



BSI Standards Publication

Stationary source emissions — Greenhouse Gas (GHG) emissions in energy-intensive industries

Part 2: Iron and steel industry

National foreword

This British Standard is the UK implementation of EN 19694-2:2016.

The UK participation in its preparation was entrusted to Technical Committee EH/2/1, Stationary source emission.

A list of organizations represented on this committee can be obtained on request to its secretary.

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© The British Standards Institution 2016.
Published by BSI Standards Limited 2016

ISBN 978 0 580 87113 9

ICS 13.040.40

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2016.

Amendments/corrigenda issued since publication

Date	Text affected
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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 19694-2

July 2016

ICS 13.040.40

English Version

**Stationary source emissions - Greenhouse Gas (GHG)
emissions in energy-intensive industries - Part 2: Iron and
steel industry**

Émissions de sources fixes - Détermination des
émissions de gaz à effet de serre (GES) dans les
industries écono-énergétiques - Partie 2: Industrie
sidérurgique

Emissionen aus stationären Quellen - Bestimmung von
Treibhausgasen (THG) aus energieintensiven
Industrien - Teil 2: Stahl- und Eisenindustrie

This European Standard was approved by CEN on 5 May 2016.

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CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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Ref. No. EN 19694-2:2016 E

Contents

Page

European foreword.....	4
Introduction	5
1 Scope	6
2 Normative references	7
3 Terms and definitions	7
4 Abbreviations	8
5 Scope of reporting for the iron and steel industry.....	9
5.1 Plants, processes and boundaries.....	9
5.2 Products and by-products.....	11
5.3 Energy, utilities and other materials	12
5.4 Greenhouse gases in the steel industry	12
5.5 Processes and reference products.....	12
5.6 Units	13
6 Basic principles of CO ₂ emission determination.....	13
6.1 General.....	13
6.2 Principle of the carbon mass balance	14
6.3 Determination of activity data	14
6.4 Determination of emission factors	14
7 Determination of CO ₂ emissions at facility level.....	16
8 Assessment of CO ₂ emission performance	19
8.1 Assessment of CO ₂ impact of a facility, including process emissions.....	19
8.2 Assessment of actual CO ₂ impact of a facility	19
8.3 Indicator-based assessment of CO ₂ emission performance.....	20
9 Determination of CO ₂ reference values.....	32
10 Assessment of data quality	33
10.1 Preliminary checks to detect unrealistic data.....	33
11 Uncertainty assessment.....	35
11.1 General.....	35
11.2 Uncertainty of activity data	35
11.3 Uncertainty of carbon content.....	35
11.4 Determination of uncertainty of CO ₂ emissions for individual sources.....	36
11.5 Uncertainty of total direct emissions for a facility.....	37
Annex A (informative) Definition of the technical boundaries of processes.....	38
Annex B (informative) Products and by-products of the iron and steel Industry	45
Annex C (informative) Default values for emission factors and upstream data	52
Annex D (informative) Examples of application of carbon mass balance methodology	55
Annex E (informative) Assessment of emission performance at facility level (carbon input performance).....	60
Annex F (informative) Determination of process performance.....	64

Annex G (informative) Description of data checks on process data.....	69
Annex H (informative) Elements on sampling, analyses and uncertainty	73
Bibliography	80

European foreword

This document (EN 19694-2:2016) has been prepared by Technical Committee CEN/TC 264 “Air quality”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2017, and conflicting national standards shall be withdrawn at the latest by January 2017.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate M/478 given to CEN by the European Commission and the European Free Trade Association.

This European Standard deals with sector-specific aspects for the determination of greenhouse gas (GHG) emissions from steel production. This standard can be used to measure, report and compare the GHG emissions of a steel facility. It can also be used to assess the GHG performance of a steel facility or parts of it.

EN 19694, *Stationary source emissions — Determination of greenhouse gas (GHG) emissions in energy-intensive industries* consists of the following parts:

- *Part 1: General aspects*
- *Part 2: Iron and steel industry*
- *Part 3: Cement industry*
- *Part 4: Aluminium industry*
- *Part 5: Lime industry*
- *Part 6: Ferroalloy industry*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The steel industry recognizes the urgent need to take action to combat climate change. Slowing and halting global warming will require substantial reductions in greenhouse gas emission on a global scale. To play a part in achieving these reductions, steel production sites, recognized as major emitters of GHG, should as a first step assess their CO₂ emission performance relating to the production of steel products in order to identify and quantify emission reduction opportunities.

Steel production involves complex chemical reactions, successive heating cycles, and the recycling of various by-products. A variety of inputs, including raw materials, reactive agents, fuel and heat sources are transformed into a wide range of steel products, by-products, waste materials and waste energy.

Steel sites manufacture a wide range of products including, among others, sheet products, plate products, long products, pipe and tubes. In addition, some steel sites produce unique high-performance specialty steel products, which are created by employing various sub-processes including micro-alloying and surface treatment, thus requiring additional heat treatments. Therefore, there are no two steel sites in the world which are the same. As a consequence, a sound assessment of performance should be made independent of the production structure.

Regulations related to climate change require steel companies to devise methods to reduce CO₂ emissions from steel sites while continuing to produce steel products from these diverse and complex steelmaking processes. To accomplish this, it is desirable to have universally common indicators for determining the CO₂ emission performance of a site.

It has been the usual practice to determine CO₂ emissions at facility level, from which a CO₂ intensity per unit of reference product, usually “crude steel”, can be derived. ISO TC 17/SC /WG 21 has proposed and issued a standard for the determination of CO₂ intensity derived from the method developed by worldsteel (the world steel association) as ISO 14404-1 and ISO 14404-2.

Although giving a valuable insight on CO₂ emission performance, the “CO₂ intensity” approach suggested by the ISO 14404 standards series has some limitations as it provides only one single CO₂ value for any specific facility, regardless of the complexity of its structure.

With a view to better evaluating the CO₂ performance of a facility along the steel value chain, the European Steel Industry has, since 2005, worked to set up CO₂ accounting rules aimed at carrying out the CO₂ emission performance assessment of steel production facilities while taking into account and properly addressing potential distortions due to differing facility structure. To this end, this standard goes beyond the mere “CO₂ intensity” approach to determine the performance of each process and unit that is part of the facility in order to identify the strengths and weaknesses in the value chain and, at a later stage, consolidate the performance at facility level.

As stressed in Part 1 of this standard series, this standard does not prejudice the content or application of any other standard or legal provision.

1 Scope

This European Standard provides a harmonized methodology for calculating GHG emissions and GHG performance in the steel industry.

This European Standard applies to facilities producing any of the multiple products of the steel value chain. It is supported by a set of worksheets [1].

This European Standard deals with the specific aspects for the determination of GHG emissions from steel production and the assessment of emission performance. This standard is to be used in conjunction with EN 19694-1, which contains overall requirements, definitions and rules applicable to the determination of GHG emissions for energy-intensive sectors, thereby providing a common methodological approach.

EN 19694-1 and EN 19694-2 provide a harmonized method for:

- a) measuring, testing and quantifying methods for the determination of greenhouse gas (GHG) emissions;
- b) assessing the level of GHG emissions performance of production processes over time, at production sites;
- c) the establishment and provision of reliable and accurate information of proper quality for reporting and verification purposes.

In addition, this standard provides a stepwise approach for the determination of CO₂ emissions and the assessment of CO₂ performance of steel facilities, providing a set of methodologies allowing for a fair and reliable assessment of the CO₂ performance of each individual process along the steel production value chain.

It can be seen as a toolbox which enables the determination of CO₂ emissions and the assessment of CO₂ performance of steel production facilities at various levels of disaggregation, establishing a sound system for:

- the evaluation of the global CO₂ performance of a steel production facility taking its production structure into account;
- setting a reliable basis for evaluation of the CO₂ reduction potential in a facility and the contributing processes;
- setting a basis for accurate evaluation of new technologies.

Next to the determination of the direct and indirect CO₂ emissions of a steel facility, this standard has a strong focus on performance assessment which it strives to address through the following aspects:

- assessment of CO₂ impact, including process emissions: this methodology evaluates the total CO₂ emission of a steel facility, with the carbon content of the waste gases burdened as CO₂ to the processes giving rise to them;
- assessment of the actual CO₂ impact: this methodology evaluates the total CO₂ emissions released by a steel facility, but considers waste gases exported or used in a power plant as equal to natural gas in terms of CO₂ emissions;
- carbon input CO₂ performance at facility level: this methodology delivers an indicator comparing the facility performance with best practice, on the basis of the carbon input to the system;

- CO₂ performance assessment at process level: this methodology delivers a set of indicators comparing process performance with best practice at unit level. These indicators are then combined as a consolidated figure for the whole facility. This methodology also provides a theoretical assessment of the CO₂ saving potential up to best practice.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 19694-1, *Stationary source emissions — Determination of greenhouse gas (GHG) emissions in energy intensive industries — Part 1: General aspects*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

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

3.1

boundaries

organizational or technical limits of a facility or plant

Note 1 to entry: The wording of “battery limits” can also be utilized.

3.2

Electric Arc Furnace facility

steel production facility based entirely or partially on the use of recycled scrap melted in an electric arc furnace

Note 1 to entry: By extension, this type of facility can incorporate a direct reduction production unit.

3.3

integrated facility

steel production facility based on use of virgin iron ores applying the blast furnace route

3.4

net use

net use of a source stream is the amount of fuel, material or energy which is used at the reporting boundaries during the reporting period.

Note 1 to entry: It can be calculated for the total facility from procurements, deliveries and stock variations or at process level from external use and net generation excluding internal recycling.

3.5

processing CO₂ emissions

CO₂ emissions related to the transformation of upstream to downstream products incorporating direct emissions and indirect emissions resulting from procurements

Note 1 to entry: The processing emissions do not include the indirect emissions of upstream products.

3.6 reference CO₂ saving potential

saving potential calculated by taking the difference between the emissions of a plant or facility and the emissions of the corresponding reference plant or facility

Note 1 to entry: This concept is a theoretical one and does not necessarily represent the actual CO₂ saving potential that is technically and economically achievable.

3.7 equipment or unit

technical unit for achieving a specific operation

3.8 total CO₂ emissions

sum of direct and indirect CO₂ emissions

3.9 upstream energy

energy used for the production of one unit of a source stream

4 Abbreviations

ARP achievable reference performance

ASU air separation unit

BF blast furnace

BFG blast furnace gas

BOF basic oxygen furnace

BOFG basic oxygen furnace gas

CDQ coke dry quenching

COG coke oven gas

DRI direct reduced iron

EAF electric arc furnace

EF emission factor of a source stream

GHG greenhouse gases

HBI hot briquetted iron

HM hot metal

HP high pressure

IEeq indirect emission equivalent factor of a source stream

IPCC Intergovernmental Panel on Climate Change

LP low pressure

LPG liquefied petroleum gas

SRG smelting reduction gas

5 Scope of reporting for the iron and steel industry

5.1 Plants, processes and boundaries

5.1.1 General

The steel production route involves a number of different processes, which can be operated on site or externalized. Also in each process, some operations can be externalized or may simply not exist so that particular care has to be taken when defining the system boundaries. A list of the processes that can take place in a steel production facility is given hereafter. Their technical boundaries (list of processes or units to be included in the reporting when existing) are given in Annex A.

5.1.2 Integrated steel making

The related plants and processes are:

- a) coke plant – coke making;
- b) sinter plant – sintering;
- c) pellet plant – pelletization;
- d) blast furnace plant – blast furnace iron making;
- e) BOF plant – BOF steel making including BOF converter, secondary metallurgy and casting.

5.1.3 EAF steel making

EAF steel making is a short production route since in most case, it only implements an EAF plant including the electric arc furnace, secondary metallurgy and casting.

5.1.4 Other primary processes

Beside the blast furnace, some alternative processes have been developed to produce primary iron for use in steel making processes:

- a) gas based direct reduction plant – DRI/HBI making;
- b) coal based direct reduction plant – DRI/HBI making;
- c) smelting reduction plant – iron making.

5.1.5 Rolling mills

A variety of rolling mills are used to transform crude steel into commercial products and the types of rolling mills considered in this standard are:

- a) cogging mill for primary rolling of ingots;
- b) billet mills;
- c) hot strip mill and compact strip mills for production of flat steel;
- d) plate mills;
- e) bar and rod mills;
- f) section mills for production of medium and heavy profiles;
- g) wire rod mills;
- h) seamless tube mills.

5.1.6 Downstream processes

Downstream treatments apply only to flat rolled products which are transformed into various final products by a succession of operations. Due to the large range of product quality that can be produced by these processes, the operation results vary widely between different sites and, therefore, these processes are excluded from the scope of process performance assessment. Should any operator want to enlarge the scope of assessment, the list of processes to include is given below:

- a) pickling;
- b) cold rolling;
- c) annealing which can be batch or continuous;
- d) hot dip metallization;
- e) electrolytic metallization including electro-galvanizing, tin plating, tin free plating and other metal coating;
- f) organic coating.

5.1.7 Other processes

Additional processes, which can be implemented in a steel production facility, are among others:

- a) forging;
- b) heat treatment (for plates, sections, tubes, forged pieces);
- c) dust treatment;
- d) lime production (calcining);
- e) steam raising and power generation;
- f) air separation;
- g) flaring of excess gas;

- h) other plants including facility offices, general maintenance shops, on-site transport, central water treatment and water networks.

5.2 Products and by-products

5.2.1 General

A product is the intended output of an activity; it can be a final product delivered to external customers or an input for a downstream plant or process. It is the reference output of a plant or process and can be accompanied by associated by-products or wastes. Only by-products having a noticeable impact on GHG emissions are considered in this standard. Products can be produced on site or procured from other operators. The full list of products and possible by-products is given in Annex B and the classification of products is indicated below.

5.2.2 Upstream products

Upstream products include all products starting from raw materials to hot rolled products which are the first level delivered to customers. They are:

- a) coke;
- b) sinter;
- c) pellets;
- d) direct reduced iron (DRI/HBI);
- e) hot metal;
- f) crude steel;
- g) roughing mill semis;
- h) hot rolled products.

5.2.3 Downstream products

Downstream products result from the primary transformation of hot rolled steel and are mainly concerning flat products. They are:

- a) pickled coils;
- b) cold rolled coils;
- c) annealed coils;
- d) hot dip galvanized coils;
- e) electro-galvanized coils;
- f) tin plated coils;
- g) tin free coils;
- h) other metal coated coils;

- i) organic coated coils.

5.2.4 Other products

Other products are:

- a) forged pieces;
- b) heat treated products;
- c) treated dust DRI/Pig iron.

5.3 Energy, utilities and other materials

The iron and steel industry uses a large number of energy sources, utilities and other material sources. A number of these streams may have an impact on GHG emissions due to their carbon content and/or the indirect emissions they involve. Based on experience of existing production sites, a list is given in Annex B according to the following classification:

- a) solid and liquid fuels and reducing agents: coal, coke, anthracite, heavy oil, light oil, diesel oil, LPG, charcoal, used plastics and tires and others. Annex B gives a detailed list of solid and liquid fuels and reducing agents considered in this standard;
- b) gaseous fuels: other than the four gases generated by the steel production processes (COG, BFG, SRG, BOFG) and listed as by-products of the corresponding processes, the steel industry uses natural gas mainly for combustion purpose but also as a reducing agent in direct reduction furnaces or blast furnaces. In specific locations, other gases can be used such as coal mine gas or tail gas from treatment of process gas;
- c) utilities: electricity, heat and industrial gases;
- d) miscellaneous materials including iron ores, scrap, fluxes, alloys and electrodes;
- e) residues which can be by-products or wastes arising from the processes are considered only when they have an impact on GHG emissions.

5.4 Greenhouse gases in the steel industry

As demonstrated by the different field tests carried out to support this standard, CO₂ is the only relevant greenhouse gas in the steel industry.

5.5 Processes and reference products

The assessment of CO₂ emission performance of a process requires, as a first step, the determination of its CO₂ emission intensity (expressed as kg of equivalent CO₂ per tonne of reference product). The reference products of the processes included in the scope of performance analysis are given in Table 1.

Table 1 — Reference products of process

Process	Reference product
Coke making	Total dry wharf coke discharged from coke quenching excluding quenching breeze or CDQ dust
Sintering	Equivalent bell sinter calculated as merchant sinter production x screening ratio at blast furnace
Pelletizing	Equivalent bell pellets calculated as gross pellet production x screening ratio at blast furnace
Gas-based DRI	Total amount of DRI/HBI delivered by the process (including DRI screening fines)
Coal-based DRI	Total amount of DRI after separation of coal char and fluxes (including DRI fines)
Blast furnace iron making Smelting reduction iron making	Total amount of liquid hot metal at tap hole
BOF/EAF steel making & cogging mills ^a	Total amount of continuous casting semis for subsequent use+ amount of ingots not used in cogging mills + amount of cogging mill semis
Hot rolling mills	Total amount of hot rolled products for subsequent use
Other process	Total amount of product
Lime kilns	Total amount of lime + dolime produced
^a In case of ingot casting, the crude steel product is not ready for hot rolling operation and a first step of rolling (cogging) is necessary to prepare a semi-product similar to crude steel from continuous casting. Including the cogging mill in the crude steel production step clearly highlights the interest of developing continuous casting for reduction of GHG emissions.	

5.6 Units

The units used in this standard are as follows:

- solid materials: metric tonne (t) of dry material;
- liquid fuels: metric tonne (t) or cubic meter (m³), depending on local practice;
- gaseous fuels (or fuel gases): the flow of any gaseous fuel can be expressed either as thousand cubic meters at normal temperature and pressure (1013,25 hPa (1 atm), 273,15 K) on dry basis or as Gigajoule net calorific value (GJ ncv) with reference to H₂O as water vapour;
- utilities and industrial gas: the units are Megawatt.hour (MWh) for electricity, metric tonne (t) for steam and hot water and thousand cubic meters at normal temperature and pressure (1 013,25 hPa (1 atm), 273,15 K) for industrial gas;
- CO₂ emissions: metric tonne (t CO₂).

6 Basic principles of CO₂ emission determination

6.1 General

The determination of CO₂ emissions can be done either through calculation (carbon mass balance method) or through stack emission measurement. Given the relatively high number of stacks in a steel

plant, the mass balance method is by far the most cost-efficient CO₂ emission determination method. This has been clearly demonstrated during the field tests carried out to support this standard.

It is also the most reliable method as the reconciliation of mass balance data along the value chain enables assessment of the quality of the CO₂ emission data (see Clause 10).

The basic principle of determination of CO₂ emission relies therefore on the application of a global carbon balance at facility or process level. This chapter gives the principle of the carbon balance and provides important information on the origin of data and the determination of emission factors.

6.2 Principle of the carbon mass balance

For any process, the determination of performance starts with the calculation of CO₂ emissions based on a balance of inputs and outputs of the process. Net flow of each source stream is reported and transformed into direct and indirect CO₂ using its direct emission factor and indirect emission equivalent factor. The total emissions of the process are calculated as follows:

Formula (1) – Basic formula for carbon mass balance calculation

$$E_{CO_2} = \sum_{i=1}^n (NU_i \cdot (EF_i + IEeq_i)) \quad (1)$$

where

i is the index for identification of source stream;

E_{CO_2} is total CO₂ emission;

EF_i is the emission factor of source stream i ;

$IEeq_i$ is the indirect emission equivalent factor of source stream i ;

NU_i is the net use of source stream i (on dry basis, where relevant).

Net use is calculated at process or facility level from the difference between inputs and outputs. It is determined according to Formula (3) at facility level or Formula (17) at process level. Net use is derived from activity data.

Reporting period shall ideally be a calendar year.

6.3 Determination of activity data

Activity data shall come from official site data. The recommended source is the Controlling or Accounting department which uses this data for the monitoring of operating costs and keeps the records.

6.4 Determination of emission factors

6.4.1 General principles

The determination of the emission factors of materials and energy sources requires careful sampling, analysis and data handling to ensure the lowest possible uncertainty of the calculation results.

Emission factors are calculated from carbon analysis data using the following conversion formula:

Formula (2) – Formula for calculation of emission factors

$$EF_i = f \cdot Total C_i \quad (2)$$

where

- EF_i is the direct emission factor of source stream i expressed as tonne of CO₂ per unit;
- Total C_i is the total carbon content of source stream i expressed as tonnes of carbon per unit (on dry basis, where relevant);
- f is the conversion factor of carbon content into respective CO₂ emissions i.e. 3,664 t CO₂/t C.

Where relevant, oxidation and conversion factors shall be used in accordance with EN 19694-1.

Indirect emission equivalent factors shall ideally be determined from actual operational data.

The use of actual results of analysis is strongly recommended for calculation of emission factors. This is especially important for coal and coke which are the major carbon sources for integrated steel making and which can show significant variations in carbon content.

A list of default emission factors is included in Annex C. The default values suggested in Annex C may differ from the ones proposed by the IPCC. They are based on European and global steel industry data and better reflect the characteristics and quality of the raw materials, fuels and gases used by the steel industry.

Alternatively, facility-specific emission factors may be used. They shall be based on analyses carried out in the past and be representative for future batches of the same material.

6.4.2 Sampling of source streams**6.4.2.1 Solid source streams**

In an integrated steel making facility solid source streams (in particular coal and coke used either as a fuel or as a reducing agent) represent more than 90 % of the direct emission sources. Therefore particular care has to be taken when sampling these materials. Operators shall implement a comprehensive sampling procedure taking into account the large volumes of material. In many cases, coals are received by ocean carriers with a capacity of up to 150 000 t which can contain several coal qualities. For a medium scale 5 Mt per year facility, this represents an amount of 3,5 Mt of coals and coke or 25 vessels per year with 10 to 20 different origins.

Sampling shall be performed in accordance with the requirements of EN 19694-1.

6.4.2.2 Gaseous and liquid source streams

Liquid source streams (heavy oil, diesel oil, light oil and others) shall also be sampled and analysed in accordance with existing standards. For gaseous fuels (natural gas, by-product gases and others), analysis given by the supplier (external supplier or internal producing process) can be used.

6.4.3 Carbon analysis of materials

Carbon analysis of materials shall be performed in accordance with EN 19694-1. For coals and coke the preferred procedure is to measure in parallel the proximate analysis (fixed carbon, ash and volatile matter) and the net calorific value which can be used to ascertain the quality of data.

6.4.4 Determination of carbon contents for reporting

In most cases, for a given source stream a number of batches from each of several origins are used. As an example, coke making starts from a blend of coking coal made from 5 to 10 different coals. All these coals are accumulated as “coking coal”.

Procured materials are generally deposited in primary stockyards from where they are reclaimed to prepare blends for use in the processes. For any generic material, the reported carbon content shall be a weighted average of the carbon contents of individual materials according to their mass flow.

7 Determination of CO₂ emissions at facility level

The straight application of the carbon balance at facility level will lead to the estimation of direct and indirect emissions linked to the activity. In this case, the principle given in Formula (1) is applied and net use is calculated by the formula given in Formula (3). Inventory changes are calculated with Formula (4) or Formula (5) which are equivalent and depend on the preferred data presentation.

Formula (3) – Calculation of net use (NU)

$$NU_i = \text{External Purchase}_i - \text{External Delivery}_i - \text{Inventory Change}_i \quad (3)$$

where

- i is the index of the considered source stream;
- NU_i is the net use of source stream i (on dry basis where relevant);
- $\text{External Purchase}_i$ is the total amount of purchased source stream i (on dry basis where relevant);
- $\text{External Delivery}_i$ is the total amount of sold source stream i (on dry basis where relevant);
- $\text{Inventory Change}_i$ is the total variation of stock inventory (on dry basis). Inventory change is positive if stock increases and negative if stock decreases.

Inventory change can be calculated by one of the following formulae:

Formula 4 – Calculation of inventory change (Method 1)

$$\text{Inventory Change}_i = \text{Storage}_i - \text{Stock Reclaimed}_i \quad (4)$$

where

- Storage_i is the total amount of material sent to stocks for source stream i (on dry basis);
- Stock Reclaimed_i is the total amount of material reclaimed from stocks for source stream i (on dry basis).

Formula (5) – Calculation of inventory change (Method 2)

$$\text{Inventory Change}_i = \text{Final Stock}_i - \text{Initial Stock}_i \quad (5)$$

where

Final Stock_i is the total stock inventory at end of reporting period for stream *i* (on dry basis);

Initial Stock_i is the total stock inventory at beginning of reporting period for stream *i* (on dry basis).

For adequate treatment of exported flows of energy or material, deliveries to external power plants are separated from deliveries to other activities. Two subtotals are calculated as presented in the following formulae:

Formula (6)– Calculation of external delivery

$$\text{External Delivery}_i = \text{Delivery to power plant}_i + \text{Delivery to other activities}_i \quad (6)$$

Formula (7) – Determination of total procurement

$$\text{Total Procurement}_i = \text{External purchase}_i + \text{Stock Reclaimed}_i \quad (7)$$

Formula (8) – Determination of total deliveries

$$\text{Total Delivery}_i = \text{External Delivery}_i + \text{Storage}_i \quad (8)$$

Table 2 gives an example of calculation of net use of materials and energy for a steel production facility. In this example, the net use is calculated by applying the formula given in Formula (4). An example of this net use determination is given in Annex D.

Table 2 — Model for determination of Facility balance – Determination of net use

Source stream	Procurements			Deliveries				
	External purchase	Stock reclaimed	Total procurement	To power plants	To other activities	Storage	Total deliveries	Net use
Source stream ₁	P_1	R_1	$Tin_1 = P_1 + R_1$	PP_1	O_1	S_1	$Tout_1 = PP_1 + O_1 + S_1$	$NU_1 = Tin_1 - Tout_1$
Source stream ₂	P_2	R_2	$Tin_2 = P_2 + R_2$	PP_2	O_2	S_2	$Tout_2 = PP_2 + O_2 + S_2$	$NU_2 = Tin_2 - Tout_2$
Source stream ₃	P_3	R_3	$Tin_3 = P_3 + R_3$	PP_3	O_3	S_3	$Tout_3 = PP_3 + O_3 + S_3$	$NU_3 = Tin_3 - Tout_3$
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Source stream _n	P_n	R_n	$Tin_n = P_n + R_n$	PP_n	O_n	S_n	$Tout_n = PP_n + O_n + S_n$	$NU_n = Tin_n - Tout_n$
where P_i is the amount of source stream <i>i</i> purchased during the reporting period; R_i is the amount source stream <i>i</i> recovered from stocks during the reporting period; Tin_i is the total available amount of source stream <i>i</i> during the reporting period; PP_i is the amount of source stream <i>i</i> exported to external power plant during the reporting period; O_i is the amount of source stream <i>i</i> delivered to external activities (customers) during the reporting period; S_i is the amount of source stream <i>i</i> stored during the reporting period; $Tout_i$ is the total amount of source stream <i>i</i> not used by processes in the facility during the reporting period; NU_i is the net amount of source stream <i>i</i> used or delivered by the process during the reporting period.								

The net use of each material is converted into direct and indirect CO₂ emissions, as shown in Table 3.

Table 3 — Model for determination of Facility balance – Determination of CO₂ emissions

	Net use	CO ₂ emissions (t)		
Source stream		Direct	Indirect	Subtotal
Source stream ₁	NU_1	$Dir_1 = EF_1 \cdot NU_1$	$Ind_1 = IEeq_1 \cdot NU_1$	$Dir_1 + Ind_1$
Source stream ₂	NU_2	$Dir_2 = EF_2 \cdot NU_2$	$Ind_2 = IEeq_2 \cdot NU_2$	$Dir_2 + Ind_2$
Source stream ₃	NU_3	$Dir_3 = EF_3 \cdot NU_3$	$Ind_3 = IEeq_3 \cdot NU_3$	$Dir_3 + Ind_3$
Electricity	NU_{elec}		$Ind_{elec} = IEeq_{elec} \cdot NU_{elec}$	Ind_{elec}
Heat	NU_{Heati}		$Ind_{Heati} = IEeq_{Heati} \cdot NU_{Heati}$	Ind_{Heati}
Source stream _n	NU_n	$Dir_n = EF_n \cdot NU_n$	$Ind_n = IEeq_n \cdot NU_n$	$Dir_n + Ind_n$
Total		ΣDir_i	ΣInd_i	$\Sigma (Dir_i + Ind_i)$
where NU_i is the net use of source stream i as per above; EF_i is the emission factor of source stream i; Dir_i is the direct CO₂ equivalent of source stream i during the reporting period; $IEeq_i$ is the indirect emission equivalent of source stream i; $IEeq_{elec}$ is the indirect emission equivalent of electricity; $IEeq_{Heati}$ is the indirect emission equivalent of heat i (HP steam, LP steam, Hot water); Ind_i is the total indirect CO₂ equivalent of stream i during the reporting period.				

In this table, CO₂ emissions are calculated using the following formulae:

Formula (9) – Calculation of direct emissions

$$Direct\ CO_2 = \sum_{i=1}^n Dir_i = \sum_{i=1}^n (EF_i \cdot NU_i) \quad (9)$$

Formula (10) – Calculation of indirect emissions

$$Indirect\ CO_2 = \sum_{i=1}^n Ind_i = \sum_{i=1}^n (IEeq_i \cdot NU_i) \quad (10)$$

Formula (11) – Calculation of total emissions

$$Total\ CO_2 = Direct\ CO_2 + Indirect\ CO_2 \quad (11)$$

The equivalent emission factor for electricity is set at country level or at the level of the relevant regional electricity market (see EN 19694-1). The electricity emission factor retained has to be used to determine the equivalent emission factor of industrial gases (oxygen, nitrogen, argon and compressed air) based on standard equivalents, as given in Annex C.

8 Assessment of CO₂ emission performance

8.1 Assessment of CO₂ impact of a facility, including process emissions

By setting the net use of by-product gases as equal to zero, Formula (11) gives an estimate of the total equivalent CO₂ emissions due to the activity. By burdening CO₂ emissions to the processes giving rise to them, this methodology avoids distortions between on-site or outside use of these gases. An example of this calculation is given in Annex D.

8.2 Assessment of actual CO₂ impact of a facility

Where integrated facilities using the BF/BOF route export by-product gas to external power plants or other users, the straight application of the carbon mass balance methodology to a production facility does not clearly identify the actual impact of the activity on total CO₂ emissions.

As an example, exporting BF gas to a power plant consuming 9,8MJ/kWh (36,7 % efficiency, see Table C.2) results in electricity with an equivalent emission of ca 2,7 kg CO₂/kWh. This value has to be compared with electricity procurements usually showing a much lower national grid emission factor (0,06 to 1,00 kg CO₂/kWh). The methodology used to determine the emissions of the facility without subtracting the emission related to export gas solve this problem only partly since it introduces some double counting by including both the emissions related to power generation from the gas and the CO₂ equivalent of the corresponding electricity.

The same effect exists, at a lower magnitude, when excess gas is exported to other external activities where it replaces fossil fuels with lower emission factors.

The actual CO₂ impact of the facility is determined by taking into consideration these two effects and making the following corrections on indirect emissions:

- gas exports to external power plants are transformed into equivalent electricity on the basis of the reference energy equivalent given in Annex C and the corresponding electricity is subtracted from the facility procurements diminishing the indirect emissions;
- gas exports to other activities are accounted for at the level of natural gas (chosen as reference alternative fuel) and attributed to indirect emissions.

The details of this methodology, which charges the producer of by-product gas with the excess of CO₂ emission resulting from their low quality, rather than the user, are given in Table 4.

Table 4 — Model for assessment of GHG impact of an integrated facility

	Energy	Equivalent Electricity	CO ₂ emissions (t)		
	GJ ncv	MWh	Direct	Indirect	Total
Straight balance			Dir_{CO_2}	Ind_{CO_2}	$Dir_{CO_2} + Ind_{CO_2}$
By-product gas exports to:	$PP_{Exp} + Oth_{Exp}$				
power plants	PP_{Exp}	$Eq_{Elec} = PP_{Exp} / 9.8$		$-IEeq_{Elec} \cdot Eq_{Elec}$	$-IEeq_{Elec} \cdot Eq_{Elec}$
other activities	Oth_{Exp}			$-EF_{NG} \cdot Oth_{Exp}$	$-EF_{NG} \cdot Oth_{Exp}$
Global GHG impact			Dir_{CO_2}	$Ind_{CO_2} - IEeq_{Elec} \cdot Eq_{Elec} - EF_{NG} \cdot Oth_{Exp}$	$Dir_{CO_2} + Ind_{CO_2} - IEeq_{Elec} \cdot Eq_{Elec} - EF_{NG} \cdot Oth_{Exp}$
where Dir_{CO_2} is the total direct CO ₂ as given by facility balance (see Formula (9)); Ind_{CO_2} is the total indirect CO ₂ as given by facility balance (see Formula (10)); PP_{Exp} is the export of by-product gas to power plants; Eq_{Elec} is the equivalent electricity of gas exported to power plants; Oth_{Exp} is the export of by-product gas to other activities; EF_{NG} is the emission factor of natural gas.					

An example of application of this impact assessment is given in Annex D. The correction of indirect emissions for gas exports gives a more realistic estimate of the global impact and comparable results for similar plants differing by the ownership of the power plant.

The cumulative value of CO₂ emissions at company or group level sums up the values of calculated net use, direct and indirect emissions for each reported stream for all consolidated facilities. This rule also applies to the determination of CO₂ impact after accounting for gas exports.

8.3 Indicator-based assessment of CO₂ emission performance

8.3.1 Basic principles of performance assessment

The performance assessment of CO₂ emissions goes beyond the determination of an emission inventory. An inventory gives a snapshot of the situation but, owing to the large influence of the production structure on the level of the emissions, falls short of providing reliable and fully comparable information in terms of CO₂ efficiency.

This section of the standard proposes specific methodologies for assessment of performance at process or facility level, ultimately leading to Key Performance Indicators (KPIs) which allow comparison of emission performance between operators and give an estimate of the potential for improvement. KPIs establish a fair comparison between different operators and give reliable information on the actual variation of performance.

8.3.2 Assessment of emission performance at facility level (carbon input performance)

8.3.2.1 General

This section of the standard proposes a methodology to assess the direct CO₂ performance of a facility by looking at the total carbon input to the facility. It enables the comparison between facilities with different production profiles with reference to a reference performance level (Likely CO₂ emissions).

8.3.2.2 Determination of reference emissions for the BF/BOF route

In integrated steel making three sources account for the large majority of the CO₂ emissions:

- a) coke making via the final combustion of coke oven gas wherever it occurs and the partial combustion of coke during oven pushing and coke quenching;
- b) burden preparation at the sinter plant via the combustion of solid fuels (coke and anthracite) and the decomposition of basic fluxes (limestone). In most cases, the ignition process uses coke oven gas already accounted for at coke plant and not charged to sinter making;
- c) hot metal production at the blast furnace via the final combustion of blast furnace gas wherever it occurs, and the final combustion of the BOF gas (recovered or not) resulting from the refining of the carbon contained in the hot metal and the recycling of gas cleaning dust at the sinter plant.

An analysis of the energy balance of an integrated steel production facility shows that sufficient by-product gas is generated, of adequate quality, to secure the energy requirements of all production stages from coke making to hot rolling with significant excess to send to downstream activities or the power plant so that no other fuel is required over and above metallurgical coals (coking coal, anthracite for sintering and BF injection coal), purchased external coke and other blast furnace injections.

If there is no coke plant on site, there is not enough rich process gas for the operation and some external high quality fuel will be necessary for feeding processes such as the hot rolling mills with, as a consequence, an additional carbon input.

As a consequence, Likely CO₂ emissions shall be calculated with Formula (12) for facilities with a coke plant or Formula (13) for facilities without a coke plant.

Formula (12) – Calculation of reference emissions for an integrated facility with a coke plant

$$\text{Likely CO}_2 \text{ emission} = \alpha \cdot \text{Coke} + \beta \cdot \text{Sinter} + \gamma \cdot \text{Hot metal} \quad (12)$$

Formula (13) – Calculation of reference emissions for an integrated facility without coke plant

$$\text{Likely CO}_2 \text{ emission} = \beta \cdot \text{Sinter} + \gamma \cdot \text{Hot metal} + \delta \cdot \text{Hot rolled} \quad (13)$$

In these formulae, α , β , γ and δ represent the CO₂ emission intensity (kg/t product) of the considered processes and coke, sinter, hot metal and hot rolled are the production volumes of these processes. Values for the coefficients (α , β , γ , δ) are suggested in Annex E.

This assessment can be enlarged to include lime kilns.

8.3.2.3 Determination of reference emissions for the EAF route

Steel production sites based on the EAF route are much simpler, usually consisting only of an EAF steel shop and hot rolling mills. A number of facilities also include DRI production which almost exclusively uses natural gas as a CO₂ source. Likely direct emissions of an EAF based facility shall be calculated with Formula (14).

Formula (14) – Calculation of reference emissions for an EAF Facility

$$\text{Likely CO}_2 \text{ emission} = \alpha \cdot \text{DRI} + \beta \cdot \text{Crude Steel} + \gamma \cdot \text{Hot rolled} \quad (14)$$

In this formula, α , β and γ represent the CO₂ emission intensity (kg/t product) of the considered processes and DRI, Crude Steel and Hot rolled are the production volumes of these processes.

Determining the Likely CO₂ emissions of the EAF route is not as easy as for the integrated route owing to the possible energy switch between electricity and fossil fuels in the EAF. Values for the coefficients (α , β , γ) are suggested in Annex E.

8.3.2.4 Carbon input CO₂ performance indicator

For both categories of facilities, a facility CO₂ performance indicator (carbon input performance indicator) shall be calculated using Formula (15). It evaluates the gap between the operation of the facility and the reference.

Formula (15) – Determination of Facility CO₂ performance indicator

$$\text{Facility performance indicator} = \frac{\text{Accounted equivalent direct CO}_2 \text{ input}}{\text{Likely CO}_2 \text{ emission}} \quad (15)$$

In this Formula, the accounted equivalent direct CO₂ input is derived from the sum of energy and materials used for the considered processes, excluding the external fuels used for boilers and power plants and for downstream operations (e.g. annealing furnaces) as calculated by Formula (16).

Formula (16) – Determination of Accounted equivalent direct CO₂ input.

$$\text{Accounted equivalent CO}_2 \text{ input} = \text{Total direct CO}_2 - \sum_{i=1}^n (\text{Excluded external stream}_i \cdot EF_i) \quad (16)$$

where

Total Direct CO₂ is the total emission of the facility as per Formula (11);

Excluded External Stream_i is the amount of external source stream *i* (natural gas, oil, steam coal) going to excluded processes (lime kilns, power plants, downstream processes);

EF_i is the emission factor for source stream *i*.

For average balance facilities using classical raw materials, this indicator gives a quick insight on important deviations from reference. Examples of application of this methodology are given in Annex E.

8.3.3 Assessment of emission performance at process level

8.3.3.1 Direct and indirect emissions at process level

At process level, the assessment of performance considers not only direct emissions but also indirect emissions which are relevant to get a realistic view of the efficiency of the operation.

In the performance assessment, the carbon contained in intermediate iron bearing materials are not be accounted as carbon output of the process. The corresponding amount is charged to the product in the calculated CO₂ intensity and thus transferred to user.

8.3.3.2 Choice of indirect emission equivalent factors

8.3.3.2.1 General rules

The straight estimation of performance cannot be limited to the calculation of the CO₂ intensity of a process (expressed as kg CO₂ per tonne of reference product), since such a figure does not carry any information about the efficiency of the process:

- it can be influenced by local conditions (e.g. the equivalent emission factor of electricity varies in a 1-20 range and can make any comparison of CO₂ intensity meaningless);
- in multiple process production systems such as steel production, CO₂ emissions of upstream products shall be incorporated in the calculation for a downstream product. In a straight

comparison, performance of upstream processes would impact the result for downstream process in a different way for each site;

- a CO₂ performance reference value has to be provided in order to derive information on the ranking of performance and potential savings.

The performance assessment should as far as possible be independent from local conditions and give a reliable result when applied to any facility worldwide. In order to neutralize the effect of conditions which are not under the control of the operator (e.g. electricity grid emission factor), the proposed methodology assumes that any input to a process will have a unique upstream emission factor:

- a) natural raw materials and energy have no upstream value, thus eliminating the potential impact of different mining conditions or transport to user;
- b) utilities have identical upstream values, thus eliminating the impact of different CO₂ grid intensity. Electricity is charged at average world level and industrial gases are charged on the basis of their electricity equivalents as indicated in Annex C;
- c) external procurements of manufactured products are charged at a level of upstream emission representative of the producing sector;
- d) in-house intermediate products used in downstream processes are charged at a reference upstream level in order not to impact the performance of an operator by the performance of the other operators in his Facility. The determination of this reference upstream value for facility products is presented in Clause 9. Owing to the difference between BOF and EAF steel in terms of carbon intensity, it is impossible to determine a single reference value for crude steel used in rolling mills. Hence, the reference value shall be calculated on the basis of the relative amounts of BOF and EAF steel used by each individual facility;
- e) ordinary wastes used in the processes have no upstream emission value. They are just charged at the level of their actual carbon content;
- f) by-products delivered by the processes carry a direct emission credit based on their actual carbon content. They do not carry indirect emission value in the assessment of the performance with a possible exception for some specific materials.

8.3.3.2.2 Choice of emission factors for steel plant by-product gas

Integrated steel production sites using the BF/BOF route generate large amounts of by-product gas which are used as energy carriers in the process or sent to power plants to generate heat (steam) and power.

Some processes can use a very versatile mix of gases. Notably in coke making the fuel for battery heating may range from 100 % coke oven gas to 100 % blast furnace gas, with similar energy consumptions. Owing to the differences in emission factor between these two gases, namely a factor 1 to 6, the use of BF gas will result in higher emissions and the CO₂ intensity of coke making will primarily measure the heating gas mix, so preventing any meaningful assessment of emission performance. Furthermore, using BF gas at the coke plant will just displace part of the emissions without changing anything at facility level.

To solve this problem, the proposed methodology includes specific ways for treatment of by-product gas ensuring fair assessment of CO₂ impact at facility or process level by considering a unique emission factor for all by-product gases which shall be charged for the user at the level of natural gas which is their most common substitute. The difference from the actual emission factor will remain a charge to

the gas production process. Table 5 gives an estimate of the effect for the four by-product gases of the steel industry.

Table 5 — Accounting emission factors for by-product gases

Gas	Actual emission factor (t/GJ)	Harmonized emission factor (t/GJ)	Charge to producer (t/GJ)
Coke oven gas	0,045	0,056	-0,011
Blast furnace gas	0,270	0,056	0,214
Smelting reduction gas	0,195	0,056	0,139
BOF gas	0,180	0,056	0,124

The application of this option to coke oven gas gives a bonus for the coke making process which will offset some of the higher charge for users in all processes.

8.3.3.2.3 Special rules for specific materials

Some specific materials which do not carry upstream CO₂ emissions can play a significant role in terms of CO₂ performance, next to purely technical operating parameters, because they can displaced CO₂ upwards or downwards the value chain. If deemed relevant, provision shall be made to take this aspect into account in order to enable a meaningful assessment of process performance and avoid distortions arising from very specific conditions affecting such materials.

As the purpose of this standard is to assess CO₂ emissions and performance at process and facility level with a view to improving operations, the rules applying for assigning a CO₂ value to by-products or other streams in other standards, are not relevant to this standard.

The methodology chosen to explain their effect or bring the necessary adjustments to the indicators shall be justified, documented and ideally peer-reviewed.

a) Effect of magnetite ore

Three main qualities of iron ore are used by the iron and steel industry. Hematite ores (Fe₂O₃) are largely predominant followed by magnetite ores (Fe₃O₄) and siderite ores (FeCO₃).

Owing to oxidation of magnetite during the process of blast furnace burden preparation, the use of magnetite ores reduces the energy requirements and saves CO₂.

On the other hand, the use of siderite ores for burden preparation will decrease the energy consumption owing to oxidation of iron while increasing the CO₂ emissions owing to decomposition of carbonates.

Therefore, the use of magnetite or siderite cannot be chosen for defining reference operations. Such effects shall be taken into account when analysing performance. If data is available, appropriate corrections shall be brought to the performance indicators.

b) Adjustment for iron making slag

Slag generation affects the CO₂ intensity of the iron making process. As the volume of slag often depends on factors which are beyond the responsibility of the operator such as local conditions or company choices regarding raw material procurements, it may be deemed necessary to assign a CO₂ value to iron making that appropriately offsets the impact of slag so as to have a fairer assessment of the CO₂ performance.