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

Part 5: **Lime industry**

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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.

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

Part 5: **Lime industry**

1 Scope

This document provides a harmonized methodology for calculating greenhouse gas (GHG) emissions from the lime industry. It includes the manufacture of lime and any downstream lime products manufactured at the plant, such as ground or hydrated lime. This document allows for reporting of GHG emissions for various purposes and on different basis, such as plant basis, company basis (by country or by region) or international organization basis.

This document addresses all of the following direct and indirect sources of GHG included as defined in ISO 14064-1:

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

— calcination of carbonates and combustion of organic carbon contained in the kiln stone;

— combustion of kiln fuels (fossil kiln fuels, alternative fossil fuels, mixed fuels with biogenic carbon content, biomass fuels and bio fuels) related to lime production and/or drying of raw materials;

— combustion of non-kiln fuels (fossil kiln fuels, mixed fuels with biogenic carbon content, biomass fuels and bio fuels) related to equipment and on-site vehicles, heating/cooling and other on-site uses;

— combustion of fuels for on-site power generation;

— indirect greenhouse gas emissions [see ISO 14064-1:2018, 5.2.4 b)] from the generation of imported electricity, heat or steam consumed by the organization;

— other indirect greenhouse gas emissions [see ISO 14064-1:2018, 5.2.4 c) to f)], which are a consequence of an organization's activities, but arise from greenhouse gas sources that are owned or controlled by other organizations, except emissions from imported kiln stone, are excluded from this document.

This document is intended to be used in conjunction with ISO 19694-1, 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 defines the details for applying the rules. The application of this document to the sector-specific standards ensures accuracy, precision and reproducibility of the results.

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

ISO 13909 (all parts), *Hard coal and coke — Mechanical sampling*

ISO 18283, *Coal and coke — Manual sampling*

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*

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
activity data
quantitative measure of activity that results in a GHG emission or removal

EXAMPLE Amount of energy, fuels or electricity consumed, material produced, service provided, area of land affected.

3.2
dolime
product resulting from the calcination of *kiln stone* (3.6) consisting of calcium carbonate and magnesium carbonate

3.3
downstream lime product
downstream lime products including *run-of-kiln lime* (3.13), *lime kiln dust* (3.8) and products made from them at the plant including ground lime and hydrated lime

3.4
free CaO and MgO
free calcium oxide and magnesium oxide
calcium oxide or magnesium oxide that has been produced in the kiln during the decarbonation of calcium carbonate or magnesium carbonate

Note 1 to entry: The terminology free CaO and MgO as used in this document can differ from the terminology applied in other standards.

3.5
kiln battery
group of kilns at the same plant and of the same design

EXAMPLE Parallel flow regenerative kilns, annular shaft kilns, mixed feed shaft kilns, preheater rotary kilns or long rotary kilns.

3.6
kiln stone
limestone (3.9) that is fed into the kiln

3.7
lime
LI
generic name for *quicklime* (3.11), *dolime* (3.2) or *sintered dolime* (3.14)

3.8
lime kiln dust
LKD
partly calcined *kiln stone* (3.6) material which is extracted by the kiln particulate abatement system

3.9
limestone
LS
sedimentary rock consisting of calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), mineral and other minor impurities, including in some cases a small fraction of organic carbon

3.10
non-kiln stone aggregate
stone extracted from a quarry except that used as *kiln stone* (3.6)

3.11
quicklime
product resulting from the calcination of *limestone* (3.9) consisting primarily of calcium carbonate

3.12
residual CO_2
CO_2 that remains in the product leaving the kiln which is bound with CaO in the form of $CaCO_3$ and possibly with MgO in form of $MgCO_3$

3.13
run-of-kiln lime
ROK
direct output from the kiln

3.14
sintered dolime
dolime (3.2) heated to temperatures below its melting temperature, so as to increase its density

4 Symbols and abbreviated terms

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

AF	alternative fuel	
$m_{CO2-stack}$	mass of CO_2 emitted through the stack	t
$\bar{x}$	arithmetic mean of the measured values	
$CaCO_{3\ LI-ROK}$	mass fraction of calcium carbonate in the dry ROK lime produced by the kiln	
$CaCO_{3\ LKD}$	mass fraction of calcium carbonate in the dry LKD	
$CaCO_{3\ LS}$	mass fraction of calcium carbonate in the dry limestone fed into the kiln	
CaO_{bd}	CaO bound in form of $CaCO_3$	
CaO_{fr}	free CaO	
$CaO_{\ LI-ROK}$	mass fraction of free calcium oxide in the dry ROK lime produced by the kiln	
CaO_{LKD}	mass fraction of free calcium oxide in the dry LKD	
CaO_t	total CaO	

CV_{Fy}	calorific value of the fuel (y). It is important to note that the applied calorific value always has to match the status of the fuel, especially with respect to the correct moisture content during its weighing (e.g. raw coal or dried coal)	GJ/t or GJ/m^{3}N
d_i	the transport distance of the kiln stone for the mode i	
EF_{LI}	emission factor of the ROK lime, here the CO_2 emissions resulting from the calcination of the limestone factor per mass of ROK lime	CO_{2e}/t
EF_{LS}	emission factor of the limestone, here the CO_2 emissions resulting from the calcination of the limestone factor per mass of limestone	CO_{2e}/t
EF_{ELEC}	emission factor of externally generated electricity	(CO_{2e}/kWh)
EF_{Fy}	emission factor of the fuel (y) expressed as (combustion emissions)	t_{CO2e}/GJ
$EF_{LS\text{-}PUR\ i}$	greenhouse gas emission factor of imported kiln stone	
IPCC	Intergovernmental Panel on Climate Change	
LI	lime	
LKD	lime kiln dust	
LS	limestone	
$m_{CO2-oxy}$	mass of CO_2 from oxidation of organic carbon in the raw materials	
$m_{LI\text{-}ROK}$	dry mass of ROK lime	t
m_{LKD}	dry mass of LKD generated by the process	t
m_{LS}	dry mass of limestone fed into the kiln or kiln battery	t
M_{MgCO3}	molar mass of magnesium carbonate	84,314 g/mol
M_{MgO}	molar mass of magnesium oxide	40,304 g/mol
M_{CaCO3}	molar mass of calcium carbonate	100,087 g/mol
M_{CaO}	molar mass of calcium oxide	56,077 g/mol
M_{CO2}	molar mass of carbon dioxide	44,010 g/mol
m_{Fy}	material flow of a fuel (y), i.e. the fuel consumption expressed as mass for solid and liquid fuels or as volume for gaseous fuels	t or $m^3{}_N$
$MgCO_{3LI\text{-}ROK}$	mass fraction of magnesium carbonate in the dry ROK lime produced by the kiln. In practice, this mass fraction can be considered as close to 0 as the magnesium carbonate is fully converted to magnesium oxide due to the temperatures prevailing in the kiln	
$MgCO_{3LKD}$	mass fraction of magnesium carbonate in the dry LKD	
$MgCO_{3LS}$	mass fraction of magnesium carbonate in the dry limestone fed into the kiln	
$MgO_{LI\text{-}ROK}$	mass fraction of free magnesium oxide in the dry ROK lime produced by the kiln	
MgO_{LKD}	mass fraction of free magnesium oxide in the dry LKD	
MgO_{fr}	free *MgO*	

MgO_t	total *MgO*	
m_i	mass of load i	t
$m_{LI\text{-}Prod}$	measured mass of downstream lime product	
$m_{LKD\text{-}out}$	dry mass of LKD that is not blended with the downstream lime	t
$m_{LS\text{-}PUR\ i}$	annual total (wet) mass of imported kiln stone from the third party that is imported into the plant and used for lime manufacture during the 12 month reporting period	t
Ox_{Fy}	oxidation factor of the fuel (*y*)	
Q_{ELEC}	quantity of electricity consumed	
ROK	run of kiln	
TOC	total organic carbon	
T	tonne	t
t_e	tonnes of aggregates used for the production of fillers	t_e
$TF_{LS\text{-}PUR}$	emission factor per wet mass for kiln stone imported	$kgCO_2/t$
$TF_{LS\text{-}PUR\ i}$	GHG emission factor of transport mode i	
t_{gt}	given period of time	t_{gt}
TOC_{LS}	total organic carbon content of the limestone	
Ua	uncertainty associated with the overall analytical procedure	
U_i	relative expanded uncertainty	
Um	uncertainty associated with the sampling procedure	
Umi	uncertainty of the weighbridge for measurement of load I	
Umtotal	total relative uncertainty of the mass measurement	
w	average moisture content of the kiln stone determined according to the provisions of 9.2.2.3	
x_i	absolute amount of mass flow or material in stock in the mass balance	
y	fuel consumed	
η_{LI}	mass flow of LKD generated in the dedusting system(s) of the kiln divided by the mass flow of ROK lime produced by the kiln	
η_{LS}	mass flow of LKD generated in the dedusting system(s) of the kiln divided by the dry mass flow of limestone fed into the kiln	

5 General

5.1 Introduction

Since lime is defined as the generic name for quicklime, dolime and sintered dolime, plants manufacturing at least one of these products shall be covered by this document.

In conjunction with ISO 19694-1, this document provides a harmonized method for:

a) measuring, testing and quantifying methods for GHG emissions;

b) assessing the level of GHG emissions performance of production processes over time, at production sites;

c) establishment and provision of reliable, accurate and quality information for reporting and verification purposes.

GHG emissions offset mechanisms, including but not limited to voluntary offset schemes or nationally or internationally recognized offset mechanisms, shall not be used at any point in the GHG assessment according to this document.

5.2 Overview of the lime manufacturing process

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

a) kiln stone preparation including quarrying, crushing, washing, screening and transporting to the lime kiln;

b) kiln operation including lime manufacture using pyro-processing to calcine the kiln stone in a lime kiln;

c) downstream processing including crushing, screening, transporting to silos, grinding/milling, hydrating and packing.

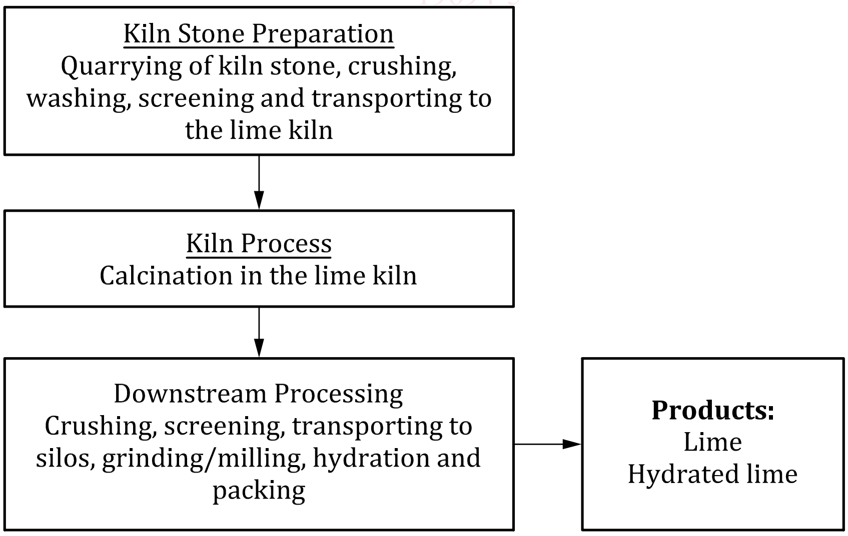

Figure 1 — Process steps in lime manufacture

A lime manufacturing plant can also encompass the use of additional fuel for on-site power generation and for preparation or processing of fuels for use in the plant.

There are two main sources of direct greenhouse gas emissions in the lime manufacturing process:

— calcination of kiln stone through pyro-processing in the lime kiln (known as process emissions);

— combustion of kiln fuels (known as combustion emissions).

These two sources are described in more detail below.

Other minor direct greenhouse gas emissions can come from non-kiln fuels such as on-site transport, pumps, room heating and other on-site uses.

The main source of energy indirect greenhouse gas emissions in the lime manufacturing process come from external power production or transport but these sources are relatively small in comparison to the direct greenhouse gas emissions.

For the lime sector, only the greenhouse gas CO_2 is relevant as demonstrated by different field tests. Details about these tests are provided in Annex A.

5.3 Direct greenhouse gas emissions from calcination of kiln stone — Process emissions

In the lime manufacturing process, CO_2 is released due to the chemical decomposition of calcium, magnesium and other carbonates in the kiln stone when the kiln stone is heated to high temperatures Formula (1):

$$CaCO_3 \rightarrow CaO + CO_2 \quad (1)$$

$$MgCO_3 \rightarrow MgO + CO_2 \quad (2)$$

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

— CO_2 from kiln stone used for lime production;

— CO_2 from materials leaving the kiln system as partly calcined LKD.

The CO_2 from lime production is dependent on the quality of the final lime product, i.e. the degree of calcination. This varies depending on the kiln design and targeted final lime product properties. The amount of LKD leaving the kiln system varies with kiln type. The associated greenhouse gas emissions are likely to be relevant and so shall be accounted for.

CO_2 emissions from calcination can be determined as a part of the measurement method or by using the following mass-balance-based methods which are in principle equivalent:

a) the input method, based on the mass of kiln stone entering the kiln and chemical composition of the limestone, lime and LKD leaving the kiln system;

b) the output method, based on the mass and chemical composition of the lime and LKD leaving the kiln system;

c) direct greenhouse gas emissions from organic carbon in kiln stone.

Some kiln stone sources contain a small fraction of organic carbon, which can be expressed as TOC content. Organic carbon in the kiln stone is converted to CO_2 during pyro-processing. The contribution of this component to the overall CO_2 emissions is typically very small. The organic carbon content of kiln stone can, however, vary substantially between locations and shall be assessed.

5.4 Direct greenhouse gas emissions from fuels for kiln operation — Combustion emissions

The lime industry uses various fossil fuels to heat the kiln, including natural gas, coal and fuel oil. In recent years, fuels derived from waste materials have become important substitutes. These AF include fossil fuel-derived fractions, such as waste oil, as well as biomass-derived fractions, such as waste wood. Furthermore, fuels are increasingly used which contain both fossil and biogenic carbon, such as municipal and pre-treated industrial wastes or waste tyres (containing natural and synthetic rubber).

Both conventional fossil and AF result in direct greenhouse gas emissions through the kiln stack. However, biomass fuels and the biomass component of mixed fuels are considered in accordance with IPCC definitions and can be reported separately as a memo item.

Greenhouse gas emissions from combustion of fuels can be calculated based on the mass, calorific value and chemical composition of fuels entering the kiln.

The mass-balance-based method used in this document is compatible with Reference [5].

Alternatively, kiln GHG emissions, from combustion, calcination and organic carbon in the kiln stone, can be determined by direct measurement at the kiln stack using the stack-measurement-based method. Emissions from the kiln stack all sources are determined based on continuous measurement of the concentration of the relevant GHG in the flue gas and of the flue gas volume flow. For the stack-measurement-based method non-kiln emissions are measured using a mass balance approach similar to the mass-balance-based method.

5.5 Direct greenhouse gas emissions from non-kiln fuels — Combustion emissions

Greenhouse gas emissions from use of fuels in non-kiln applications which are part of the lime manufacturing plant, such as on-site transport, fuel heating, and room heating are determined in a similar way to the greenhouse gas from fuels for kiln operation.

5.6 Energy indirect greenhouse gas emissions

In lime manufacture, the main energy indirect greenhouse gas emission source is electricity purchased by the plant but generated off-site. Where kiln stone is imported to the plant, the emissions associated with its manufacture to the plant shall be included within the scope of this document. The emissions associated with the off-site transport of purchased kiln stone to the plant can be included within the scope of this document.

6 Inventory boundaries

6.1 Appropriate boundaries to distinguish

The reporting entity shall define appropriate boundaries in line with ISO 14064-1 which distinguishes between organizational and reporting boundaries.

6.2 Organizational boundaries

Organizational boundaries define which parts of an organization – for example, wholly owned operations, joint ventures and subsidiaries – are covered by an inventory, and how the emissions of these entities are consolidated.

The rules for defining organizational boundaries in ISO 19694-1 shall be applied.

In particular, the lime industry shall include the following types of activities:

— kiln stone preparation including quarrying, crushing, washing, screening and transporting to the lime kiln;

— calcination in the lime kiln;

— downstream processing including crushing, screening, transporting to silos, grinding/milling, hydrating and packing;

— fuel use for on-site power generation or heat;

— preparation or processing of fuels in own installations.

6.3 Reporting boundaries

6.3.1 Emissions to be included

Reporting boundaries define the types of sources of emissions covered by this document.

The requirements for defining the scopes of emissions in ISO 19694-1 shall be applied.

Subject to the limitations set out in 6.4 below, the following greenhouse gas emissions sources shall be measured for lime manufacturing plant facilities:

— all direct greenhouse gas emissions (direct emissions) from greenhouse gas sources owned or controlled by the organization;

— all energy indirect greenhouse gas emissions (indirect emissions) from imported energy (electricity, heat or steam) consumed by the organization;

— other indirect greenhouse gas emissions (other indirect emissions) from the production and transportation of imported kiln stone.

Each lime plant shall undertake an assessment of its direct greenhouse gas emission sources, indirect greenhouse gas emission sources from imported energy and, where relevant, other indirect greenhouse gas emission sources. The assessment shall include GHG emissions from all stages of the lime manufacturing process undertaken at the plant including kiln stone preparation, calcination and downstream processing of the lime products such as into ground lime or hydrated lime. Where kiln stone is imported into the site, GHG emissions from its production shall be included for use in performance assessments.

By way of example, but not restricted to, the following greenhouse gas emissions as shown in Table 1 are relevant for a typical lime manufacturing plant.

Table 1 — Relevant GHG emissions for a lime manufacturing plant

	Category	Process steps
Kiln stone preparation	Direct greenhouse gas emissions	Direct greenhouse gas emissions including extraction, quarry operations, transport to stone processing plant, processing (washing, crushing, screening), transport to the lime kiln
	Indirect greenhouse gas emissions from imported energy	Indirect greenhouse gas emissions including extraction, quarry operations including quarry dewatering, transport to stone processing plant, processing (washing, crushing, screening), transport to the lime kiln
	Indirect greenhouse gas emissions from products used by the organization	Includes imported kiln stone extraction, quarry operations including quarry dewatering, transport to stone processing plant, processing (washing, crushing, screening), transport to the lime kiln
Kiln process	Direct greenhouse gas emissions	Direct greenhouse gas emissions from the manufacture of lime
		Direct greenhouse gas emissions from the production of LKD
		Direct greenhouse gas emissions from the combustion of fossil fuels
	Indirect greenhouse gas emissions from imported energy	Indirect greenhouse gas emissions from kiln operation and infrastructure
Downstream processing	Direct greenhouse gas emissions	Includes transport to silos, grinding/milling, hydrating or packing
	Indirect greenhouse gas emissions from imported energy	Includes transport to silos, grinding/milling, hydrating or packing

