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

Part 3: Cement industry

Émissions de sources fixes — Détermination des émissions de gaz à effet de serre dans les industries énergo-intensives —

Partie 3: Industrie du ciment

Reference number
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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 cement manufacturing process

Cement manufacture includes three main process steps (see Figure 1):

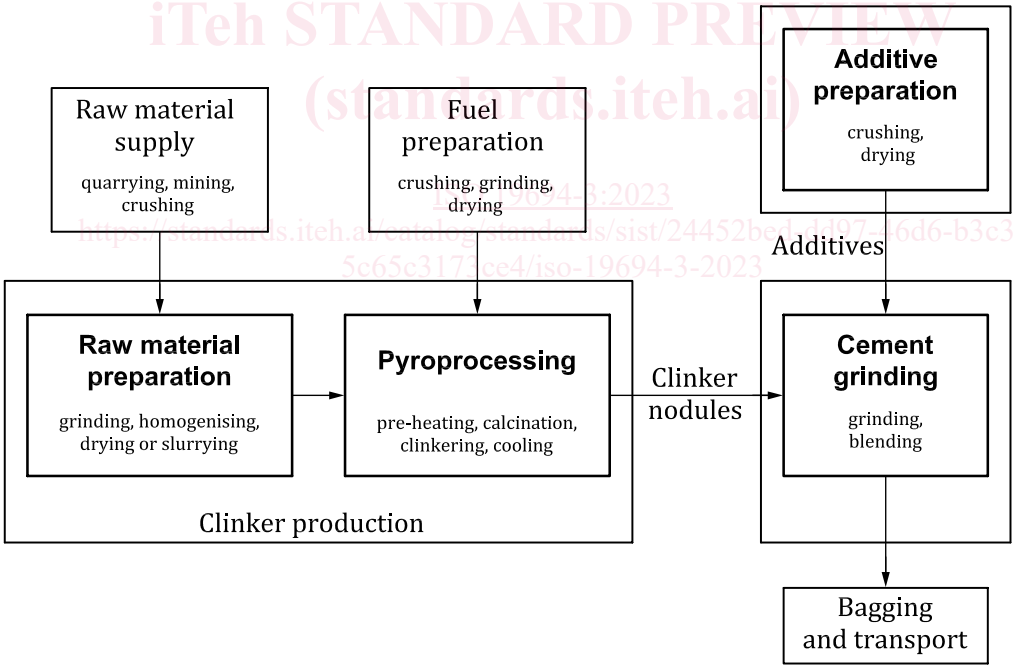
a) preparing of raw materials and fuels;

b) producing clinker, an intermediate, through pyro-processing of raw materials;

c) grinding and blending clinker with other products ("mineral components") to make cement.

There are two main sources of direct CO_2 emissions in the production process: calcination of raw materials in the pyro-processing stage, and combustion of kiln fuels. These two sources are described in more detail below. Other CO_2 sources include direct GHG emissions from non-kiln fuels (e.g. dryers for cement constituents products, room heating, on-site transports and on-site power generation), and indirect GHG emissions from, for example, external power production and transports. Non-CO_2 greenhouse gases covered by the Kyoto Protocol, apart from carbon monoxide (CO) methane (CH_4) and nitrous oxide (N_2O), are not relevant in the cement context in the sense that direct GHG emissions of these gases are negligible.

NOTE The non-CO_2 greenhouse gases covered by the Kyoto Protocol are: methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), partly halogenated fluorohydrogencarbons (HFC) and perfluorated hydrocarbons (PFC).



SOURCE Reference [8], based on Reference [16]. Reproduced with the permission of the authors.

Figure 1 — Process steps in cement manufacture

Table 1 gives an overview of places where materials enter the cement production process.

Table 1 — Overview of input places of materials

Raw meal	Input place
Raw materials from natural resources	Raw mill
Alternative raw materials	Raw mill
Raw material flows for clinker production	Input place
Raw meal	Kiln feed
Fuel ashes	Burner or precalciner or fuel dryer
Additional raw materials not part of the kiln feed	Kiln inlet
Fuels flows for clinker and cement production	**Input place**
Fossil fuels	Burner or precalciner or fuel dryer or raw material dryer
Alternative fuels	Burner or precalciner or fuel dryer or raw material dryer
Alternative fossil fuels	Burner or precalciner or fuel dryer or raw material dryer
Mixed fuels	Burner or precalciner or fuel dryer or raw material dryer
Biomass fuels	Burner or precalciner or fuel dryer or raw material dryer
Cement kiln dust	**Output place**
Dust return	Preheater
Filter dust	Precipitator / filter
By pass dust	Bypass filter
Cement constituents-based products	**Output place**
Clinker	Kiln (cooler)
Cement	Cement mill
Blast furnace slag	Cement mill or grinding station
Fly ash	Cement mill or grinding station
Gypsum	Cement mill or grinding station
Cooler dust	Cooler, is normally added to the clinker flow to the clinker silo
Cement kiln dust	Preheater or precipitator or filter or bypass filter
Limestone	Cement mill or grinding station
Burnt shale	Cement mill or grinding station
Pozzolana	Cement mill or grinding station
Silica fume	Cement mill or grinding station

0.2 CO_2 from calcination of raw materials

In the clinker production process, CO_2 is released due to the chemical decomposition of calcium, magnesium and other carbonates (e.g. from limestone) into lime:

$CaCO_3$ + heat → CaO + CO_2

$MgCO_3$ + heat → MgO + CO_2

This process is called “calcining” or “calcination”. It results in direct CO_2 emissions through the kiln stack. When considering CO_2 emissions due to calcination, two components can be distinguished:

— CO_2 from raw materials actually used for clinker production, these raw materials are fully calcined in the clinker production process;

— CO_2 from raw materials leaving the kiln system as partly calcined cement kiln dust (CKD), or as normally fully calcined bypass dust.

CO_2 from actual clinker production is proportional to the lime content of the clinker, which in turn varies little in time or between different cement plants.

NOTE A second, but much smaller factor is the CaO and MgO content of the raw materials and additives used.

As a result, the CO_2 emission factor per tonne of clinker is fairly stable with a default value in this document of 525 kg CO_2/t clinker (IPCC default: 510 kg CO_2/t clinker, CSI default: 525 kg CO_2/t clinker[19]).

The amount of kiln dust leaving the kiln system varies greatly with kiln types and cement quality standards, ranging from practically zero to over one hundred kilograms per tonne of clinker. The associated emissions are likely to be relevant in some countries or installations.

CO_2 emissions from calcination of raw materials can be calculated by two methods which are in principle equivalent: either based on the amount and chemical composition of the products (clinker plus dust leaving the kiln system, output methods B1 and B2), or based on the amount and composition of the raw materials entering the kiln (input methods A1 and A2). See 7.2.1 and 7.2.2 for details.

0.3 CO_2 from organic carbon in raw materials

The raw materials used for clinker production usually contain a small fraction of organic carbon, which can be expressed as TOC content. Organic carbon in the raw meal is converted to CO_2 during pyro-processing. The contribution of this component to the overall CO_2 emissions of a cement plant is typically very small (about 1 % or less). The organic carbon contents of raw materials can, however, vary substantially between locations and between the types of materials used. For example, the resulting emissions can be relevant if a cement company organization consumes large quantities of certain types of fly ash or shale as raw materials entering the kiln.

0.4 CO_2 from fuels for kiln operation

The cement industry traditionally uses various fossil fuels to operate cement kilns, including coal, petroleum coke, fuel oil and natural gas. Fuels derived from waste materials have become important substitutes for conventional fossil fuels. These AFs include fossil fuel-derived fractions such as, for example, waste oil and plastics, as well as biomass-derived fractions such as waste wood and dewatered sludge from wastewater treatment. Furthermore, fuels which contain both fossil and biogenic carbon (mixed fuels), like, for example, (pre-treated) municipal and (pre-treated) industrial wastes (containing plastics, textiles, paper etc.) or waste tyres (containing natural and synthetic rubber), are increasingly used.

Both traditional fossil and alternative fuels result in direct CO_2 emissions through the kiln stack. However, biomass and bioliquids are considered “climate neutral“ in accordance with IPCC definitions. The use of alternative (biomass- or fossil-derived) fuels can, in addition, lead to important emission reductions elsewhere, for instance from waste incineration plants or landfills.

Mineral components are natural and artificial materials with latent hydraulic properties. Examples of MIC include natural pozzolana, blast furnace slag and fly ash. In addition, gypsum is within this document labelled as MIC. MICs are added to clinker to produce blended cement. In some instances, pure MICs are directly added to the concrete by the ready-mix or construction company. Use of MICs leads to an equivalent reduction of direct CO_2 emissions associated with clinker production, both from calcination and fuel combustion. Artificial MICs are waste materials from other production processes such as, for example, steel and coal-fired power production. Related GHG emissions are monitored and reported by the corresponding industry sector. Utilization of these MICs for clinker or cement substitution does not entail additional GHG emissions at the production site. Consequently, these indirect GHG emissions are not included in the cement production inventory.

The basic mass balance 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)[4], and with the revised WRI / WBCSD Greenhouse Gas Protocol[9]. Default emission factors

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

The 2006 IPCC Guidelines[4] introduced a Tier 3 method for reporting CO_2 emissions from the cement production based on the raw material inputs (see Vol. III, Chapter 2.2.1.1, Formula (2).3[4]). However, a large number of raw material inputs and the need to continuously monitor their chemical composition make this approach impractical in many cement plants. The different raw materials are normally homogenized before and during the grinding process in the raw mill. The WRI / WBCSD therefore recommended alternative methods for input-based reporting of CO_2 emissions from raw material calcination in cement plants. They rely on determining the amount of raw meal consumed in the kiln system. In many cement plants, the homogenized mass flow of raw meal is routinely monitored including its chemical analysis for the purpose of process and product quality control. The input methods based on the raw meal consumed are already successfully applied in cement plants in different countries and seem to be more practical than Tier 3 of Reference [4]. They were included in the Cement CO_2 and Energy Protocol Version 3[1] (simple input method A1 and detailed input method A2, 7.2.1). This document provides guidance on how to compare the GHG performance of other companies or plants within a sector level which is different from a methodology of the IPCC National Inventory Guideline.

This document for the cement industry has been based on Reference [1].

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

Part 3: Cement industry

1 Scope

This document specifies a harmonized methodology for calculating greenhouse gas (GHG) emissions from the cement industry, with a view to reporting these emissions for various purposes and by different basis, such as, plant basis, company basis (by country or by region) or even international group basis. It addresses all the following direct and indirect sources of GHG included:

— Direct GHG emissions [ISO 14064-1:2018, 5.2.4, a)] from sources that are owned or controlled by the organization, such as emissions that result from the following processes:

  — calcinations of carbonates and combustion of organic carbon contained in raw materials;

  — combustion of kiln fuels (fossil kiln fuels, alternative fossil fuels, mixed fuels with biogenic carbon content, biomass and bioliquids) related to either clinker production or drying of raw materials and fuels, or both;

  — combustion of non-kiln fuels (fossil fuels, alternative fossil fuels, mixed fuels with biogenic carbon content, biomass and bioliquids) related to equipment and on-site vehicles, room heating and cooling, drying of MIC (e.g. slag or pozzolana);

  — combustion of fuels for on-site power generation;

  — combustion of carbon contained in wastewater;

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

— Other indirect GHG emissions [(ISO 14064-1:2018, 5.2.4, c) to f)] from purchased clinker. Excluded from this document are all other ISO 14064-1:2018, 5.2.4, c) to f) emissions from the cement industry.

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 12039, *Stationary source emissions —Determination of the mass concentration of carbon monoxide, carbon dioxide and oxygen in flue gas — Performance characteristics of automated measuring systems*

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 16911-1, *Stationary source emissions — Manual and automatic determination of velocity and volume flow rate in ducts — Part 1: Manual reference method*

ISO 16911-2, *Stationary source emissions — Manual and automatic determination of velocity and volume flow rate in ducts — Part 2: Automated measuring systems*

ISO 19694-1, *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 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/

3.1
additional raw material
ADRM
raw material (3.30) which is fed directly to the calciner or the *kiln inlet* (3.26)

Note 1 to entry: Additional raw materials are not part of the kiln feed.

3.2
alternative fuel
AF
fuel derived from waste materials

Note 1 to entry: AF can be further divided into biogenic, *fossil* (3.18) and mixed alternative fuels.

3.3
automated measuring system
AMS
measuring system permanently installed on site for continuous monitoring of emissions

Note 1 to entry: An AMS is a method which is traceable to a reference method.

Note 2 to entry: Apart from the analyser, an AMS includes facilities for taking samples (e.g. sample probe, sample gas lines, filters, flow meters, regulators, delivery pumps, blowers) and for sample conditioning (e.g. dust filter, water vapour removal devices, converters, diluters). This definition also includes testing and adjusting devices that are required for regular functional checks.

Note 3 to entry: In ISO 14064-1:2018, AMS are called “continuous emission monitoring systems (CEMS)".

3.4
alternative fossil fuel
fossil fuel derived from waste materials without biogenic content and not listed by IPCC

3.5
alternative raw material
ARM
raw material (3.30) for *clinker* (3.13) production derived from artificial resources

3.6
bioliquid
liquid fuel for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass

3.7
bypass dust
BPD
discarded dust from the bypass system dedusting unit of suspension preheater, precalciner and grate preheater kilns, normally consisting of *kiln feed* (3.23) material which is fully calcined or at least calcined to a high degree

3.8
cement
building material made by grinding *clinker* (3.13) together with various *mineral components* (3.26) such as gypsum, limestone, blast furnace slag, coal fly ash and natural volcanic material

Note 1 to entry: This term includes special cements such as the ones based on calcium aluminates

3.9
cement (equivalent)
calculated cement production value which is determined from *clinker* (3.13) produced on-site in an *integrated cement plant* (3.21) applying the plant-specific clinker/cement-factor

3.10
cement constituent
main and minor additional materials used in *cement* (3.9) plus calcium sulphates and additives in cement

3.11
cement kiln dust
CKD
discarded dust from dry and wet *kiln system* (3.22) dedusting units, consisting of partly calcined *kiln feed* (3.23) material which includes *bypass dust* (3.7) or any other dust flows coming from the *clinker* (3.13) production

3.12
cement constituents-based product
clinker (3.13) produced for *cement* (3.8) making or direct clinker sale, plus *mineral components* (3.26) consumed or processed for sale excluding pre-processed mineral components imported from another cement plant

3.13
clinker
intermediate product in *cement* (3.8) manufacturing and the main substance in cement

Note 1 to entry: clinker is the result of calcination of limestone in the kiln and subsequent reactions caused through burning (see EN 197-1[12]).

3.14
concrete addition
finely divided inorganic material with pozzolanic or latent hydraulic properties or nearly inert, used in concrete in order to improve certain properties or to achieve special properties

3.15
fossil direct GHG emission
total direct emission (3.34) of GHGs within the reporting boundaries excluding GHG emissions from biomass fuels or biogenic carbon content of mixed fuels

3.16
dust return
dust arising during *clinker* (3.13) manufacture that is ultimately returned to the raw mill or *kiln system* (3.22)

Note 1 to entry: This term does not include *bypass dust* (3.7).

Note 2 to entry: See Figure 6 for an example of mass flows in the clinker production process.

3.17
filter dust leaving the kiln system
cement kiln dust (3.11) leaving the *kiln system* (3.22) excluding *bypass dust* (3.7)

3.18
fossil fuel
fuels from fossilized materials listed by IPCC

Note 1 to entry: Examples of fossilized material are coal, oil, and natural gas and peat.

3.19
grinding station
plant for *cement* (3.8) production where cement constituents are ground without having onsite *clinker* (3.13) production

3.20
gross emission
fossil direct GHG emissions (3.15) excluding GHG emissions from on-site power production

3.21
integrated cement plant
plant where *clinker* (3.13) is produced and partly or fully ground to *cement* (3.8)

3.22
kiln system
tubular heating apparatus used in the production of *clinker* (3.13), including preheater and/or pre-calciner

3.23
kiln feed
raw materials (3.30), often processed as *raw meal* (3.31) [including *recirculated dust* (3.33)], which are fed to a preheater or directly into the *kiln system* (3.22)

3.24
kiln fuel
fuel fed to the *kiln system* (3.22) plus fuels that are used for drying or processing of *raw materials* (3.30) for the production of *clinker* (3.13) and their preparation

3.25
kiln inlet
kiln hood or entrance to the tubular heating apparatus for materials

3.26
mineral component
cement constituent (3.10) other than *clinker* (3.13) plus *concrete additions* (3.14) processed in view of changing their properties

3.27
net emission
gross emissions (3.20) excluding fossil GHG emissions from *alternative fuels* (3.2) and comparable benchmark emissions from external heat or energy transfer

3.28
non-kiln fuel
fuels which are not included in the definition of *kiln fuels* (3.24)

3.29
petcoke
petroleum coke
carbon-based solid fuel derived from oil refineries

3.30
raw material
materials used for *raw meal* (3.31) preparation for *clinker* (3.13) production

3.31
raw meal
ground *raw materials* (3.30) for *clinker* (3.13) production

3.32
raw meal consumed
part of the *raw meal* (3.31), which is consumed for *clinker* (3.13) production and the formation of calcined *bypass dust* (3.7)

3.33
recirculated dust
dust flow that is reused as *kiln feed* (3.23)

Note 1 to entry: See Figure 6 for an example of mass flows in the *clinker* (3.13) production process.

3.34
total direct GHG emission
all direct emissions of GHGs within the reporting boundaries including GHG emissions from *raw materials* (3.30) processing, *fossil fuels* (3.18), biomass and biogenic carbon content of mixed fuels, and CO_2 from waste water combustion

4 Symbols and abbreviated terms

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

ADRM	Additional raw material
AF	Alternative fuel
AFR	Alternative fuel and alternative raw material
ARM	Alternative raw material
AMS	Automated measuring system
BioC	Biogenic carbon content
BPD	Bypass dust
cem_{eq}	cement (equivalent)
$cem_{products}$	cement constituents-based product
CKD	Cement kiln dust
cli	clinker
CSI	Cement sustainablity initiative of the WBCSD
EF	Emission factor