregate oxidation factor for the activity and apply to all fuels, or attribute incomplete oxidation to one major fuel stream and apply the value 1 for the others, except when using biomass.

7.5   Combustion of biomass fuels

CO_2 from biomass fuels is reported as a "memo item", but excluded from the national emissions totals (see ISO 19694-1:2021, 12.5).

8   Indirect emissions

8.1   General

Indirect GHG emissions are emissions that are a consequence of the operations of the reporting entity but occur at sources owned or controlled by another entity. Ferro-alloys production is associated with indirect greenhouse gas emissions from various sources. The main CO_2 emissions to be considered are from:

— external production of electricity consumed by ferro-alloys producers according to ISO 14064-1:2018, 5.24 b), and

— other GHG categories, like, for example, transport of inputs (raw materials, fuels) and outputs (ferro-alloys, silica fumes, slags) by third parties are not considered.

8.2 CO_2 from external electricity production

8.2.1   General

The operator shall obtain the relevant emission factor for purchased electricity from the supplier. If relevant data are not available from the supplier, the operator shall use factors from recognized national sources for the national power grid. In the absence of other sources, the operator shall use the latest emission factors for the country published by the IEA, as outlined in Annex C.

A record shall be maintained of the reference factors and their source in the supporting evidence. Emissions associated with the consumption of electricity during transport and distribution (T&D losses) shall not be included in this calculation.

This document differentiates between the different power sources (purchase, production on-site) and paths of power usage: use for ferro-alloy production, consumption of auxiliaries (difference between gross and net power production of the power plant) and power sold externally. Power given to other

non-ferro-alloys installations (outside the set boundaries) within the same plant shall be treated like power sold externally.

NOTE   The consumption of auxiliaries covers various support systems like fans, heat exchangers, raw material handling, keeping ladles warm, etc.

8.2.2   GHG from heat transfer

In closed electric arc furnace, the off-gas contains a very high percentage of CO, which is collected without being burned above the charge surface. This CO is a high-quality fuel that can be used for:

— electricity production and consumption site (scope 1),

— as a synthesis gas that serves as raw material in chemical processes, and

— as fuel for raw material preheating or coke drying.

In semi-closed furnace, an energy recovery system can be implemented; this highly depends upon the local circumstances (users).

Waste heat from off gases with temperature >500 °C can be used in steam production and subsequent production of electricity. This is an option in cases where there are now alternatives to direct use of steam or hot water for industrial processes or district heating.

Production of electricity gives a reduced yield, typically 20 % to 30 % of the energy in the waste heat source, compared with more than 85 % if recovered directly and utilized as steam or hot water.

9   Baselines, acquisitions and disinvestments

GHG emissions performance is often measured relative to a past reference year (the "base year"). As a default, the "Kyoto base year" 1990 can be used as a reference. In many cases however, the lack of reliable and accurate historical data justifies the use of a more recent base year.

Acquisitions and divestitures, as well as the opening or closing of plants, influence a company's emissions performance, both in absolute and specific terms. To ensure consistency of baselines (i.e. the emissions in and after the base year), companies shall apply the following rules in a consistent way.

— Adjust the baseline for change by acquisition and divestiture: Consolidated emissions reported for past years shall always reflect the current amount of shares held in a company. If a company is acquired, its past emissions shall be included in the consolidated emissions of the reporting company. This shall be done either back to the base year, or back to the year the acquired company came into existence, whichever is later. If a company is divested, past emissions shall be removed from the consolidated emissions. These adjustments shall be made in accordance with the consolidation rules (see 7.2).

— No baseline adjustment for "organic" change: In case of organic growth of production due to investment in new installations, capacity expansions or improved capacity utilization, the baseline shall not be adjusted. In the same sense, the baseline shall not be adjusted for organic negative growth: closure of kilns or decrease of production shall not result in a change of the baseline.

10 Reporting

10.1 General

GHG emissions monitoring and reporting has multiple goals, such as: internal management of environmental performance, public environmental reporting, reporting for taxation schemes, voluntary or negotiated agreements, and emissions trading. Additional purposes can be, for example, performance benchmarking and product life cycle assessment.

GHG reports should be complete, consistent, accurate, relevant and transparent. The organization should determine the content, structure, public availability and methods of dissemination of GHG reports, based on requirements of the applicable GHG programme, internal reporting needs and the needs of intended users of the report.

This document has been designed as a flexible tool to satisfy these different reporting purposes.

The overall uncertainty of a GHG inventory should also be reported, see Clause 11.

A GHG report shall contain at least the following information (based on ISO 14064-1):

— description of the reporting organization;

— person responsible;

— reporting period covered;

— documentation of organizational boundaries;

— direct GHG emissions, quantified separately for each GHG, in tonnes of $CO_{2,eq}$;

— a description of how CO_2 emissions from the combustion of biomass are treated in the GHG inventory;

— if quantified, GHG removals, quantified in tonnes of $CO_{2,eq}$;

— explanation for the exclusion of any GHG sources or sinks from the quantification;

— energy indirect GHG emissions associated with the generation of imported electricity, heat or steam, quantified separately in tonnes of $CO_{2,eq}$;

— the historical base year selected and the base-year GHG inventory;

— explanation of any change to the base year or other historical GHG data, and any recalculation of the base year or other historical GHG inventory;

— reference to, or description of, quantification methodologies including reasons for their selection;

— explanation of any change to quantification methodologies previously used;

— reference to, or documentation of, GHG emission or removal factors used;

— description of the impact of uncertainties on the accuracy of the GHG emissions and removals data (including uncertainty assessment description and results, including measures to manage or reduce uncertainties);

10.2 Reporting periods

Reporting GHG emissions can be based on calendar or financial years. Changes in the reporting year should be clearly indicated.

10.3 Performance indicators

10.3.1 General

The definition of emission totals and ratio indicators is highly dependent on the reporting context and purpose, such as: input to national inventories, GHG compliance regimes and emissions trading, industry benchmarking, etc. System boundaries for such reporting depend largely on conventions and practical requirements, rather than on scientific arguments.

Generally, the section on performance indicators is conceived as a flexible vessel where companies can introduce additional parameters according to their needs, for instance different emission (sub-) totals.

10.3.2 Denominator for specific, unit-based emissions

From a sustainable development and business point of view, the reporting of GHG efficiency – the specific or unit-based emission – is at least as important as the reporting of absolute emissions. This raises the question of how the denominator of the specific emissions should be specified.

The denominator "t tapped ferro-alloy" is appropriate in the ferro-alloys industry.

10.3.3 Denominator for other ratio indicators

Other ratio indicators which do not use GHG in the numerator can be used like specific power consumption per tonne of ferro-alloy.

10.3.4 Key performance indicators

A number of KPIs have been determined for the ferro-alloys industry. The following list is not applicable for all plants. Each plant has to assess which ones are relevant to it:

— specific GHG per tonne of ferro-alloy produced in kg CO_2/t FA;

— specific indirect GHG from external power generation per tonne of tapped FA in kg CO_2/t FA;

— total biomass fuel rate at plant level in %;

— specific total power consumption in kWh/t FA;

— specific total power consumption including auxiliaries in kWh/t FA.

10.3.5 Recovery of waste gas and waste heat

10.3.5.1 General

This document offers the possibility of reporting voluntarily waste heat utilization within the plant (e.g. for preheating, coke drying) in order to allow a fair comparison between plants exporting heat and plants using the heat internally. The calculation has to be done separately and the total energy flow in GJ/a can be reported.

This document distinguishes between waste heat recovery and separate on-site power generation. In any case, when applying in their voluntary reporting, companies should consider whether their actions indeed contribute to a global reduction in GHG emissions or merely to a shift of emissions between different entities.

10.3.5.2 Recovery as electricity

For recovery as electricity the companies' operator shall obtain the relevant emission factor for purchased electricity from the supplier. If relevant data are not available from the supplier, the operator shall use factors from recognized national sources for the national power grid. In the absence of other sources, the operator may use the latest emission factors for the country published by the IEA (see Reference [4] for the latest update).

10.3.5.3 Internal use of heat

For internal use of heat, the reduction in GHG emissions can be calculated by using national standards or EU standards for allocation of GHG quotas connected to heat recovery from utilizing hot water or steam.

11 Uncertainty of GHG inventories

11.1 Introduction to uncertainty assessment

11.1.1 Basic considerations

Part of "General aspects" of Reference [6] is primarily concerned with the expression of uncertainty in the measurement of a well-defined physical quantity – the measure and – that can be characterized by an essentially unique value. The GUM provides general rules for evaluating and expressing uncertainty in measurement rather than detailed technology-specific instructions.

Further, it does not discuss how the uncertainty of a particular measurement result, once evaluated, may be used for different purposes.

ISO 20988[2] provides a comprehensive guidance and specific statistical procedures for uncertainty estimation in air quality measurement. It applies the general recommendations of the GUM to boundary conditions met in air quality measurement. The boundary conditions considered include measure and varying rapidly in time, as well as the presence of bias in a series of observations obtained under conditions of intended use of methods of air quality measurement.

So far, standards for measurement of specific materials, energy consumption or any other emissions include the analysis of uncertainty which have to be applied.

Applying the described mass balance method to determine GHG emissions of the ferro-alloy industry in this document, the procedures for analysing the uncertainty of measured or calculated values should be considered as described in the following sections. They specify the general rules of Reference [6].

The overall uncertainty depends on the uncertainty of the different parameters:

a)   reporting of fuel quantities or production volumes;

b)   analyses of conventional parameters like carbon content, calorific values;

c)   representativeness of sampling.

Due to their scientific nature, the parameters required for estimating GHG emissions, such as fuel volumes, lower heating values and emission factors, are not precise point estimates, but involve an uncertainty that can be expressed as an uncertainty range or confidence interval.

The aggregate uncertainty of an emissions estimate for a plant or company will depend on the individual uncertainties of the underlying parameters.

Quantifying parameter uncertainties is demanding in terms of data and procedures. As a result, statements about the aggregate uncertainty of emissions estimates are inherently uncertain themselves and often involve a subjective component. Nevertheless, there are clear incentives to assess and minimize uncertainty:

—   companies may want to rank the sources of uncertainty in their inventory in order to identify priority areas to focus on when improving inventory quality;

—   some GHG reporting schemes, set quantitative limits for the uncertainty of key parameters used to estimate emissions from ferro-alloys plants;

—   with this background, it is recognized that uncertainty in GHG inventories is a longer-term challenge which deserves attention.

Table 7 identifies the sources of uncertainty which are typically the most relevant in a ferro-alloy company, along with measures to minimize them.

Table 7 — Typical major sources of uncertainty in ferro-alloy sector CO_2 inventories and measures to minimize them[a]

Parameter	Measures to minimize parameter uncertainty
Activity data of cokes	Use the most accurate method available, such as draught survey.
Sampling of cokes	Use the minimal frequency of analysis in Annex B.
Analysis of cokes	Use the right standards for analysis and in a laboratory meeting the requirements of ISO/IEC 17025 laboratory.
Sampling and analysis of alloy, slag en dust	Check for relevancy in uncertainty calculation, if needed increase frequency.
[a] Electrode and limestone are not included in the list above because normally these inputs have a very stable carbon content and the activity data are much lower than for cokes. Therefore, both components are not considered major sources of uncertainty.	

11.1.2 Materiality thresholds

Materiality thresholds are typically applied in the process of independent verification of GHG inventories.[3] For example, a verifier can apply a pre-defined threshold of 5 % to determine whether a single or aggregate error in an inventory leads to a material misstatement. The level of such a threshold depends on the purpose for which the inventory data are intended to be used.

A materiality threshold should not be interpreted as a permissible quantity of emissions which a company can leave out of its inventory. For example, exclusion of all sources which contribute less than 1 % to the overall emissions of a ferro-alloy plant would introduce a systematic bias which is not compatible with the guiding principle that an inventory should be complete. On the other hand, it is important to acknowledge that a company's resources available for preparing a GHG inventory are always limited, and that companies should focus on reducing the uncertainty related to their main emission sources.

With this background, this document does not specify a minimum threshold below which an emission source should be considered "immaterial". Instead, companies are encouraged to apply simplified methods for quantifying their minor sources of CO_2.

11.2 Uncertainty of activity data

11.2.1 Measuring instruments for the determination of fuel and material quantities

The information on the uncertainty of a measuring instrument can be found in different sources:

— certificates on calibration under national metrological control (where the operational error limits the uncertainty under normal operational conditions),

— the specification from the manufacturer of an instrument, or

— an individual uncertainty assessment under operational conditions (e.g. via regular testing and adjustment of scales).

11.2.2 Aggregated uncertainties in case of mass balances

In case of mass balance, the aggregated uncertainty for the activity data has to be calculated via error propagation considering the diverse uncertainties of each involved weighing instruments.

11.3 Uncertainties of fuel and material parameters

The uncertainty of analysed parameters of fuels and materials depends mainly on:

— the analysing method,

— the analysing frequency (a decrease of uncertainty is possible by raising the analysing frequency), and

— representative sampling.

Also, the qualification and experience of the persons, who perform the analyses, influences the quality of analysing results.

11.4 Evaluation of the overall uncertainty of an GHG inventory

In order to determine the overall uncertainty of a GHG inventory, the assessed uncertainties beforehand regarding activity data and parameters have to be aggregated by the error propagation laws.

Annex A
(normative)

Tier 1 emission factors

Table A.1 contains reference emission factors for the tier 1 level that permit the use of non-activity-specific emission factors for the combustion of fuel. If a fuel does not belong to an existing fuel category, the operator shall use his expert judgement to assign the fuel used to a related fuel category, subject to the approval of the competent authority.

Table A.1 — Fuel emission factors related to net calorific value and net calorific values per mass of fuel

Fuel type description	Emission factor tCO$_2$/TJ	Net calorific value TJ/Gg
	2006 IPCC guidelines[1] (except biomass)	2006 IPCC guidelines[1]
Crude oil	73,3	42,3
Orimulsion	77,0	27,5
Natural gas liquids	64,2	44,2
Motor gasoline	69,3	44,3
Kerosene	71,9	43,8
Shale oil	73,3	38,1
Gas/diesel oil	74,1	43,0
Residual fuel oil	77,4	40,4
Liquefied petroleum gases	63,1	47,3
Ethane	61,6	46,4
Naphtha	73,3	44,5
Bitumen	80,7	40,2
Lubricants	73,3	40,2
Petroleum coke	97,5	32,5
Refinery feedstocks	73,3	43,0
Refinery gas	57,6	49,5
Paraffin waxes	73,3	40,2
White spirit and SBP	73,3	40,2
Other petroleum products	73,3	40,2
Anthracite	98,3	26,7
Coking coal	94,6	28,2
Other bituminous coal	94,6	25,8
Sub-bituminous coal	96,1	18,9
Lignite	101,0	11,9
SOURCE: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use - Chapter 4: Metal Industry Emissions.[6]		

Table A.1 *(continued)*

Fuel type description	Emission factor tCO$_2$/TJ	Net calorific value TJ/Gg
Oil shale and tar sands	107,0	8,9
Patent fuel	97,5	20,7
Coke oven coke and lignite coke	107,0	28,2
Gas coke	107,0	28,2
Coal tar	80,7	28,0
Gas works gas	44,4	38,7
Coke oven gas	44,4	38,7
Blast furnace gas	260,0	2,5
Oxygen steel furnace gas	182	7,1
Natural gas	56,1	48,0
Industrial wastes.	143,0	n.a
Waste oils	73,3	40,2
Peat	106,0	9,8
Wood/wood waste	0	15,6
Other primary solid biomass	0	11,6
Charcoal	0	29,5
Biogasoline	0	27,0
Biodiesels	0	27,0
Other liquid biofuels	0	27,4
Landfill gas	0	50,4
Sludge gas	0	50,4
Other biogas	0	50,4
Other sources		
Waste tyres	85,0	n.a
Carbon monoxide	155,2	10,1
Methane	54,9	50,0
SOURCE: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use - Chapter 4: Metal Industry Emissions.[6]		