

GCCA Cement CO₂ and Energy Management Protocol V4.2

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1. Introduction

1.1. Preface for the Revised Protocol - Version 3.1

Under the umbrella of Global Cement and Concrete Association (GCCA) - building on previous tremendous work done by the World Business Council for Sustainable Development (WBCSD) Cement Sustainability Initiative (CSI), cement companies are leading the way on Environment Social Governance (ESG) reporting. One of these issues is the industry's emissions of carbon dioxide (CO₂), the main greenhouse gas (GHG) contributing to man-made global warming.

In 2001, cement companies agreed – under the auspices of the former CSI - on a methodology for calculating and reporting CO₂ emissions: the Cement CO₂ Protocol (the Protocol). While accounting for the specific needs of the cement industry, the Protocol was closely aligned with the overarching Greenhouse Gas Protocol developed under a joint initiative of the WBCSD and the World Resources Institute (WRI).

The Version 2 of the Cement CO₂ Protocol was published in June 2005. It incorporates changes based on extensive practical application of the Protocol by many cement companies worldwide. In addition, the revised protocol has again been aligned with the revised edition of the Greenhouse Gas Protocol (GHGP) which was published in April 2004.

In 2011, Version 3 of the Cement CO₂ Protocol was published taking account of the further extended experiences with the application of the Protocol Version 2 and its evaluation for several years by many cement companies worldwide and in the CSI Getting the Numbers Right project (GNR). As reporting of energy (fuels, power) data is significantly important for the calculation of CO₂ emissions, the name of the protocol was amended to Cement CO₂ and Energy Protocol. The latest review of the CO₂ Protocol was released in 2013 as Version 3.1 and incorporates some changes and corrections to the previously released version.

This Version 4.2 of the CO₂ and Energy Protocol is published in September 2026 in response to new guidance from Science Based Target Initiative (SBTi), the GHG Protocol review of Scope 3 emissions accounting as well as technological advancements on the path to net zero like CCUS (Carbon Capture Use and Storage) and calcined clays. Version 4.2 is the result of a thorough review of Version 3.1.

The main changes between Version 3.1 and Version 4.2 of the Protocol relate to

- Mineral Inorganic Clinker Substitutes (MICs)/purchased clinker/sold clinker;
- fuels used for clinker manufacturing and other processes;
- kiln fuels;
- inclusion of hydrogen as a separate fuel category;
- calcined clays units;
- Carbon Capture Use and Storage (CCUS) units;

- power balance.

Those are summarized A14 Main Changes in the Cement CO₂ and Energy Protocol from Version 3.1 to Version 4.2

1.2. General Objectives

The Cement CO₂ and Energy Protocol is intended as a tool for cement companies worldwide.

It provides a harmonized methodology for calculating CO₂ emissions, it addresses all direct and the main indirect sources of CO₂ emissions related to the cement manufacturing process, CO₂ capture, calcined clays production and on-site power generation. It includes relevant emissions indicators, in absolute as well as specific or unit-based terms.

The protocol comprises three main elements:

- a) This guidance document,
- b) An Excel spreadsheet. The spreadsheet is designed as a practical tool to help cement companies to prepare their CO₂ inventories. An overview of the spreadsheet structure is provided in Appendix 1, and
- c) An Internet Manual for more detailed explanations and FAQs on the spreadsheet and guidance, available at [www.Cement-CO₂-Protocol.org](http://www.Cement-CO2-Protocol.org) which will be updated from Version 3 to Version 4.2 during the testing period of Version 4.2

Please note: The internet manual will not be ready when we publish the protocol. The work on internet manual updating will start in 2026.

The guidance document and the spreadsheet are collectively referred to as "the Protocol".

The purpose of this guidance document is to explain the rationale and structure of the spreadsheet, and to provide calculation and reporting instructions. In order to make the protocol comprehensible to stakeholders from outside the cement sector, some background information on the cement production process has been included in Appendix 2.

Section 12 contains a Glossary of acronyms and abbreviations. Please note that in this protocol, metric tonnes are used, where 1 tonne (t) = 1000 kilograms (kg). For other abbreviations of units and numeric prefixes, see Appendix 6.

1.3. Relation to other CO₂ Protocols

The basic calculation methods used in this protocol are compatible with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [4] issued by the Intergovernmental Panel on Climate Change (IPCC), and with the Greenhouse Gas Protocol [1] Default emission factors suggested in these documents are used, except where more recent, industry-specific data has become available.

The 2006 IPCC Guidelines introduced a Tier 3 method for reporting CO₂ emissions from the cement production based on the raw material inputs (Vol. III, Chapter 2.2.1.1, Equation 2.3). However, the 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. Therefore, the CO₂ and Energy Protocol is based on alternative methods for input-based reporting of CO₂ 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 the 2006 IPCC Guidelines. They were included in the Cement CO₂ and Energy Protocol Version 3 (Simple Input Method A1 and Detailed Input Method A2, Section 3.3) and maintained in Version 4.2.

For many parameters, Version 4.2, as did Version 3, offers the possibility of reporting on at least two different levels of detail. For example, for internal company use or for companies starting the CO₂ reporting with the Protocol, it is possible to use more simple methods and default values. More detailed methods are offered for companies reporting in specific schemes like the European Greenhouse Gas Emissions Trading Scheme (EU ETS) or companies with long-term experience with CO₂ reporting.

Various changes from Version 2 to Version 3 and subsequently to Version 4.2 of the Protocol were motivated by experience gained through parallel reporting under other schemes.

Therefore, the CO₂ and Energy Protocol allow cement companies to report their CO₂ emissions to national governments in accordance with IPCC requirements and, in addition, it can be applied as a flexible tool that facilitates reporting under various schemes, such as:

- The European Greenhouse Gas Emissions Trading Scheme (EU ETS) and its Carbon Border Adjustment Mechanism (CBAM) [5]
- "Act on promotion of global warming countermeasures" and "Act on the Rational Use of Energy" [6] of the Japanese Government
- SBTi initiatives
- Paris Agreement Article 6 implementation

Generally, it should be noted that reporting requirements under specific voluntary or mandatory schemes can sometimes deviate from this Protocol.

For a product-level assessment, Scope 3 emissions must be considered. In this case, the relevant indicator is line 82b: specific indirect CO₂ from net clinker imports (+) or exports (–) per tonne of cementitious product.

Consequently, companies reporting their CO₂ emissions should always state which protocol or standard they have followed.

1.4. Defining Organizational and Operational Boundaries

Drawing appropriate boundaries is one of the key tasks in an emissions inventory process. In line Greenhouse Gas Protocol (2004) [1] and the international standard ISO 14064-1 [8] this protocol distinguishes organizational and operational 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. Chapter 7 provides guidance on organizational boundaries. In particular, cement companies shall include the following types of activities in their voluntary reporting under this Protocol, to the extent that they control or own the respective installations:

- Clinker production, including raw material quarrying and preparation.
- Grinding of clinker, additives and MICs such as slag, both in integrated cement plants and stand-alone grinding stations.
- Additional fuel use for on-site power generation
- Preparation or processing of fuels or fly ash in own installations
- Calcined clays production; and
- CCUS

In this new Version 4.2 of the protocol, the MICs blended in vertically integrated businesses like concrete/ready-mix, precast, blocks & mortars are also reported. See Chapter 7 for further guidance.

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

- Direct emissions are emissions from sources that are owned or controlled by the reporting company. For example, emissions from fuel combustion in a cement kiln are direct emissions of the company owning (or controlling) the kiln. This includes the direct emissions from additional fuel use for on-site power generation.
- Indirect emissions are emissions that result as a consequence of the activities of the reporting company but occur at sources owned or controlled by another company. For example, emissions from the

generation of grid electricity consumed by a cement company will qualify as indirect.

Chapter 3 provides detailed guidance on the different sources of direct emissions occurring in cement plants. Indirect emissions are addressed in Chapter 4.

In the context of operational boundaries, it is useful to recall the concept of scopes as defined in the revised GHG Protocol [1]

- **Scope 1** emissions are direct emissions occurring from sources that are owned or controlled by the company. For example, emissions from combustion in owned or controlled boilers, kilns, vehicles, etc. (...). Direct CO₂ emissions from the combustion of biomass shall not be included in Scope 1 but reported separately, e.g. as Memo-Item.
- **Scope 2** emissions are indirect emissions from the generation of purchased electricity consumed in the company's owned or controlled equipment. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundaries of the company. Scope 2 emissions physically occur at the facility where electricity is generated.
- **Scope 3** allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. Some examples of Scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services. Additional examples are listed in ISO 14064-1 [8], Annex B. ISO 19694-3 Greenhouse gas emissions from energy-intensive industries — Part 3: Stationary combustion processes, clause 6.2 covers the reporting of scope 3 emissions of purchased clinker. GCCA has developed a separate Scope 3 guidance document which can be referred to account for the necessary Scope 3 emissions from the company value chain. Email GCCA Secretariat at info@gccassociation.org to know more about the Scope 3 guidance. Scope 3 accounting is not included as a part of this document.

The GHG Protocol [1] requires that companies shall separately account for and report on Scopes 1 and 2. Verification shall also cover Scope 1 and 2 emissions. The Cement CO₂ and Energy Protocol is consistent with this reporting requirement, except for some deviations and additions which are summarized in 13.10

2. Principles for the CO₂ and Energy Protocol

2.1. GHG accounting principles

GHG accounting and reporting shall be based on the following principles:

- **Relevance:** Ensure that the GHG inventory appropriately reflects the GHG emissions of the company and serves the decision-making needs of users – both internal and external to the company.
- **Completeness:** Account for and report on all GHG emission sources and activities within the chosen inventory boundary. Companies are encouraged to disclose and justify any specific exclusions.
- **Consistency:** Use consistent methodologies to allow for meaningful comparison of emissions over time. Transparently document any changes to the data, inventory boundaries, methods, or any other relevant factors in the time series.
- **Transparency:** Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.
- **Accuracy:** Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information.

This Protocol was designed with a view to the above principles, which are consistent with the GHG Protocol [1]. In addition, the protocol aims to meet the following principles:

- Avoid double-counting at plant, company, group, national, and global levels.
- Allow to distinguish between different drivers of emissions (technological improvement, internal and external growth).
- Allow to report emissions in absolute as well as specific (unit-based) terms.
- Reflect the full range of direct and indirect CO₂ abatements achieved.
- Provide a flexible tool suiting the needs of different monitoring and reporting purposes, such as internal management of environmental performance, public corporate environmental reporting, reporting under CO₂ taxation schemes, reporting under CO₂ compliance schemes (voluntary or negotiated agreements, emissions trading systems), target setting initiatives such as SBTi, industry benchmarking, and product life-cycle analysis.
- Reflect full accounting of direct emissions and indirect emissions separately

2.2. Calculation versus measurement

In principle, the GHG emissions of an installation could be determined by calculation or measurement. Version 4.2 of the Cement CO₂ and Energy Protocol relies – as did Version 3 – on calculation methods.

Using calculation-based methodologies emissions from source streams are determined based on input or production data obtained by means of measurement systems and additional parameters from laboratory analyses (calorific factor, carbon content, biomass content, etc.) and/or standard factors. Measurement-based methodologies for the determination of emissions from an emission source are based on continuous measurement of the concentration of the relevant greenhouse gas in the flue gas and of the flue gas flow.

It has been demonstrated in the framework of the development of [ISO/ DIS 19694-3: Cement](#) that Stack CO₂ emission measurements were subject to the highest relative uncertainty in the verification tests.

The key influence on the uncertainty of the stack emission method is the accuracy of calibration of the continuous measuring instruments for the stack gas velocity and volume flow. It strongly depends on the uncertainty of the applied standard reference method (SRM).

The overall uncertainty depends on the accuracy of the determination methods of the different parameters. Industry has long-term experience with accurate reporting of fuel quantities or production volumes. Also, the analyses of conventional parameters like calorific values can be carried out with a very high accuracy. An important influencing factor on the uncertainty of the determination of CO₂ emissions by calculations is the representativeness of sampling. The accuracy of concentration measurement techniques has been proven over a long time to be high. Again, the representativeness of sampling is key. The limiting factor of applying the measurement methodology is:

- the low accuracy of volume flow measurement
- the impossibility of assessment of abatement measures and
- limited experience with the comparison of measured versus calculated data which makes it – for the time being – more recommendable to use the calculation methodologies.

In conclusion, calculation as per this Protocol has a higher degree of certainty and accuracy.

3. Direct Greenhouse Gas Emissions from Cement Manufacturing

3.1. Overview

Direct emissions are emissions from sources that are owned or controlled by the reporting entity. In cement plants, direct CO₂ emissions result from the following sources:

1. Calcination of raw materials
 - a. calcination of carbonates
 - b. combustion of organic carbon contained in raw materials
 for both clinker (Section 3.2) and calcined clays production (Section 3.3)
2. Combustion of
 - a. primary fossil fuels
 - b. alternative fossil fuels (also called fossil AF or fossil wastes) and mixed fuels with biogenic carbon content
 - c. biomass fuels and biofuels (including biomass wastes)
 for clinker manufacturing related to clinker production (see Section 3.4.2)
3. Combustion of fuels for other processes (see Section 3.4.3):
 - a. equipment and on-site vehicles
 - b. room heating/cooling
 - c. drying of MIC such as slag or pozzolana
 - d. on-site power generation in separately fired boilers
 - e. SCMs preparation
 - f. clay calcination (see Section 3.3)
 - g. power and steam generation for CCUS (see Section 3.5)

Please note: Drying of MICs, such as slag, pozzolana or fly ash, is accounted for separately from SCM preparation. This distinction is important. Users should input fuel used data from all the MICs reported under V3.1 and all the fuel used for the SCMs being processed should be reported under SCM usage.

4. CO₂ from carbon capture utilization and storage unit.
5. Combustion of carbon contained in wastewater.
See *Protocol Spreadsheet Kiln fuels section for default CO₂ emission factors of fuels.*

Table 1 Parameters and proposed data sources for calculation of direct CO₂ emissions

Emission components	Parameters	Units	Proposed source of parameter
CO₂ from raw materials: Methods based on raw material input (A1, A2)			
Calcination of raw material consumed for clinker production	Raw meal consumed	t	Calculated / Measured at plant level
	Kiln feed dust return	t	Determined at plant level
	correction: CO ₂ content in raw meal or	Mass fraction	Measured at plant level
	loss on ignition (LOI)	Mass fraction	Measured at plant level
Calcination of dust	Dust leaving kiln system excluding bypass dust	t	Measured/ Determined at plant level
	CO ₂ content in dust or loss on ignition (LOI)	mass fraction	Measured at plant level
Furthermore, for detailed input method (A2) >Partial calcination of bypass dust	Bypass dust leaving kiln system and	t	Measured / Determined at plant level

	Bypass dust CO ₂ content	mass fraction	Measured at plant level
>Additional raw materials not included in kiln feed	Additional raw materials	t	Measured at plant level
	Additional raw materials CO ₂ content	mass fraction	Measured at plant level
CO₂ from raw materials: Methods based on clinker output (B1, B2)			
Calcination of raw material consumed for clinker production	Clinker produced	t cli	Measured / Determined at plant level
	Emission factor clinker	kg CO ₂ / t cli	Default = 525; or as calculated in detailed output method (B2)
Calcination of dust	Dust leaving kiln system	t	Measured / Determined at plant level
	Emission factor clinker	kg CO ₂ / t cli	Default = 525; or as calculated in detailed output method (B2)
	Dust calcination degree	Calcined fraction	Measured at plant level
Organic carbon in raw materials	Clinker produced	t cli	Measured at plant level
	Raw meal: clinker ratio	t cli	Default = 1.55; can be analysed
	TOC content of raw meal	t/ t cli mass fraction	Default = 0.2%; can be adjusted
Furthermore, for detailed output method (B2)			
>Calcination of raw material consumed for clinker production	CaO + MgO in clinker	mass fractions	Measured at plant level

>Corrections of emission factor clinker		CaO + MgO from - carbonate sources in raw materials	mass fractions	Measured at plant level
		Ca + Mg silicate sources in raw materials (e.g. as part of clay minerals)	mass fractions	Measured at plant level (e.g. with QXRD with Rietveld refinement) Measured at plant level
CO ₂ from raw materials: Method based on input and output for Calcined clay (C1)				
Calcination of raw material consumed for calcined clay production		Raw meal consumed	t	Calculated / Measured at plant level
		Loss on ignition (LOI)	mass fractions	Measured at plant level
		Total carbon	mass fractions	Measured at plant level
Calcination of raw material consumed for calcined clay production		Calcined clay produced	t	Calculated / Measured at plant level
		Loss on ignition (LOI)	mass fractions	Measured at plant level
		Total carbon	mass fractions	Measured at plant level
Calcination of clay dust leaving kiln system		Dust leaving System	t	Measured at plant level
		Emission factor Calcined Clay	kg CO ₂ / t cli	Measured at plant level
		Dust calcination degree	Calcined fraction	Measured at plant level
CO ₂ from Fuels: Method based on input and output for Calcined clay (C1)				
CO ₂ from kiln and non-kiln fuel combustion:		Fuel consumption		Measured at plant level
Primary fuels	Fuel consumption	t fuel		Determined at plant level

	Lower heating value	GJ /t fuel		Analysed at plant level
	Emission factor	t CO ₂ /GJ fuel		IPCC / GCCA defaults, or measured at plant level
Alternative fossil fuels (fossil AF) and mixed fuels	Fuel consumption	t fuel		Measured at plant level
	Lower heating value	GJ /t fuel		Measured at plant level
	Emission factor	t CO ₂ /GJ fuel		GCCA defaults, or measured
	Biogenic carbon content	mass fraction		GCCA defaults, or measured at plant level
Biomass fuels (biomass AF)		Fuel consumption	t fuel	Measured at plant level
		Lower heating value	GJ /t fuel	Measured at plant level
		Emission factor	t CO ₂ /GJ fuel	GCCA/IPCC defaults, or measured at plant level
Wastewater combusted		-	-	Quantification of CO ₂ not required

t = metric tonne, AF = Alternative fuels, cli = clinker, TOC = Total organic carbon, QXRD = Quantitative X-Ray Diffractometry

Emission factors, formulas, and reporting approaches for these sources are described in the following sections of this chapter. Table 1 summarizes the parameters involved, and the proposed data sources. Detailed information on the input parameters of the spreadsheet is provided in a manual, which is available in the internet manual (www.Cement-CO₂-Protocol.org). Generally, companies are encouraged to measure the required parameters at plant level. Where plant- or company-specific data is not available, the recommended international default factors should be used. Other default factors (e.g., national) may be preferred to the international defaults if deemed reliable and more appropriate. The following sections provide guidance for choosing between different methods for reporting CO₂ Emissions from raw material calcination.

3.2. CO₂ from Raw Material Calcination

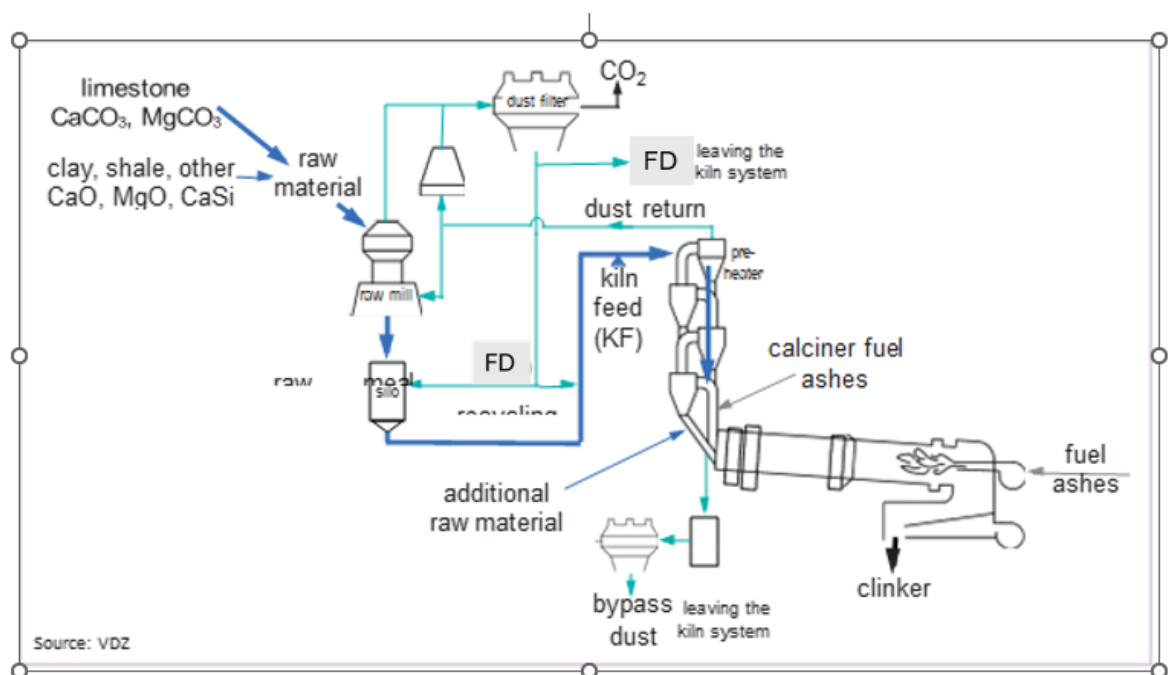
3.2.1. Introduction

Calcination is the release of CO₂ from carbonates during pyro-processing of the raw meal.

Calcination CO₂ is directly linked with clinker production. In addition, calcination of filter dust (FD) and bypass dust can be a relevant source of CO₂ where such dust leaves the kiln system for direct sale, addition to cement or other products, or for discarding as a waste.

Figure 1 gives an example of relevant mass flows in the clinker production process, as they often occur in plants with a cyclone pre-heater.

Figure 1 Example of the mass flows in the clinker production process in a plant for the production of clinker with cyclone pre-heater



On plant level, calcination CO₂ can basically be calculated in two ways: based on the volume and carbonate or Carbon content of the raw meal consumed (input method – Section 3.2.2) or based on the volume and composition of clinker produced (output method – Section 3.2.3) plus dust leaving the kiln system. The clinker-based method is often used in Europe. Both input and output-based methods are included in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [4] (Output Tier 1 and 2, Input Tier 3) [9] and the Guidelines for Monitoring and Reporting of Greenhouse Gas Emissions (MRG)[5] in the European Emission Trading System (EU ETS, Input Method A, Output Method B).

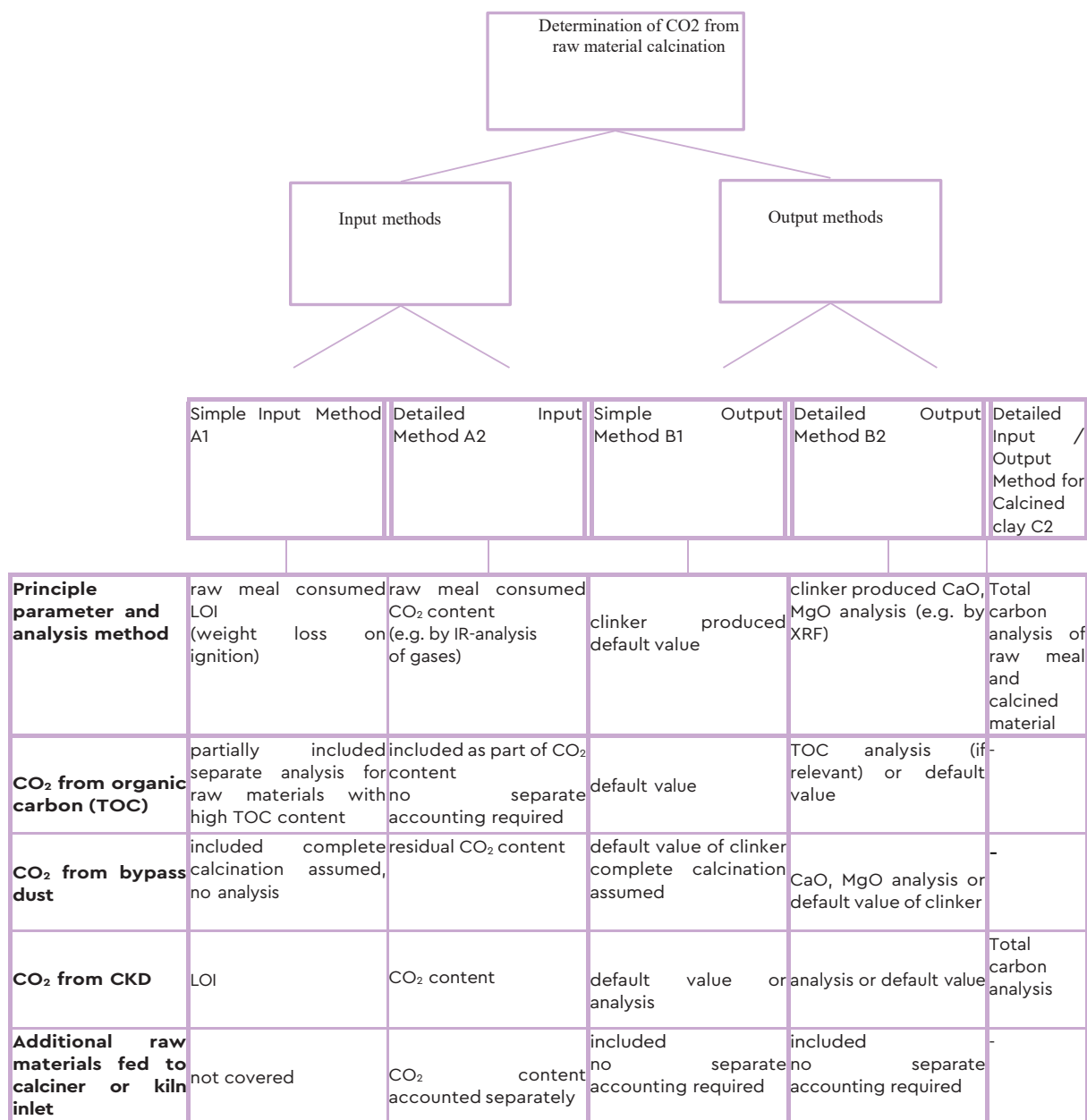
Input and output methods are, in theory, equivalent. Both methods have been maintained in the Protocol Version 4.2. Companies may choose to apply the raw

meal-based input method or the clinker-based output method. The choice should be made according to the availability of adequate data and measurements of mass flows.

Furthermore, the spreadsheet allows for each type to apply a simple and a detailed method. The choice between the simple and the detailed method depends on both the intended use of reporting and the availability of data. The detailed reporting methods shall be preferred, if the data required for the more detailed methods can be made available with sufficient accuracy and within the limits of practicability. The simple methods are also intended for companies that have just started CO₂ reporting. After a few years such companies should start using the detailed methods – in order to apply detailed methods in all plants where possible – after gaining experience with CO₂ reporting, appropriate measurements and the quality control of measurements by using one of the simple methods. In any case, possible sources of error such as direct additions of carbonate-containing materials to the kiln, internal recycling of dust, as well as incomplete calcination of dust leaving the kiln system shall be accounted for.

In the spreadsheet mass flows and parameters of the raw meal, kiln feed, filter dust (FD), bypass dust and clinker refer to a dry state (< 1% humidity). Normally, the residual moisture of these materials is negligible when measurements are performed in the process of the kiln system.

The CO₂ emissions from the calcination of relatively small amounts of carbonates in fuel ashes added to the kiln system shall be completely accounted for by the reporting of fuel CO₂ emissions. Normally, this is assured by determining the CO₂ emission factors for fuels based on the total carbon content (TC) of the fuels, which includes both total organic carbon (TOC) and total inorganic carbon (TIC). Materials with high contents of both TOC and TIC (e.g. municipal sewage sludge) can be regarded as fuel and/or raw material. In any case, the complete CO₂ emissions resulting from their use shall be accounted for. For this purpose, the ash content of fuels has been included as part of the Fuel section of the Protocol. For the applicable fuels, the percentage of ash content, ash CaO and ash MgO content (in mass %) has been added as a parameter to correct the calcination emission factor.



3.2.2. Input Methods (A1) and (A2)

The input methods are based on determining the amount of raw meal consumed for clinker production from the kiln feed considering a correction for dust return. Both methods (simple input method A1 and detailed input method A2) account for:

- CO₂ emissions from raw material calcination for clinker production,
- CO₂ emissions from calcination of bypass dust and filter dust (FD) leaving the kiln system,
- CO₂ emissions from the organic carbon content (TOC) of raw materials.

The necessary calculations are performed in Calcination sheet in the spreadsheet, which are separate from the plant sheet. The results from one of the calcination sheets 'Calcination_in' serve as input into the plant sheet.

- (1) Raw meal consumed:** The amount of raw meal consumed for the production of clinker in the kiln including calcined bypass dust leaving the kiln system is determined from the amount of kiln feed measured at plant level. The kiln feed weighing is the principal measurement, which determines the final accuracy of reporting according to the input method to the largest extent.

The amount of kiln feed is corrected in the auxiliary 'Calcination_in' by subtracting the amount of dust, that is returned, e.g. from the pre-heater, and which is either recycled to the kiln feed, raw meal silo or discarded as filter dust (FD) leaving the kiln system. The concept of mass flow is illustrated in Figure 1. The correction of the kiln feed by the rate of dust return prevents double counting of recycled dust. According to this concept, the amount of FD leaving the kiln system is accounted as part of the dust return and therefore subtracted from the amount of kiln feed. As principal term, the input methods thus calculate the amount of raw meal that is consumed for the production of clinker including bypass dust leaving the kiln system, where relevant.

The **fraction of dust return** with reference to the kiln feed shall be determined at plant level. For that purpose, different methods can be applied.

Three common methods are either

- direct measuring (weighing) the amount of dust return or
- determining the fraction of dust return from a kiln mass balance. In such a balance, the mass inputs from the kiln feed and fuel ashes, and the output of clinker output, the loss on ignition of the raw meal and dust leaving the kiln system (e.g. as bypass dust) are balanced to yield the mass of dust returned to the dust cycle in a certain period. An example of this method is presented in the manual that describes the use of the spreadsheet on the internet ([www. Cement-CO₂-Protocol.org](http://www.Cement-CO2-Protocol.org)).
- Raw Gas Measurement after pre-heater

In any case, the methods applied for determining the fraction of dust return shall provide sufficient accuracy. When measurements from certain periods of kiln operation are used, these must be representative of the kiln operation during the

period for which the emission report is prepared. Normally, this will require repeated measurements in order to account for potential changes in the fraction of dust return over time and/or changes with different modes of kiln operation.

The amount of CO₂ emissions from the calcination of the raw meal consumed is calculated by multiplication with the weight fraction of the CO₂ content of uncalcined raw meal (RM).

in the detailed input method A2 or in the simple input method A1 its loss on ignition (LOI). The corresponding parameter of the raw meal shall be measured regularly at plant level.

Instead of the raw meal parameter, the respective parameter analysed in samples of the kiln feed can be used, when the difference remains insignificant and a regular analysis of the raw meal cannot be achieved. The difference remains small when the dust returned from the pre-heater system shows a very low degree of calcination (as often observed for kiln systems with dry process and cyclone pre-heaters) or if only very small amounts of dust are recycled from the pre-heater to the kiln feed.

- For this parameter substitution in the simple input method A1, the difference of the kiln feed to the raw meal parameter shall not exceed 1% and the degree of calcination d in the dust returned from the pre-heater shall not exceed 5%.
- For the parameter substitution in the detailed input method A2, the difference between both parameters shall be analysed and it shall be demonstrated that the CO₂ emission reporting is complete, and no systematic difference exists between the use of parameters determined from raw meal or kiln feed samples, with regard to the limits of accuracy and practicality.

In addition to inorganic carbonates, the raw materials used for clinker production normally contain a small fraction of organic carbon, which is mostly converted to CO₂ during pyro-processing of the raw meal. CO₂ emissions originating from the total organic carbon content (TOC) shall be included in the parameters used for reporting of CO₂ emissions by the input methods:

For the detailed input method A2, the measurement of the CO₂ content should determine the complete CO₂ emissions from the raw meal and any additional raw materials. This means it should encompass CO₂ released from the inorganic carbon content (TIC) and the organic carbon content (TOC) of the corresponding materials. Such measurements can be performed, e.g. by total carbon (TC) analysis or by CO₂ IR-analysis of the gases released from the heated and fully oxidized sample.

In the simple input method A1, the weight fraction of the loss on ignition (LOI) accounts for all CO₂ from the calcination of carbonates. CO₂ emissions from the organic carbon content (TOC) are normally relatively small. They are also accounted by the LOI, but only partially. On the other hand, the mass difference between TOC and the carbon dioxide (CO₂) emissions from TOC is often more than fully compensated by small amounts of residual humidity in raw meal samples, which is released as water vapor (H₂O) during heating. This weight loss is also accounted by the LOI. Thus, emission reporting based on the LOI in the simple input method in most cases provides a relatively accurate estimate of the total CO₂ emissions from the calcination and pyro- processing of the raw meal consumed. If raw materials with high organic carbon content are used, then – instead of the LOI measurements – the CO₂ content including CO₂ emissions from the total organic carbon content (TOC) shall be used as in the detailed input method A2. This could be necessary, for example, if a plant consumes substantial volumes of shale or fly ash high in TOC content as raw materials entering the kiln. In certain cases, it can make sense to treat the TOC of such materials separately as a “virtual” fuel component. This means that the material will be distinguished (by calculation) in a raw material component (covering the mineral part/carbonates) and a “fuel part” (based on the TOC content).

FD Filter Dust (FD) leaving the kiln system refers to all dust that is not recycled to become part of the kiln feed again. For example, it could be sold directly, added to cement or other products, or discarded as a waste. In this Cement CO₂ and Energy Protocol, the definition of FD leaving the kiln system excludes bypass dust, which is treated separately. The amount of FD leaving the kiln system is subtracted as part of the dust return from the measured kiln feed according to the concept of determining the raw meal consumed (see above). Consequently, CO₂ emissions from the calcination of FD leaving the kiln system must be considered separately. In the dry process, FD is often uncalcined. However, partially calcined FD often is extracted in plants with semi-dry, semi-wet and wet processes. The CO₂ emissions from its calcination need to be accounted. The CO₂ emissions from calcination of raw meal that will form FD are already accounted as calcination CO₂ originating from the raw meal consumed.

CO₂ from filter dust (FD) leaving the kiln system shall be calculated based on the relevant volumes of dust and either the CO₂ content or the LOI of FD measured at plant level. From the CO₂ content or LOI of FD and uncalcined raw meal (RM) the CO₂ emission factor EF_{FD} is calculated in the auxiliary sheets for the input methods A1 and A2 according to the following equations:

$$\text{Equation 1: } EF_{FD} = \frac{fCO2_{RM} \times d}{1 - fCO2_{RM} \times d}$$

$$\text{Equation 2: } d = 1 - \frac{fCO2_{FD} \times (1 - fCO2_{RM})}{(1 - fCO2_{FD}) \times fCO2_{RM}}$$

Where, EF_{FD} = emission factor of partially calcined filter dust (t CO₂/t FD)
 $fCO2_{RM}$ = weight fraction of carbonate CO₂ in the raw meal (--)
 d = FD calcination rate (released CO₂ expressed as a fraction of the total carbonate CO₂ in the raw meal)
 $fCO2_{FD}$ = weight fraction of carbonate CO₂ in the FD (--)

The variables $fCO2_{RM}$ and $fCO2_{FD}$ are replaced by LOI_{RM} and LOI_{FD} respectively in the simple input method A1, i.e. the weight fractions of the loss on ignition. The calcination rate, d , of the FD shall preferably be based on plant-specific data. In the absence of such data, a default value of 0 shall be used for dry process kilns because FD is usually not, or only to a negligible degree, calcined in this process. In other processes (half dry, half wet or wet), calcination rates can be significant. In the absence of data, a default value of 1 shall be used for these kiln types. This value is conservative, i.e. in most cases it will lead to an overstatement of FD-related emissions. Equation 1 is based on raw meal analysis, while Equation 5 is based upon the CO₂ emission factor of clinker. Both calculation methods should lead to the same result. See Appendix 3 for details on Equations 1, 2 and 5.

In the absence of plant-specific data on dust volumes, the IPCC default for CO₂ from discarded dust (2% of clinker CO₂, see Appendix 3) shall be used. It should be noted, however, that this default value is clearly too low in cases where relevant quantities of dust leave the kiln system. Therefore, using plant-or company-specific data is clearly preferable.

(2) Partial calcination of bypass dust: Normally, bypass dust extracted from the kiln system is fully calcined. This assumption is made in the simple input method A1. However, in certain types of installations bypass dust is only partially calcined. Depending on the amount of bypass dust extraction and its degree of calcination, this can be relevant for the accuracy of reporting emissions from raw material calcination. In such cases, the detailed input method A2 should be preferred, and the amount of bypass dust leaving the kiln system and the CO₂ content of the bypass dust shall be measured at plant level. The amount of residual CO₂ in the mass flow of bypass dust leaving the kiln system shall then be subtracted from the amount of CO₂ from the calcination of raw meal consumed. This is a correction for the uncalcined fraction of the bypass dust.

(3) Additional raw materials not included in kiln feed: Options for considering additional raw materials are provided in the detailed input method A2. In the case of raw material additions which are not included in the kiln feed, e.g. directly to the rotary kiln inlet, the simple input method cannot be used. For each type of material, its quantity and CO₂ content including CO₂ emissions from the organic carbon content (TOC) shall be measured at

plant level. Only if the same material is additionally reported as fuel with an emission factor based on a relatively high TOC content, then the reporting of CO₂ emissions as additional raw material shall be restricted to its total inorganic carbon content (TIC, compare Section 3.6).

Equation for the simple input method A1 as implemented in Clacination_in sheet in the plant file

Equation 3: CO₂ Raw Materials = Kiln Feed × (1 – Dust Return Correction) × LOIRM + FD leaving kiln system × EFFD

Equation for the detailed input method A2 as implemented in Calcination_in in the plant file

Equation 4: CO₂ Raw Materials = Kiln Feed × (1 – Dust Return Correction) × fCO₂RM + FD leaving kiln system × EFFD – BypassD leaving kiln system × fCO₂BypassD + $\sum_i (ARM_i \times fCO_{2ARM,i})$

where for Equation 3 and 4: CO₂ Raw Materials = total CO₂ from raw material (t CO₂/yr), plant sheet line 39 Kiln Feed = amount of kiln feed measured at plant level (t/yr)

Dust Return Correction = fraction of returned dust with reference to the Kiln Feed (–)

LO_{IRM} = weight fraction of the loss on ignition of raw meal (–)

fCO₂RM = weight fraction of CO₂ content in the raw meal here including CO₂ emissions from TOC (–)

FD leaving kiln system = amount of filter dust leaving the kiln system (t/yr)

EF_{FD} = CO₂ emission factor of partially calcined filter dust (t CO₂/t FD)

BypassD leaving kiln system = amount of bypass dust leaving the kiln system (t/yr)

fCO₂ByPassD = weight fraction of CO₂ content in the bypass dust (–)

ARM_i = amount of additional raw material i (t/yr), which is not part of the Kiln Feed

fCO₂ARM_i = weight fraction of CO₂ content in the additional raw material i (–)

Adjustments to the concept of the input methods: In special cases an adjustment of the concept of the input methods might be necessary, in order to reflect certain material flows in a plant and to ensure their correct accounting. In that case, the corresponding adjustments shall be made in a customized auxiliary sheet, not in the plant sheet. The adjustments shall be explained and accompanied by an overview of all relevant material flows. Furthermore, it shall be demonstrated that CO₂ emissions from the complete and partial calcination of raw materials and from the organic carbon content of raw materials are completely and more accurately accounted by the adjusted method.

3.2.3. Output Methods (B1) and (B2)

To apply the clinker-based output methods, companies shall use their plant-specific data, as follows:

- (1) Clinker:** Calcination CO₂ shall be calculated based on the volume of clinker produced and an emission factor per tonne of clinker. The emission factor shall be determined based on the measured CaO and MgO contents of the clinker and corrected if relevant quantities of CaO and MgO in the clinker stem from non-carbonate sources. This could be the case, for example, if calcium silicates or fly ash are used as raw materials entering the kiln.

The determination of the emission factor for clinker shall be clearly documented. To this end, an auxiliary worksheet has been included in the spreadsheet (Detailed output method B2, in the calcination_calc sheet in the plant file). The detailed method refers to the CaO and MgO analysis of the clinker and a correction for non-carbonate sources of these oxides. Aside from the (partially) calcined raw materials, we consider the ashes of fuels in this calculation. A more detailed description of the procedure will be given in A3 Details on Calcination CO₂.

In the absence of data clearly documented calculation, a default of 525 kg CO₂/t clinker shall be used (Simple output method B1). This value is comparable to the IPCC default (510 kg CO₂/t) corrected for typical MgO contents in clinker. See Appendix 3 for details on the default emission factor. The calculation for the simple output method B1 can be performed entirely in the plant sheet and no separate auxiliary sheet is required.

- (2) Dust:** CO₂ from bypass dust (BPD) or filter dust (FD) leaving the kiln system shall be calculated based on the relevant volumes of dust and emission factors. The calculation shall account for the complete volumes of dust leaving the kiln system, irrespective of whether the dust is sold directly, added to cement, or discarded as a waste.

BPD is usually fully calcined. Therefore, emissions related to bypass dust shall be calculated using the emission factor for clinker.

FD, as opposed to bypass dust, is usually not fully calcined. The emission factor for FD shall be determined based on the emission factor for clinker

Equation 5:

$$EF_{FD} = \frac{\frac{EF_{cli}}{1 + EF_{cli}} \times d}{1 - \frac{EF_{cli}}{1 + EF_{cli}} \times d}$$

and the calcination rate of the FD, in accordance with Equation 5. This equation has been incorporated in the spreadsheet.

where EF_{FD} = emission factor of partially calcined filter dust (t CO₂/t FD)
 EF_{cli} = plant specific emission factor of clinker (t CO₂/t clinker)
 d = FD calcination rate (released CO₂ expressed as a fraction of the total carbonate CO₂ in the raw meal)

The calcination rate, d , of the FD shall preferably be based on plant-specific data. In the absence of such data, a default value of 0 shall be used for dry process kilns because FD is usually not or only to a negligible degree calcined in this process. In other processes (half dry, half wet or wet), calcination rates can be significant. In the absence of data, a default value of 1 shall be used for these kiln types. This value is conservative, i.e. it will in most cases lead to an overstatement of FD-related emissions. Equation 1 is based on raw meal analysis, while Equation 5 is based upon the CO₂ emission factor of clinker. Both calculation methods should lead to the same result. See Appendix 3 for details on the calcination rate d and Equations 1, 2 and 5.

In the absence of plant-specific data on dust volumes, the IPCC default for CO₂ from discarded dust (2% of clinker CO₂, see Appendix 3) shall be used. It should be noted, however, that this default value is clearly too low in cases where relevant quantities of dust leave the kiln system. Therefore, using plant-or company-specific data is clearly preferable.

(3) CO₂ from Organic Carbon in Raw Materials: In addition to inorganic carbonates, the raw materials used for clinker production usually contain a small fraction of organic carbon which is mostly converted to CO₂ during pyro- processing of the raw meal. The total organic carbon (TOC) contents of raw materials can vary substantially between locations, and between the types of materials used.

Data compiled by the former WBCSD CSI Task Force indicates that a typical value for TOC in the raw meal is about 0.1-0.3% (dry weight). This corresponds to CO₂ emissions of about 10 kg /t clinker, representing about 1% of the typical combined CO₂ emissions from raw material calcination and kiln fuel combustion.

CO₂ emissions from organic carbon in raw materials shall be quantified and reported to ensure completeness of the inventory (cf. Section 8.3 on materiality thresholds). However, since their contribution to overall emissions is small, a simplified self-calculating mechanism has been implemented in the spreadsheet which multiplies clinker production with the following default values:

- Default raw meal to clinker ratio: 1.55
- Default TOC content of raw meal: 2 kg /t raw meal (dry weight, corresponding to 0.2%)

This default factor for the TOC content has been checked by collecting and analyzing more than 100 analyses from different raw materials from cement plants all over the world. Based on the analysis of the data by the Former WBCSD CSI "Climate Protection" the value of the default factor of 0.2% is maintained noting that it is always recommended to use for each plant material specific values.

Companies are not required to analyze these emissions any further unless they have indications that organic carbon is more relevant in their context. This could be the case, for example, if a company consumes substantial volumes of shale or fly ash high in TOC content as raw materials entering the kiln. Furthermore, please note that any volumes of dust leaving the kiln system are not automatically reflected in this default calculation.

Companies producing substantial quantities of dust should enter their plant-specific raw meal to clinker ratios if they wish to analyze their TOC-related emissions in more detail. Plant-specific raw meal to clinker ratios should exclude the ash content of the fuels used, to avoid double-counting. For example, if fly ash with a high carbon content is accounted for as a fuel (i.e., by assigning it a heating value and CO₂ emission factor), its ash content should not be included in the raw meal to clinker ratio for the purpose of calculating emissions from TOC in raw meal.

Equation for the output methods B1 and B2 as implemented in the Calcination in sheet in the plant file:

Equation 6: CO₂ Raw Materials = Clinker × EF_{cli} / 1000 + BypassD leaving kiln system × EF_{cli} / 1000 + FD leaving kiln system × EF_{FD} + Raw Meal Consumed × fTOC_{RM} × 3,664

The Raw Meal Consumed is here calculated by

Equation 7: Raw Meal Consumed = Clinker × RM/ Cli-ratio

Where for Equation 6 and 7:

CO₂ Raw Materials = total CO₂ from raw material (t CO₂/yr), plant_calc sheet line 39 in the plant file

Clinker = clinker production measured at plant level (t/yr)

EF_{cli} = CO₂ emission factor of clinker (kg CO₂/t clinker); simple output method (B1): default value

= 525 kg CO₂/t clinker; detailed output method (B2): determined in auxiliary sheet Calcination_in sheet in the plant file

BypassD leaving kiln system = amount of bypass dust leaving the kiln system (t/yr)

FD leaving kiln system = amount of filter dust leaving the kiln system (t/yr)

EF_{FD} = CO₂ emission factor of partially calcined filter dust determined according to Equation 5 (t CO₂/t FD)

Raw Meal Consumed = amount of raw meal consumed for clinker production and bypass dust (t/yr)

$f\text{TOC}_{\text{RM}}$ = weight fraction of total organic carbon (TOC) in the raw meal (--);
default value = 0.2%

RM/Cli-ratio = raw meal clinker mass ratio (raw meal consumed per clinker production, --), the addition of fuel ashes and dust leaving the kiln system must be accounted for its determination; default value = 1.55

3.3. CO₂ from Calcined Clay Production

The term "calcined clay" refers to clay materials, such as e.g. kaolinite, illite, montmorillonite, which are calcined to be subsequently used as a MIC for cement grinding. CO₂ emissions of calcined clay production are part of the Protocol in case the respective site processes clay on site, following the same organizational and operational boundaries set by the reporting company. Elements relating to the CO₂ emissions from calcined clay production are indicated and calculated in a dedicated section present in the protocol spreadsheet.

Direct CO₂ emissions occur from fuel combustion and raw material calcination. Different technologies can be used by cement companies to calcine clay materials, namely

- Rotary kiln (separate from cement kiln)
- Rotary kiln (using, possibly amongst other fuels, also waste heat from cement kiln)
- Flash calciner
- Electric calciner

Figure 2 Rotary Kiln (Separate from Cement Kiln)

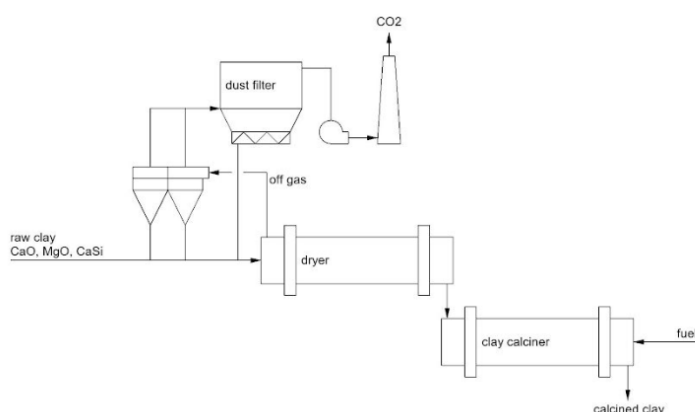


Figure 3 Rotary kiln (using, possibly amongst other fuels, also waste heat from cement kiln)

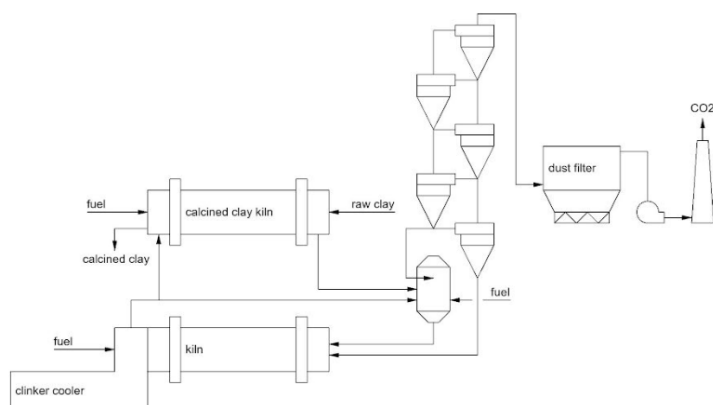
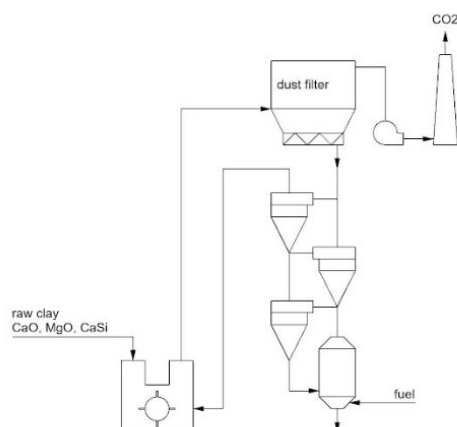


Figure 4 Flash Calciner



The respective production technology is selected from a dropdown menu present in the Calcined Clay section of the protocol spreadsheet.

The reporting indicators added to Version 4.2 will allow any plant using one of these technologies to report CO₂ emissions accurately.

Fuels consumed in the calcined clay process are treated under Section CO₂ from Fuels for other processes. Respective CO₂ emissions are integral part to the plant's total CO₂ emissions and are reported accordingly, however, the thermal energy used for the clay calcination process is not added to clinker and cement specific performance KPIs e.g. specific thermal energy consumption of clinker production. However it is to be noted that, the emissions from usage of Clay Calcination is included at Cementitious level in the performance KPI section. Instead, the thermal energy consumed for Calcined clay production is accounted for in a Calcined Clay specific KPI, i.e. specific thermal energy consumption of calcined clay production.

Carbonated impurities in clay raw materials, such as traces of calcium carbonate or magnesium carbonate, may cause CO₂ emissions upon clay calcination. If containing such carbonate fractions, the respective CO₂ emissions must be reported in the calcined clay related calculation sheet.

CO₂ emissions related to decarbonization of carbonates in the raw clay are treated in a dedicated calcined clay spreadsheet. The method builds on the analysis of both input material (raw clay) and output material (calcined clay). Contrary to clinker, the analysis of both, i.e. raw clay and calcined clay, is necessary since carbonates are not necessarily 100% decarbonated and because of the likely presence of mineral water. A simple one-sided mass balancing approach is not suitable to derive CO₂ emissions. However, the total carbon content is required for the input and output materials (i.e. raw clay and calcined clay) to calculate the CO₂ emitted in the process in an accurate manner. For plants without possibility of weighing both mass flows of input and output materials, as a fall back method the weighing of either input or output and inferring the other based on very precise, regular and representative analysis of loss on ignition (LOI at 950 °C) on input and output materials can provide the required mass balance information.

A simplified method using default emissions or method might be developed as part of the next Protocol review, i.e. once more data is available on typical raw material related CO₂ emissions of calcined clay production.

Indirect emissions relating to the electricity or heat consumed in the calcined clay production process to be reported as indirect CO₂ emissions under the power balance in the plant input sheet

Non- CO₂ GHG for calcined clay process

For CH₄ and N₂O,

Conclusions and recommendations for CO₂ Protocol:

A data collection process amongst existing calcined clays installations will be performed in 2026 to assess the materiality of CH₄ and N₂O emissions in calcined clay production. Halogenated hydrocarbons emissions should be considered non-material.

The GCCA Cement CO₂ and Energy Protocol Version 4.2 provides a tool for reporting CO₂ emissions from the Calcined Clay process.

Today, additional information on other non-CO₂ greenhouse gases is lacking for a clear assessment of their relevance.

Companies are encouraged to analyse their raw clay materials and exhaust gases of the calcined clay process, and to consider separate, additional reporting of any relevant quantities of CH₄ or N₂O emissions, considering their significantly higher greenhouse warming potential (GWP) according to IPCC.

Furthermore, reporting companies are highly invited to share their assessment with the GCCA CO₂ Protocol Task Group for future further assessment.

3.4. CO₂ from Fuels

3.4.1. Fuels emissions accounting

CO₂ Emissions accounting for primary fuels

Primary fuels are fuels from fossilized materials e.g. coal, pet coke, fuel oil and natural gas. The preferred approach is to calculate CO₂ from primary fuels (but also alternative and - fuels for other processes, see Sections 3.4.1.2 and 3.4.3) based on fuel consumption, lower heating values, and the matching CO₂ emission factors.

Fuel consumption and lower heating values (LHV or net calorific value NCV) of fuels are routinely measured at plant level. It is important to note that the applied heating 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). Normally the lower heating value is determined from a dried sample.

Subsequently, a moisture correction has to be applied to the result, correcting the mass reference from the dried sample back to the original moisture content of the fuel as it is consumed or weighed.

Furthermore, the correct reference of the CO₂ emission factors (EF) must be assured. The reference shall be to the heat determined by the lower heating value (LHV). For the conversion of higher heating values (HHV or gross calorific value GCV) to LHV the equation defined in the 2006 IPCC Guidelines [4] (Vol. II, Section 1.4.1.2, Box 1.1) can be applied.

Default emission factors per GJ lower heating value are listed in the protocol spreadsheet. The defaults for coal, fuel oil and natural gas are from IPCC (1996). Small differences exist to the default emission factors stated in 2006 IPCC Guidelines (Vol. II, Section 1.4.2.1, Table 1.4; Section 2.3.2.1, Table 2.3). Historic data based on IPCC 1996 default values shall not be recalculated. From 2011 reporting IPCC 2006 default values shall be used. Both are offered in the spreadsheet. The default value for petcoke is based on analyses compiled by the Former WBCSD CSI Task Force (see Appendix 4 for details). When default factors are used, they should be used for both lower heating value and emission factor.

Measured plant-specific lower heating values (LHV) shall be used, if available. Alternatively, IPCC or GCCA default values can be applied. If the same type of fuel is used as fuel for clinker manufacturing and for other processes, then the CO₂ emission factors and LHV used for reporting shall correspond.

The emission factor of fuels shall be based on the total carbon content. If a fuel contains significant amounts of inorganic carbon (TIC), it can be reported based on its total organic carbon (TOC) content if, in addition, CO₂ emissions from its total inorganic carbon content (TIC) are reported as CO₂ emissions from raw material calcination. Direct calculation of emissions based on fuel consumption (in tonnes) and fuel carbon content (in percent) is acceptable on the condition that material variations in the composition of the fuel, and especially its water content, are adequately accounted for.

Generally, IPCC recommends accounting for incomplete combustion of fossil fuels. However, usually 99% to 100% of the carbon is oxidized [11]. In cement kilns, incomplete oxidation is negligible, due to very high combustion temperatures and long residence time in kilns and no, or minimal, residual carbon found in clinker. Consequently, carbon in all Fuels for clinker manufacturing shall be treated as fully oxidized. The CO₂ emission factors of fuels shall always be determined based on the total carbon (TC) content.

CO₂ Emissions accounting Alternative Fossil Fuels, Mixed Fuels and Biomass Fuels

The cement industry increasingly uses a variety of alternative fuels (AF) which are typically derived from wastes and therefore, without this use, would have to be disposed of in some other way, usually by landfilling or incineration. AF serve as a substitute for primary fossil fuels. They include fossil fuel-based fractions, such as, waste oil and plastics which cannot be recycled in another way, and biomass fractions, such as waste wood and sewage sludge.

IPCC 1996 and 2006 guidelines for national GHG inventories require the following:

- **CO₂ from biomass fuels** is considered climate- neutral, because emissions can be compensated for by re-growth of biomass in the short term. CO₂ from biomass fuels is reported as a " memo item", but excluded from the national emissions totals. It has to be noted that biomass is only really climate-neutral if sustainably harvested. Climate neutrality of primary biomass is more and more questioned (see IPCC AR6 report), but most biomass used in the cement industry is secondary biomass sourced from waste. It is recommended that when using biomass, companies assess whether such biomass is sustainably sourced.
- **CO₂ from fossil fuel-derived wastes** (also called **alternative fossil fuels or fossil AF**), in contrast, is not a priori climate-neutral.

According to IPCC guidelines, GHG emissions from industrial waste-to-energy conversion are reported in the "energy" source category of national inventories, while GHG emissions from primary waste disposal (landfilling, incineration) are reported in the "waste management" category.

- **CO₂ from mixed fuels with biomass and fossil fractions:** In the case that biofuels are combusted jointly with fossil fuels (e.g. pre-treated industrial and/or domestic wastes), a split between the fossil and non-fossil fraction of the fuel should be established and the emission factors applied. (IPCC 2006, Vol. II, Section 2.3.3.4).

To ensure consistency with the guidelines of IPCC as well as GHG Protocol, there is thus a need for transparent reporting of the direct CO₂ emissions resulting from AF combustion in cement plants. Therefore, this protocol requires reporting as follows:

- Direct CO₂ from combustion of **biomass** (including biomass fuels, biomass wastes and the biomass fraction of mixed fuels) shall be reported as a memo item but excluded from emissions totals. The IPCC default emission factor of 110 kg CO₂/ GJ for solid biomass shall be used, except where other, reliable emission factors are available [12]. This value lies in the range of different values for solid biofuels, which are specified as default emission factors in IPCC 2006 (Vol. II, Section 1.4.2.1).
- Direct CO₂ from combustion of **fossil** AF and the fossil fraction of mixed fuels shall be calculated and included in the direct CO₂ emissions (**gross emissions and gross CO₂ Emissions, including CO₂ from separate on-site power generation, excluding CO₂ stored or used permanently, i.e. total direct CO₂ emissions**). CO₂ emission factors depend on the type of AF or mixed fuel used and, therefore, shall be specified at plant level where practical. In the absence of plant- or company-specific data, companies shall use the default emission factors provided in the spreadsheet, which are based on measurements and estimates suggested and compiled by GCCA CO₂ Protocol Task Group.
- Indirect **GHG savings** achieved through the utilization of AF shall be accounted as net emissions in the Protocol.
- carbon credits (fossil CO₂) sold as well as removal (biogenic CO₂) sold shall be discounted under this Protocol to avoid double counting. Generally, the CO₂ emission factors of all fuels shall represent the complete CO₂ emissions from the use of fuel based on the total carbon content (TC).

Some AF, for example used tires and impregnated saw dust, contain both fossil and biomass carbon. These fuels shall be treated as mixed fuels, and the CO₂ emissions shall be separated into their fossil and biogenic parts. This is done by determining the share of the biogenic carbon in the fuel's overall carbon content, according to international standards (e.g. EN 21644). For some fuel types, this share is difficult and costly to measure, and very variable. Companies are advised to use a conservative approach in determining the biogenic carbon content, meaning that the biogenic carbon content should not be overestimated. A fossil carbon content of 100% shall be assumed for fuel types in case of a lack of reliable information on their biogenic carbon content until more precise data becomes available.

Fuels, which contribute significantly to the mass of the product clinker with their ash content, and which have a significant total inorganic carbon (TIC) content can be reported as fuel with a CO₂ emission factor based on the total organic carbon (TOC) content. In this case and when reporting CO₂ emissions from raw materials based on their input (Section 3.2.2), the CO₂ emissions from the TIC content must be reported additionally [9] this shall be done by using the detailed input method A2 and the option for reporting additional raw materials (ARM) which are not part of the kiln feed. If CO₂ emissions from TOC of the material are already reported as fuel, the CO₂ content specified for the additional raw material shall only reflect the remaining TIC content so that CO₂ emissions from the total carbon content (TC) are reported (compare Section 3.3 (4)).

CO₂ emissions accounting for Hydrogen

The cement industry is increasingly using hydrogen as a key component to reduce CO₂ emissions. Hydrogen is being used either as an alternative fuel consumption enhancer (in combination with other fuels to optimize combustion efficiency) or as a fuel for clinker manufacturing and other processes inside the cement plant. Therefore, Version 4.2 incorporates the inclusion of Hydrogen as a distinct fuel category, separate from traditional fossil fuels, alternative, mixed fuels, and biomass fuels categories. This differentiation acknowledges the unique properties and benefits of hydrogen, particularly its potential to significantly lower greenhouse gas emissions. By categorizing hydrogen separately, this Protocol aims to provide clearer guidelines for its use and reporting, thereby encouraging its adoption within the industry.

Regardless of the production method of hydrogen, its consumption as fuel generates zero CO₂ emissions, as hydrogen combustion results in water vapor as the primary byproduct. Therefore, its direct CO₂ Emission Factor is set as 0 in the corresponding part of the Excel Spreadsheet. This characteristic simplifies the reporting process and eliminates the need to categorize hydrogen into different colour categories.

The LHV of the hydrogen used shall be reported in the corresponding cell, with corresponding units.

The production of hydrogen is not included in this version of the CO₂ Protocol as it involves processes and emissions that are outside the scope of cement manufacturing, requiring its own set of guidelines and protocols. However, the energy consumption of the on-site hydrogen production equipment is considered in the Power Balance section of the Protocol, accounting for the on-site power generation and the external power delivered to the on-site hydrogen production unit.

3.4.2. CO₂ from Fuels for Clinker Manufacturing

Fuels for clinker manufacturing in this protocol are all fuels fed to the kiln system plus fuels that are used for drying and processing raw materials and other fuels used for clinker production. This is covered under "Kiln_Fuel_in" under the plant sheet for V4.2

Included in this definition are fuels inserted through a main firing system of the kiln as well as fuels added to a calciner or directly to the kiln inlet. In this Protocol, such fuels are regarded as fuels for clinker manufacturing, irrespective of the potential use of waste heat for the production of electrical power. Also, fuels used for fuel heating (e.g. for heavy fuel oil used for clinker production) shall be reported under this category. Fuels used for the drying of MICs used in cement grinding and fuels used for electricity production in an installation that is separate from the kiln system shall be reported as fuels for other processes.

The specific CO₂ emissions and the specific fuel energy consumption of clinker production are determined by the use of fuels consumed in the kiln, including fuels consumed for the raw material and fuel preparation.

3.4.3. CO₂ from Fuels for other processes

Fuels for other processes include all fuels which are not included in the definition of Fuels for clinker manufacturing (Section 3.4.2). For instance, fuels used

- for plant and quarry vehicles,
- for room heating,
- for thermal process equipment (e.g. dryers), which could be used in the preparation of cement constituents for cement grinding or for Supplementary Cementitious Materials (SCM) preparation to sell externally,
- for calcined clays production (see Section 3.3)
- for power and steam generation for CCUS (see Section 3.5)
- in a separate installation for on-site production of electrical power.

Cement companies shall ensure the complete reporting of CO₂ emissions from fuels from other processes combusted on site. These emissions are accounted for in the spreadsheet as follows:

- CO₂ from fuels for other processes is reported separately, by application type, to provide flexibility in the aggregation of emissions. The spreadsheet distinguishes the following applications:
 - equipment and on-site vehicles
 - room heating/cooling
 - drying of MIC such as slag or pozzolana
 - on-site power generation in separately fired boilers
 - SCMs preparation
 - Clay calcination (see Section 3.3)
 - Power and steam generation for CCUS (see Section 3.5)

Note that fuels consumed for drying of raw materials for the production of clinker and kiln fuels are included in the Fuels for clinker manufacturing section.

CO₂ from off-site transport by company-owned fleets is currently excluded from the boundary (see section 3.4.4).

Carbon in fuels from other processes is assumed to be fully oxidized as described in Section 3.4.1.1, i.e. carbon storage in soot or ash is not accounted for. The resulting overestimation of emissions will usually be small (approximately 1%) [11]. Companies wishing to account for incomplete oxidation of carbon in fuels from other processes shall do so in accordance with GHG Protocol for stationary fuel combustion [1]

See also Table 8 in A13 Recommendation for Reporting regarding the process steps which need to be covered to ensure complete reporting according to this protocol.

Note 1: In Version 4.2, the Alternative Fossil and Mixed Fuels sections of the Kiln_Fuels_in and Other_Kiln_Fuels_in sheets do not include a separate row for gases used as fuels. Where a cement plant procures waste gases that are classified as alternative fuels under national regulations, companies should report them under "Other fossil-based wastes and mixed fuels". Before reporting, the gas volume should be converted from Nm³ to tonnes in a separate worksheet using an appropriate standard conversion method. GCCA does not provide a default conversion factor, as the conversion depends on the density of the specific gas.

As a reference companies can refer this standard approach

The conversion depends on the gas density:

$$\text{Nm}^3 = \frac{\text{Mass (kg)}}{\text{Density at normal conditions (273K, 1atm) (kg/Nm}^3\text{)}}$$

or

$$1000 \text{ Nm}^3 = \text{Density (kg/Nm}^3) \times 1000/1000$$

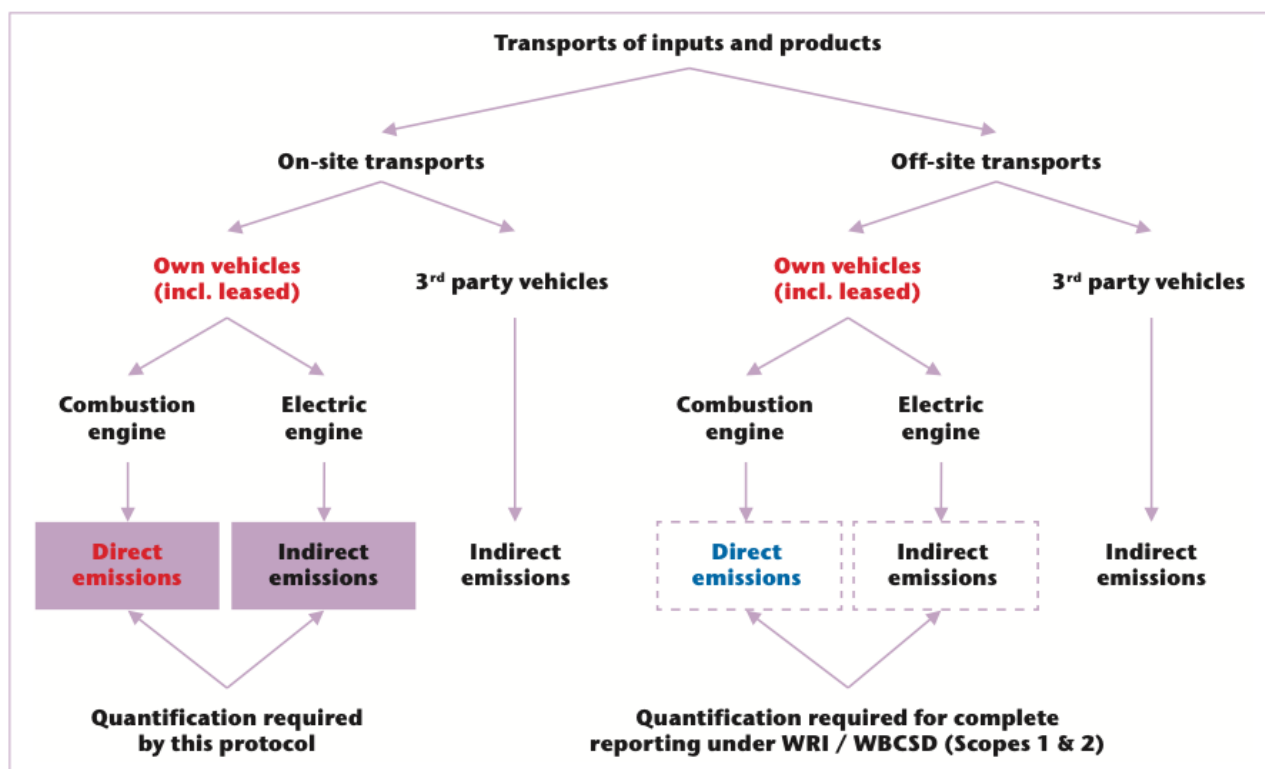
Note 2: GCCA has provided default emission factors for the fuels. Companies can either use the default emission factors, or they can choose their own plant specific emission factors. In case companies need to update the emission factors, they can do so in the plant sheet. For ash content in kiln fuels [mass %], Ash CaO content of kiln fuels [ash mass %] and Ash MgO content of kiln fuels [ash mass %] companies should use their own plant specific factors. Default values for the ash content(s) cannot be determined / generalised.

3.4.4. CO₂ from Transport

Like any other manufacturing process, cement production requires transports for the provision of raw materials and fuels as well as for the distribution of products (clinker, cement, concrete). In some cases, clinker is transferred to another site for grinding. Transport modes include conveyer belts, rail, water, and road. If transports are carried out by independent third parties, the associated emissions qualify as indirect. See Chapter 4 for details on indirect emissions.

Figure 2 provides a breakdown of transport types related to cement production. This protocol requires that companies account for energy consumption and associated emissions of on-site transport carried out with own vehicles (including leased vehicles). Examples include the fuel consumption of quarry vehicles and the electricity consumption of conveyor belts. Note that emissions related to consumed electricity qualify as indirect, except if the electricity is produced by the company itself (on-site power production).

Figure 5 Breakdown of transports by type, and coverage of this protocol



In contrast, this protocol does not quantify emissions related to the following types of transport:

- On-site transports carried out by third parties (i.e. vehicles not owned or controlled by the reporting entity); this should be reported as scope 3
- All off-site transport, (e.g. of fuels, intermediates and finished products), irrespective of whether the transport is carried out by third parties or by company-owned fleets.

Please note, however, that the complete exclusion of off-site transport can represent a deviation from the requirement of GHG protocol to report the emissions from all owned and controlled sources. Companies aiming to comply with this GHG Protocol requirement have to report the emissions of their owned and controlled fleets, both for on- and off-site transport.

3.5. CO₂ from Carbon Capture, Utilisation and Storage unit

3.5.1. Overview

Carbon Capture Utilization and Storage (CCUS) is the only lever for the cement industry to achieve carbon neutrality. As the technology is evolving with several

projects on the pipeline to be finalized by 2030, GCCA aims to include all necessary elements to account for the CO₂ reductions, removals, as well as the additional CO₂ required for the operations of CCUS installations (i.e. for power and steam needs).

Carbon Capture and Storage (CCS) means the separation of carbon dioxide from the flue gas stream of an installation, the purification and liquefaction of the CO₂, transport to a sequestration site and finally underground long- term storage. Carbon Capture and Utilization refers to technologies that aim at the transformation of the captured CO₂ into a useful product.

Different types of technologies will be used for CO₂ capture, like so-called pre-combustion (e.g. gasification and carbon separation from fossil fuels), post-combustion (absorption or adsorption techniques) or oxyfuel technologies. All these technologies require large amounts of energy (e.g. for desorption of absorbents or oxygen generation by air separation), leading to a significant energy penalty. For the clinker burning process, current research results show e.g. a doubling of the power consumption for oxyfuel technology and a doubling of both power and fuel energy consumption for the amine scrubbing (ECRA Technology Papers 2022).

Operations of CCUS will require additional energy needs (power and steam). Depending on the power and steam ownership, these emissions could be reported as direct or indirect emissions. Direct emissions are dealt with in this section, whilst indirect emissions are dealt with under Section 4 – Indirect emissions.

3.5.2. CO₂ generated due to CCUS operations

Direct CO₂ emissions from CCUS

A company must report as direct emissions, the CO₂ resulting from the generation of electricity and steam of the installations that it owns. All fuels that are required for the generation of power and steam, volumes, emission factors and total CO₂ footprint will be reported as part of the category Fuels for other processes in the calculation sheet.

CO₂ captured, storage and/or utilization

The development of CCUS offers 2 potential solutions after carbon capture:

- a) either the CO₂ is stored/ sequestered [this includes both geological storage and mineralization]
- b) or the CO₂ is processed for further use as feedstock.

Both actions are helping to mitigate climate impact, on one hand to reduce CO₂ from entering the atmosphere and on another supporting circularity. Both cases will have the impact of reducing CO₂ emissions from Scope 1.

CO₂ Storage

The sequestered CO₂ will be classified according to the process from which it has been captured (CO₂ from the kiln installation and the CO₂ from the CCUS processes (i.e. power)) as well as the corresponding share of fossil, alternative, and biogenic CO₂. The fuels distinction allows companies to account for the CO₂ removals due to the combustion and storage of biogenic fuels.

Stored/ sequestered CO₂ will be counted by companies as a Scope 1 emissions reduction, including biogenic CO₂ captured and stored, as it is a carbon removal, meaning negative emissions.

The CO₂ captured from the operation of the energy needs for CCUS facilities (i.e. power and steam) as well as the corresponding biogenic emissions for these processes will be accounted in the KPI (new KPI incl. CCUS)

CO₂ Utilization

To contribute to the circular economy, the cement industry acknowledges the importance of CO₂ utilization cases. This will contribute to reducing CO₂ emissions and creating value across the supply chain.

As the CO₂ Protocol aims for rigorous CO₂ accounting and not a commercial instrument, in the case of partial utilization, companies must report the type of CO₂ that has been sent to use (fossil – primary and alternative-or biogenic), and this will become part of their Scope 3.

Captured and utilized CO₂ will be counted by companies as a Scope 1 emissions reduction, excluding biogenic CO₂ captured and utilized, as it is already carbon neutral in the protocol. The CO₂ sent for utilization will be reported in Scope 3 and will be accounted in the KPI (new KPI incl. CCUS).

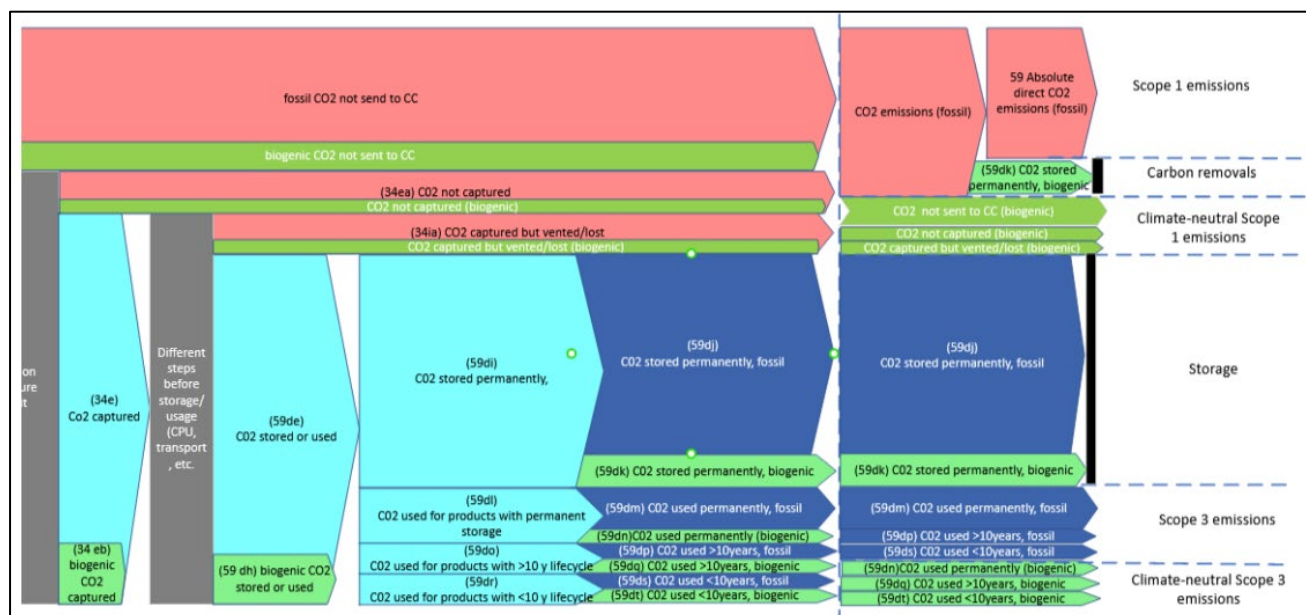
Ensuring CO₂ balance

With transparent CO₂ accounting on the storage and usage of CO₂, GCCA aims to provide assurance on CO₂ company balance. By clearly following the CO₂ across the supply value chain, a company will be able to identify if the CO₂ has been reduced or if it has become part of Scope 3.

The Protocol will allow companies to account for different CCUS sets, either full storage, full utilization cases, or partially stored and partially used CO₂.

Although several combinations will be possible, Figure 3 shows CO₂ streams and CO₂ allocations across Scope 1 and 3, ensuring a transparent CO₂ accounting. Additional CO₂ generated due to the own operations of power and steam installations will be shown in KPIs "100d and e"

Figure 6t: CCUS combinations illustrating Carbon Balance across Scope 1 and 3- source ECRA



*Company sent to use alternative and biogenic CO₂

3.6. CO₂ from Wastewater

Some cement plants inject wastewater into their kilns, for example as a flame coolant for control of nitrogen oxides (NO_x). The carbon contained in the wastewater is emitted as CO₂. This protocol does not require cement companies to quantify their CO₂ emissions related to wastewater consumption, because these emissions are usually small and, in addition, difficult to quantify:

- Most cement plants do not consume wastewater.
- Where wastewater is consumed, its carbon content will usually contribute less than 1% of the plant's overall CO₂ emissions[13]. In addition, the carbon contained in the wastewater can be of biomass origin (e.g., sewage), in which case it would have to be counted as a memo item only.

However, companies should be prepared to show that their consumption of wastewater has no material impact on their overall CO₂ emissions.

3.7. CO₂ from use of explosives in quarry activities

CO₂ emissions from the use of explosives in quarry activities are non-material and therefore neglected. For details see A7 CO₂ from use of explosives in quarry activities.

3.8. CO₂ from use of urea for NO_x reduction

CO₂ emissions from the use of urea for NO_x reduction are non-material and therefore neglected. For details see A8 CO₂ from use of urea for NO_x reduction.

3.9. Non-CO₂ Greenhouse Gases

Emissions of methane (CH₄) from cement kilns are very small due to the high combustion temperatures in the kilns. CH₄ emissions are typically about 0.04% of kiln CO₂ emissions on a CO₂-equivalent basis.[14] Likewise, data compiled by the Former WBCSD CSI Task Force and current GCCA CO₂ protocol Task force indicate that emissions of nitrous oxide (N₂O) from cement kilns are typically small, but these data are currently too limited in scope to allow for generalized conclusions[15]. The ISO/DIS 196964-3:2021 (*Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries, Cement Industry section A.5 Relevance of non-CO₂ GHG*), concludes that non-CO₂ GHG emissions should be assumed to make rather insignificant contribution to total GHG emissions from Cement plants.

The other GHG covered by the Kyoto Protocol (PFC, HFC, SF₆) are found not to be relevant in the cement context. Therefore, this protocol does not require cement companies to quantify their non-CO₂ GHG emissions from kilns as the impact of these gases is non-material in the context of cement production.

Relevant emissions of CH₄ and N₂O may, however, result from the stationary combustion of non-kiln fuels (e.g., dryers, on-site power generation). If required, these emissions should be reported using the GHG Protocol [1] calculation tool for stationary fuel combustion (see www.ghgprotocol.org).

We understand that in some of our member companies' plants small quantities of SF₆ gas are released when circuit breakers are used in Transformers as a safety measure. The GCCA CO₂ protocol task force conducted a detailed literature review and found that this is non-material to cement companies as the emissions are non-significant. More detailed explanation is provided in the A9 SF₆ Emissions – Non-Materiality in Cement Plant , dedicated to the assessment of non-CO₂ GHG.

Also, further information for non-CO₂ GHG gases is provided in A 10 Relevance of non-CO₂ GHG.

4. Indirect Greenhouse Gas Emissions

Indirect GHG emissions are emissions that are a consequence of the operations of the reporting entity but occur at sources owned or controlled by another entity. Cement production is associated with indirect greenhouse gas emissions from various sources. The GHG Scope 03 Protocol lists 15 categories related to indirect emissions. GCCA CO₂ Scope 3 Protocol Guidance for the cement industry defines the methodology to follow for each of those categories.

The key examples linked directly to the production of clinker and cement are:

- External production of electricity consumed by cement producers: this is included as part of this protocol and calculated as a part of the Scope 2 emissions
- Production of clinker and other raw materials bought from other producers and interground with own production: the emissions released from the production of clinker and other raw materials purchased from other producers shall be accounted as part of Scope 3 Category 1: "Purchased Goods and Services". and the emissions released from material extraction, production and transportation (Tier 2) of clinker and cement purchased from third parties are also included in Scope 3. [A more in-depth analysis can be found in ISO 19694-3 clause 6.2 and in the GCCA scope 3 guidance]
- Production and processing of primary and alternative fuels by third parties: this is part of Scope 3 accounting and is accounted with Scope 3 Category 3: "Fuel- and Energy-Related Activities" (Not Included in Scope 1 or Scope 2)
- Indirect emissions related to CCUS unit: A company must report as indirect CO₂ emissions from CCUS, the CO₂ resulting from the purchase of electricity and steam. Externally purchased power will be reported into the power part of the CO₂ Protocol in the calculation sheet. Externally purchased steam will be reported into the CCUS part of the CO₂ Protocol in the calculation sheet.
- Transport of inputs (raw materials, fuels) and outputs (cement, clinker) by third parties.: Both of these emissions are covered under Scope 03 in category 4 and 9 respectively. GHG Protocol Scope 03 Technical Guidance states that if transportation and distribution services are purchased by the reporting company in the reporting year (either directly or intermediary), including inbound logistics, outbound logistics (e.g.: of sold products) and transportation and distribution between a company's own facilities (in vehicles and facilities not owned or controlled by the reporting company) should be part of Scope 03 category 4 (upstream transportation and distribution) whereas transportation and distribution of products sold by the reporting company between reporting company's operations and the end consumer (if not paid for by the reporting company but paid by the consumer), including retail and storage (in vehicles and facilities not owned or controlled by reporting company) should be reported under Scope 3 of category 9 (Downstream transportation and distribution)

Cement companies shall calculate and report under this Protocol, 2 of the 5 above categories and further details is provided below.

4.1. CO₂ from external electricity production

CO₂ from external electricity production shall be calculated, where data are available, using both the market-based and location-based methods, based on measured electricity consumption.

- **Market based method:** A method to quantify the Scope 2 GHG emissions based on GHG emissions emitted by the generators from which the reporting company contractually purchases electricity bundled with contractual instruments, or contractual instruments on their own.
- **Location based method:** A method to quantify Scope 2 GHG emissions based on average energy generation emission factors for defined geographic locations, including local, subnational, or national boundaries. Such factors can be based on IEA data which are updated annually, (see <https://ghgprotocol.org/calculation-tools-and-guidance> for the latest update).

In accordance with requirements of the revised GHG Protocol Scope 2 guidance (Chapter 4 and Appendix A), emissions associated with the consumption of electricity during transport and distribution (T&D losses) shall not be included in this calculation, as this will be part of Scope 3 Category 3 – Fuel and Energy Related activities not included in Scope 1 and 2. Version 4 offers much more detailed possibilities to report emissions and credits from power use, on-site power production both by waste heat recovery (WHR) and separate on-site power generation (OPG), power purchase and sales as well as percentage of renewable mix in the electrical power mix.

The section called "power balance" has been expanded from V3.0 to differentiates between the different power sources (purchase, production on-site) and paths of power usage: use for cement production, consumption of power generation auxiliaries (difference between gross and net power production of the power plant) and power sold externally. Power given to other non-cement installations within the same plant shall be treated as power sold externally.

In Version 4 we have taken a further step providing clear guidance for the changes made in the protocol where we have included carbon emission accounting for among others Calcined Clay units, CCUS units.

Updates are as follows:

- Total power production from separate on-site power production:
 - a. Power delivered to Calcined Clay Production Unit
 - b. Power delivered to CCUS unit
 - c. Power delivered to Hydrogen production unit
 - d. Total renewable power generated
- Total power from waste heat recovery:
 - a. Power delivered to Calcined Clay Production Unit
 - b. Power delivered to CCUS unit
- For the external power purchased, the following lines have been added:
 - a. % renewables in grid mix (Market based)
 - b. % renewables in grid mix (location based)
- For the external power delivery:
 - a. External power delivery - Calcined clay unit
 - b. External power delivery - CCUS unit
 - c. External power delivery - For indirect CO₂ emission for the biomass used as a fuel in the production of power (self-generation)

4.2. CO₂ from production of bought clinker

CO₂ from production of bought clinker shall be calculated based on the net clinker transfer (bought clinker minus sold clinker plus internal clinker transfer) of the reporting entity, and the emission factor of the clinker. With respect to clinker transfers within the company, the real emission factor of the sending plant should be used. If clinker is bought externally, the specific supplier direct emissions are the preferred option, but if this value is not available, the most updated value from the GNR website shall be used (see www.wbcscement.org, look for Getting the Numbers Right, GNR). These values should be updated annually with the latest GNR available data. As a priority, national or regional values shall be applied, if available. As a second priority, the global average value can be used.

Double counting of clinker transfers (as well as cement and MIC transfers) is avoided automatically (see Section 7.4 for more detailed information on company internal transfers). Please note that the GNR emission factor should only be used for calculating the indirect emissions impact associated with net clinker purchases. This value shall be updated as per the latest data available in GNR. For a net clinker seller, the clinker purchase balance and hence the resulting emissions will be negative, indicating that the company's clinker sales have indirectly helped to avoid emissions at another cement plant. The same GNR emission factor should not be used for calculating the gross and net direct emissions of the reporting company.

The approaches for calculating these two types of indirect emissions are summarized in

Table 2. Quantification of other indirect emissions is not required by this protocol. This applies, in particular, for indirect emissions related to transport (see Section 3.9 – CO₂ from transports paragraph for details).

Table 2: Parameters and data sources for calculation of indirect CO₂ emissions as required by this protocol

Emission	Parameters	Units	Source of parameters
CO ₂ from external power prod. – Market Based (indirect emission)	Power bought from external grid	GWh	Measured at plant level
	Emission factor excluding T&D losses	t CO ₂ /GWh	Supplier-specific value grid factor
CO ₂ from external power prod. – Location Based (indirect emission)	Power bought from external grid	GWh	Measured at plant level
	Emission factor excluding T&D losses	t CO ₂ /GWh	Country grid factor
CO ₂ from clinker bought (indirect emission)	Net clinker purchases	t cli	Measured at plant level (Bought minus sold clinker + internal clinker transfer)
	Emission factor	t CO ₂ /t cli	Supplier specific or GNR latest available factor

5. Gross and Net CO₂ Emissions

5.1. Overview

Waste can substitute primary fossil fuels in cement production. The recovered wastes become alternative fuels (AF). As a result, direct CO₂ emissions from primary fuels are reduced, but direct CO₂ emissions from wastes ("waste-to-energy conversion") occur. The direct CO₂ emissions from waste combustion can be higher or lower than the displaced emission, depending on the emission factors of the fuels involved. Moreover, wastes can be of fossil or biomass origin. In addition to those direct effects, utilization of AFR results in indirect GHG savings for the treatment of waste. (see Figure 4).

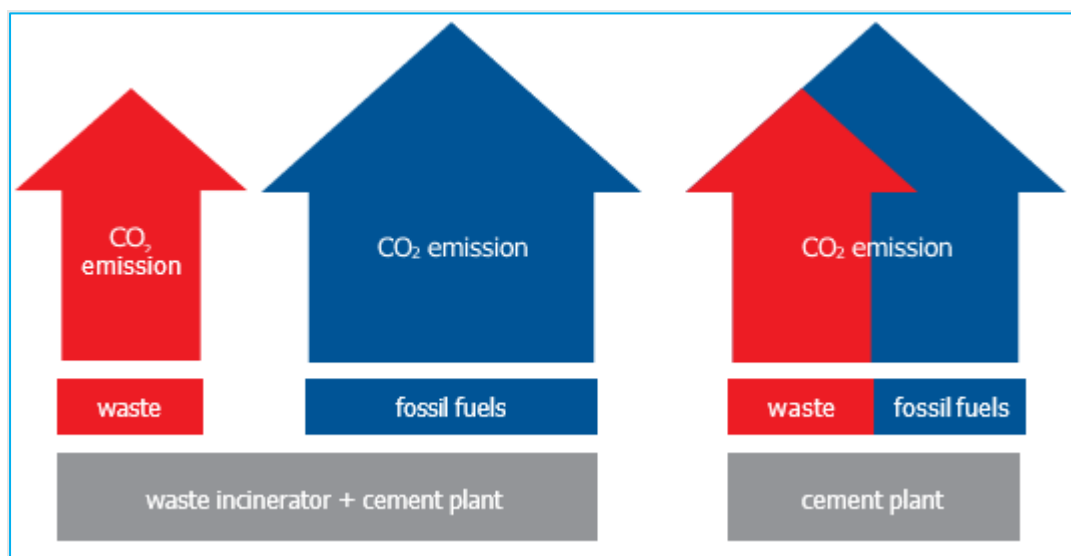
Therefore, the protocol defines the following indicators:

Gross Emissions are the total direct CO₂ emissions from a cement plant or company, including CO₂ from fossil wastes (but excluding CO₂ from biomass wastes, which is treated as a memo item).

Net Emissions are the gross emissions minus the benefits from indirect GHG savings. As far as practicable, reported AFR credits should take into account local circumstances (e.g., national agreements, life cycle analyses of local AFR use, etc.). When reporting to third parties, supporting evidence for the indirect GHG savings achieved with AFR should be provided and verified as appropriate. As a default, the protocol assumes credits for indirect savings to be equal to the direct CO₂ emission from fossil AFR use.

The protocol recognizes that this approach is a simplification of the AFR issue. It is, however, in the medium-term, the least onerous and most practicable approach, where transparency is achieved through disclosure of gross and net emissions. An international convention on the treatment of AFR has yet to be reached.

Figure 7 Indirect saving of CO₂ emissions by the use of waste as alternative fuel in a cement plant

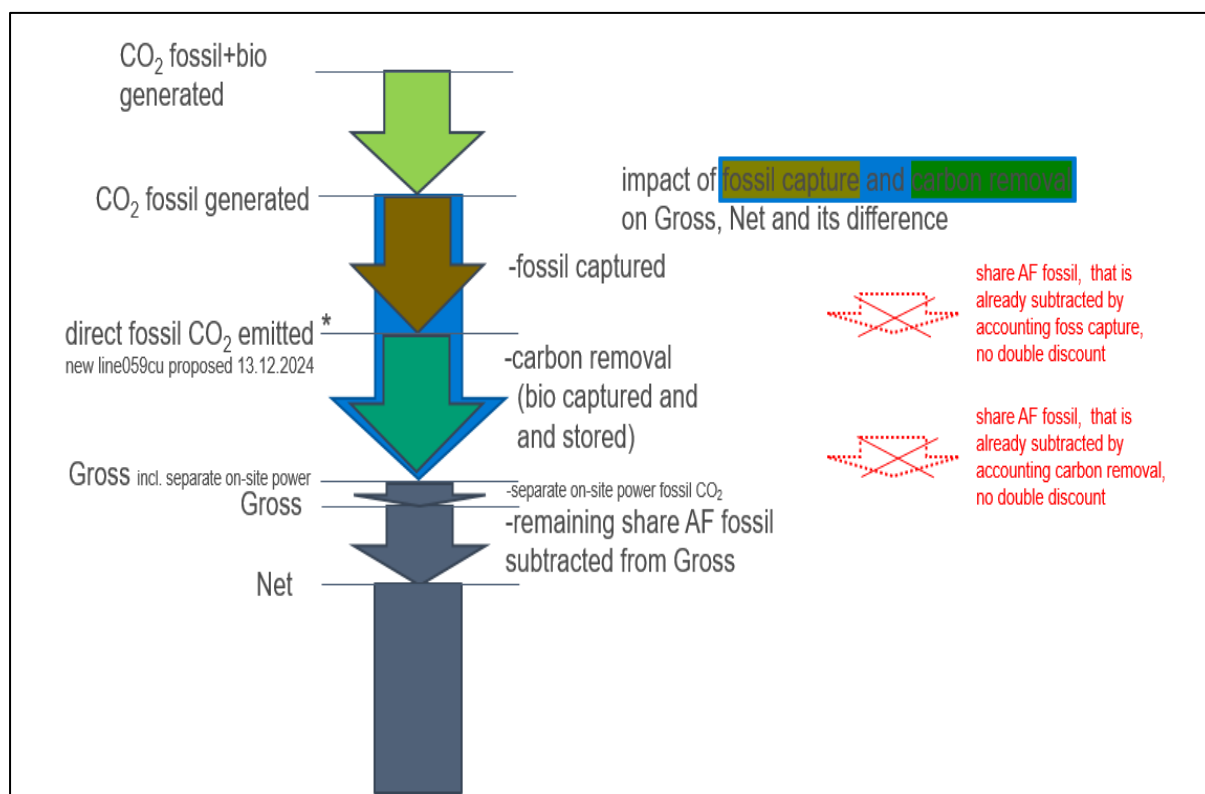


A key objective of this protocol is to ensure that cement companies can report the complete direct and fossil CO₂ emission from activities within the organizational boundaries of the company. As an increasing number of cement plants worldwide (especially in Asia) produce electric power on-site, the definition of gross and net emissions shall also reflect this fact. On the one hand, and as a basic principle, absolute emissions have to be reported including all sources, i.e. including emissions from power generation.

On the other hand, a fair comparison of cement plants with and without on-site power generation is only possible if emissions from (separate) power generation are excluded. Hence, as principal parameter direct emissions are determined as 'Absolute gross CO₂ emissions including CO₂ from on-site power generation'. Additionally, the definition of 'Absolute Gross CO₂' as parameter for the derivation of the specific performance indicators was adjusted to exclude CO₂ emissions from on-site power generation. Consequently, contrary to the exclusion of CO₂ emissions from on-site power generation, the protocol stipulates that CCUS emissions from separate power, steam, and heat generation must be fully accounted for.

The figure below summarizes CO₂ accounting from a fossil capture and carbon removal perspective

Figure 8: CO₂ accounting in Protocol Version 4.0 from a fossil capture and carbon removal perspective it is Fuel to Fossil



*Impact of proportional vs custom share of capture of fossil and bio-CO₂

The following sections describe the framework of the definition of absolute gross and net CO₂ emission values.

5.2. Gross CO₂ Emissions

Absolute gross CO₂ emissions including CO₂ from on-site power generation are the

sum of fossil and direct CO₂ emissions from a cement plant or company in a given period. Gross emissions include CO₂ from alternative fossil fuels but exclude CO₂ from biomass fuels and the biomass content of mixed fuels, since these emissions are regarded as climate neutral. CO₂ emissions from biomass and indirect CO₂ emissions are normally treated as a memo item in emission reports.

Table 3 Emission sources to be reported within "Absolute gross emissions including CO₂ from on-site power generation"

Emissions
CO ₂ from raw materials (clinker and calcined clays) + CO ₂ from primary fossil fuels + CO ₂ from alternative fossil fuels (fossil wastes) + CO ₂ from fossil carbon of mixed (alternative) fuels covering CO ₂ from all Fuels for clinker manufacturing and all fuels for other processes including CO ₂ from on-site power generation + direct emissions CO ₂ from CCUS unit
= Total direct emissions
Memo items
CO ₂ from biomass fuels
CO ₂ from biogenic carbon of mixed (alternative) fuels
Indirect CO ₂ (bought electricity & clinker)

Absolute gross CO₂ emissions are the fossil and direct CO₂ emissions (excluding on-site electrical power production) from a cement plant or company in a given period. Gross emissions include CO₂ from alternative fossil fuels, excluding CO₂ from biomass fuels and the biomass content of mixed fuels, since these emissions are regarded as climate neutral. Gross emissions further exclude CO₂ emissions from on-site power generation, in installations which are separate from the kiln system and use fuel energy other than waste heat from the kiln system, since the electrical power in many cement plants is imported from the grid and related to indirect emission. CO₂ emissions from biomass and indirect CO₂ emissions are normally treated as a memo item in emission reports.

Table 4 Emission sources to be reported within "Absolute gross emissions"

Emissions
CO ₂ from raw materials (clinker and calcined clays) + CO ₂ from primary fossil Fuels for clinker manufacturing + CO ₂ from alternative fossil Fuels for clinker manufacturing (fossil wastes) + CO ₂ from fossil carbon of mixed (alternative) Fuels for clinker manufacturing and -fuels for other processes (excluding on-site power generation) + CO ₂ from -fuels for other processes excluding CO ₂ from on-site power generation + direct CO ₂ from CCUS unit
= Gross CO ₂ Emissions
= Direct emissions (excluding CO ₂ form on-site power generation)

Memo items
CO ₂ from biomass fuels
CO ₂ from biogenic carbon of mixed (alternative) fuels
Indirect CO ₂ (bought electricity & clinker)

Note that the direct CO₂ emissions from on-site power generation are not included in the indirect CO₂ emissions reported as memo item according to Protocol Version 4.

Accounting of CO₂ emissions from the biomass content of fuels

Biomass content of mixed fuels is reported. Biomass CO₂ from these fuels is added up with the CO₂ from pure biomass fuels to total biomass CO₂ and reported as a memo item. It is subtracted when calculating gross CO₂ emissions. A default value for biomass content of such fuels has only been included for waste tires (27%). The evaluation of other waste fuels by the CSI Task Force "Climate Protection" has shown that the variation of their biogenic carbon content was so big that no representative default values could be assumed.

5.3. Net CO₂ Emissions and Indirect Emission Reductions related to Utilization of Wastes as Alternative Fuels

The cement industry recovers large quantities of waste materials for use as fuel and/or raw materials. These recovered wastes are also referred to as alternative fuels (AF) in this protocol. By utilizing AF, cement companies reduce their consumption of primary fossil fuels while at the same time helping to avoid conventional disposal of the waste materials by landfilling or incineration.

Increased utilization of AF can have an influence on the direct CO₂ emissions of a cement company because the emission factors of the AF can differ from those of the displaced fuels. Moreover, the carbon contained in the AF can be of fossil and/or biomass origin. As mentioned above, utilization of AF by the cement industry typically results in indirect GHG emission reductions for waste treatment. The combination of direct emissions impacts, indirect emission reductions, and resource efficiency makes the substitution of AF for conventional fossil fuels an effective way to reduce global GHG emissions (see e.g. IEA1998, CSI/ECRA 2022 and WBCSD/IEA 2009).

The requirements regarding the reporting of CO₂ emissions from fossil fuel-based AF (also called "fossil AF" or "alternative fossil fuels") vary widely between different schemes. The balance sheet approach described in Section 5.1 ensures completeness, rigor, and transparency of reporting under different schemes.

- Direct CO₂ emissions resulting from the combustion of fossil AF must always be included in the company's gross emissions, in accordance with Section 3.6.

With the following concept this Protocol provides a framework for reporting also indirect emission reductions achieved by using alternative fuels:

- > Indirect GHG emission reductions are accounted for by subtracting the fossil CO₂ emissions from alternative fuels.
- > The resulting net emissions, being the gross emissions minus the emission from alternative fossil fuels, reflect the emissions according to the rules of the reporting scheme under consideration.

The Protocol defines an indicator for a company's net CO₂ emissions, as follows: Net emissions are the gross emissions minus the CO₂ emissions related to the fossil part of alternative fuels.

$$\text{Net CO}_2 \text{ Emissions} = \text{Gross CO}_2 \text{ Emissions} - \text{fossil CO}_2 \text{ emissions from AF}$$

Net emissions as defined here are an indicator of a company's net carbon footprint, reflecting a company's direct emissions as well as emission reductions. As mentioned in Section 5.1, in this method, the discount for CO₂ from fossil alternative fuels are a proxy as the actual (but unknown) overall balance can result

in a higher or lower reduction. See A13 Recommendation for Reporting Table 8 for more details.

5.4. Other Indirect Emission Reductions

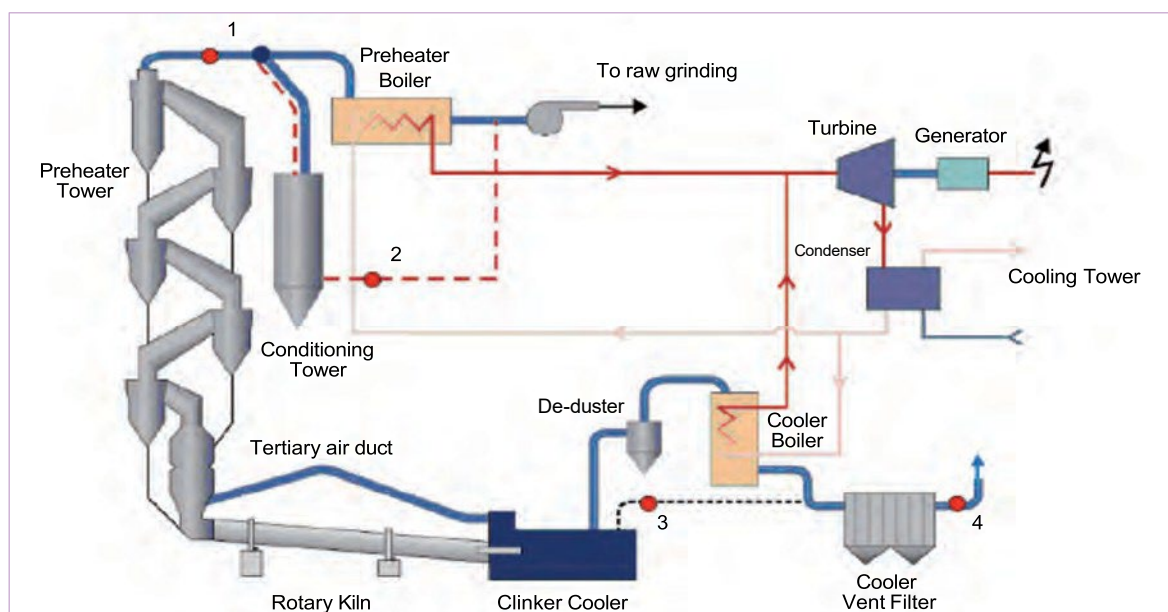
Utilization of Waste Energy

Some cement plants export waste heat to external consumers as a substitute for primary energy sources. In analogy to the indirect effects related to the use of alternative fuels, a cement company may account for the indirect GHG emission reductions resulting from such waste heat exports by separate determination and accounting outside the protocol, provided that the rules of the relevant reporting schemes allow such crediting. The credit for waste heat export shall neither influence the company's net CO₂ emissions, nor its gross CO₂ emissions which according to the definition in this protocol reflect the direct CO₂ emissions (including and excluding on-site power generation) which are associated with the production of the heat.

Similar credits may be applied for other forms of waste energy utilization. So, Version 4 (as did Version 3) offers the possibility of reporting voluntarily waste heat utilization within the plant (e.g. for raw material or slag drying) in order to allow a fair comparison between plants exporting heat and plants using the heat internally. The calculation has to be done separately from the protocol spreadsheet and the total energy flow in GJ/a can be inserted. The reporting is voluntary.

However, in the case of electrical power generation from waste heat originating from the kiln system (Figure 5) any additional fuel used in the kiln system is accounted as kiln fuel and consequently emissions are accounted as direct CO₂ emissions of the kiln system. To provide more detailed information, Version 4 distinguishes between waste heat recovery and separate on-site power generation. In any case, when applying such credits in their voluntary reporting, companies should consider whether their actions indeed contribute to a global reduction in GHG emissions, or merely to a shift of emissions between different entities. For example, if a cement company produces power on-site based on fossil fuels (as opposed to waste heat), global emissions will essentially be the same as in the case where the same amount of power is supplied by an external generator, unless there is a significant difference in generation technology; hence the appropriateness of a credit for the power generation by the cement company may be considered questionable in this case.

Figure 9 Schematic of application of Waste Heat Recovery (WHR) and electrical power generation in cement manufacture. 1 gas from preheater, 2 bypass of preheater boiler, 3 bypass of cooler boiler, 4 cooler air



Recarbonation of Cement - CO₂ Sink

Cement recarbonation or concrete carbonation refers to the process where CO₂ is absorbed by concrete during its use and end-of-life phase. The amount absorbed is significant but less than the total amount emitted in cement production. Carbonation is a process that occurs in concrete where lime in the cement reacts with CO₂ from the air. It is faster in non-reinforced products like concrete masonry. Designers ensure it is slow in reinforced concrete as prior to carbonation, the concrete protects the reinforcement from corroding.

At the end of their life, when reinforced concrete structures are demolished, the increased surface area and the exposure to air accelerate concrete carbonation. The amount of carbonation is even greater if stockpiles of crushed concrete are left exposed to the air prior to reuse.

"This is a natural process, concrete effectively becoming real stone."

The quantification of the CO₂ uptake is subject to the diversity of concrete applications and to parameters affecting the chemical reaction of carbonation. A significant amount of research is available regarding carbonation. Some CO₂ uptake models have been developed in different countries, and a European standard [EN16757] is available, with an annex on calculation of CO₂ uptake in concrete products. In 2018, IVL (IVL Swedish Environmental Research Institute is an independent research institute specialising in the environment and sustainability) published a report providing background and calculations models for IPCC implementation

In this updated protocol, the calculation method is based on IPCC compliant IVL Tier 1 methodology.

The formula to be used is:

Recarbonation (kgCO₂/tonne clinker): $\text{Clinker produced} \times 20\% \times 525 / 1000$

Some special notes to consider:

- It is the default process emission factor (525 kCO₂/tonne clinker) for "traditional" clinker that has to be used as the use of already decarbonated raw materials in the production of clinker does not influence the recarbonation potential.
- Additional recarbonation through recycling and so-called enhanced recarbonation shall not be accounted for within the boundaries of this Protocol.
- For other clinkers an additional calculation sheet based on the Steinour's formula will be provided to replace the default emission factor (525 kCO₂/tonne clinker).

6. Organizational Boundaries

6.1. Which Installations Should Be Covered?

CO₂ emissions result not only from kiln operations, but also from upstream and downstream processes, particularly from quarry operations and (indirectly) cement grinding. These facilities may be located a considerable distance from each other. In addition, quarries, kilns, and grinding stations are sometimes operated by separate legal entities. How should this be accounted for in a legal entity's inventory?

When reporting under externally imposed schemes such as the EU ETS, the boundaries with respect to installations will be guided by the rules of the respective scheme. In contrast, voluntary reporting under this protocol, shall cover the main direct and indirect CO₂ emissions associated with cement production as required in Chapters 3, and 4 of this document, and as foreseen in the protocol spreadsheet.

These emissions include also those related to consumption of fuel and electricity in upstream and downstream operations. In particular, cement companies shall include the following types of activities in their voluntary reporting under this Protocol, to the extent that they control or own the respective installations in accordance with Section 7.2 below:

- Clinker production, including raw material quarrying and preparation;
- Grinding of clinker, additives and MICs such as slag, both in integrated cement plants and stand-alone grinding stations;
- Cement blending performed in own concrete/precast businesses in vertically integrated companies;
- Additional fuel use for own power generation;
- Preparation or processing of fuels or fly ash in own installations;
- Emissions from CCUS operations, power and steam

Separate inventories may be established for individual facilities as appropriate, for instance if they are geographically separated or run by distinct operators. The impacts of such a division will cancel out when emissions are consolidated at company or group level (see also Section 7.4 regarding company-internal clinker transfers). Section 9.2 provides more guidance on voluntary environmental reporting.

There are some geographies, like United Kingdom, United States, Australia, etc. where the use of MICs to produce blended cements is traditionally performed in the concrete/precast/blocks/mortars sites instead of in the cement sites.

In this new Version 4.2 of the protocol, the MICs blended in vertically integrated businesses, including concrete/ready-mix, precast, blocks and mortars

businesses are also reported, as they are part of the company efforts to further blend its cements within its company boundaries, always to the extent that the company controls or owns these businesses. These MICs consumed are reported separately at country/company level, and they are consolidated for different KPIs in a new reporting organizational layer including these integrated businesses (indicators with "including Integrated Ready-Mix /Precast Businesses" in their names).

6.2. Operational Control and Ownership Criteria

The GHG Protocol distinguishes two basic approaches according to which companies can consolidate the emissions of their operations: the equity share approach and the control approach. The latter is again divided based on whether financial control or operational control is used as a criterion.

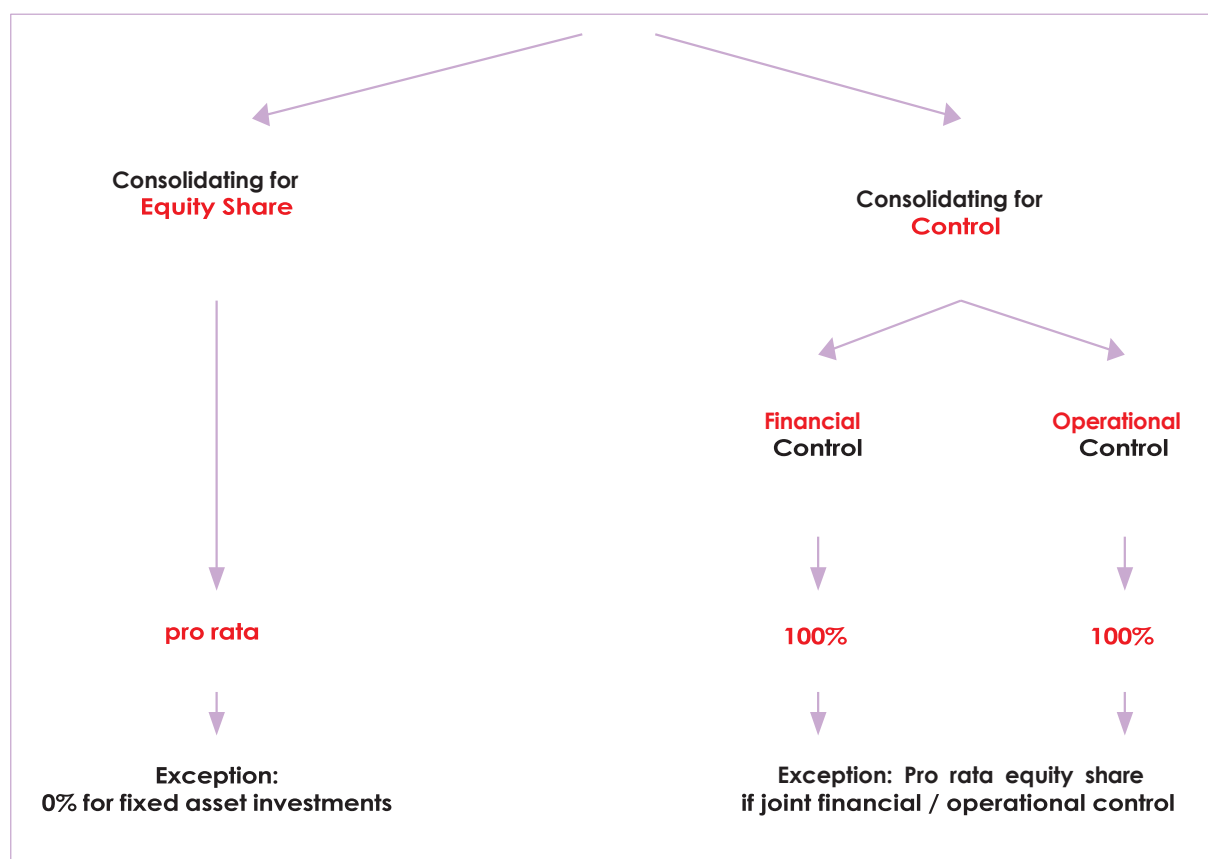
These three approaches are briefly summarized below and illustrated in Figure 9. Text in *italics* denotes quotations from the revised GHG Protocol. For details on each approach as well as illustrative examples, please refer to Chapter 3 of the GHG protocol document [1].

- Equity share: Under this approach, a company consolidates its GHG emissions according to the (pro rata) equity share it holds in each operation, i.e. according to ownership. As an exception, no emissions are consolidated for so-called fixed asset investments where a company owns only a small part of the total shares of an operation and exerts neither significant influence nor financial control. Other possible exceptions relate to the economic substance of a relationship (see GHG Protocol for details).
- Financial control is defined as the ability of a company to direct the financial and operating policies of an operation with a view to gaining economic benefits from its activities. For example, the financial control usually exists if the company has the right to the majority benefits of the operation (...), or if it retains the majority risks and rewards of ownership of the operation's assets. Under this approach, companies consolidate 100% of the emissions of those operations over which they have financial control. As an exception, consolidation according to equity share is required for joint ventures where partners have joint financial control.
- Operational control is defined as a company's full authority to introduce and implement its operating policies at an operation. This criterion is usually fulfilled if a company is the operator of a facility, i.e. if it holds the operating license. Under this approach, companies consolidate 100% of the emissions of those operations over which they have operational control. As an exception, consolidation according to equity share is required for joint ventures where partners have joint operational control.²⁰

In defining control for GHG accounting purposes, companies are advised to follow their existing rules and practices for financial reporting. Companies should explicitly state which methodology they apply. Likewise, the GHG Protocol recommends to account for any special contracts in joint operations that specify how the ownership of emissions, or the responsibility for managing emissions and associated risk, is distributed between the parties.

The GHG protocol makes no recommendation as to whether voluntary public GHG emissions reporting should be based on the equity share or any of the two control approaches. Instead, it encourages companies to apply the equity share and a control approach separately, and states that companies need to decide on the approaches best suited to their business activities and GHG accounting and reporting requirements.

Figure 10 Options for consolidating emissions as recommended by GHG Protocol



With a view to the characteristics of the cement industry, the GHG protocol – A corporate accounting and reporting standard, decided that cement companies shall consolidate primarily according to the operational control criterion, and secondly according to the ownership criterion in case operational control is not clearly assigned to a single legal entity. Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard. Revised Edition.

<http://www.ghgprotocol.org> for more detailed guidance and illustrative examples for these consolidation rules

Table 5 Key for consolidating corporate GHG emissions of cement companies, as adopted by the GHG Protocol

Criterion for Consolidation	% GHG to consolidate by reporting entity
First criterion: Operational control	
The reporting entity has operational control	100%
Another legal entity has operational control	0 %
Operational control is not clearly assigned to a single shareholder ("Joint operational control")	Relative to share ownership (see below)
Second criterion: Equity share ownership	
0% – 100% ownership	pro rata ownership

Companies are expected to follow this guidance where appropriate and should clearly state in their reporting that this is the case, i.e. 'data is reported in accordance with GCCA guidelines'. Where company consolidation practice differs from GCCA guidelines, companies are expected to clearly state the procedure used so that any differences are clear to interested stakeholders.

6.3. Clinker, Cement and MICs Transfers and Purchases

Many cement companies transfer large volumes of clinker, cement and mineral components (MICs) / Mineral Inorganic Cement Substitutes (MICs) like slag or fly ash internally, between different plants, grinding stations and to their own vertically integrated businesses. These transferred materials are processed further to other products, like lower clinker cements and thus have an impact on the clinker/cement factor of the receiving plant. Additionally, there are some cases where cement plants purchase clinker, cement constituents/MICs or cements from external suppliers, for further blending in their facilities. In all these cases, the risk of double counting occurs at different levels.

At plant level, **internal clinker transfers** (within the same company) shall be reported as "internal clinker transfer", differentiating from clinker transferred between plants in the same country and cross-border transfers (indicators 10b and 10x in V4.2 of the CO₂ Protocol Plant sheet; plus(+) for received and minus(-) for sent clinker).

At plant level, **internal transfer of MICs** (within the same company) shall be reported as "Processed MIC internal transfer with company's own cement plants" (indicator 19c; with minus (-) sign for received and plus (+) for sent MICs) or "processed MICs transferred to company's own Ready-Mix / Precast businesses" (indicators 19e and 19f in V4.2 of the CO₂ Protocol Plant sheet).

In the case of processed MIC internal transfer with company's own cement plants, when a plant is processing MICs to transfer to another plant of the same company, it is using electricity and/or fuels in the preparation (processing) of these materials. Therefore, it is fair that the plant accounts these materials as part of their cements + substitutes and cementitious products. In the receiving plant, these materials are accounted as part of its cement production (indicator 20), as they are consumed for blending. However, if they were to be accounted also as part of their cements + substitutes (indicator 21) and cementitious products (indicator 21a), this would result in a double counting at company level, as these materials have already been considered in the indicators 21 and 21a of the processing plant. The receiving plant will therefore not account for the received MICs as part of their indicators 21 and 21a. If a plant that receives this type of transfers, would like to account for these materials in indicators 21 and 21a for an internal exercise of comparison between plants, a calculation including them could be performed aside of this Protocol.

At vertically integrated company level (including integrated Ready-Mix / Precast Businesses), transferred MICs to own vertically integrated businesses are accounted at plant level, but are deducted at company level when including all SCMs consumed in Ready-Mix / Precast Businesses to avoid double counting (new in Version 4).

At plant level, the **clinker portion of a cement transferred internally** (within the same company) shall be reported only if the received cement is further blended to produce another cement type. The clinker portion shall be reported as "Clinker portion from internal transfer of processed cement within country" (indicator 10c) if the transfer occurs between plants in the same country, and as "Clinker portion in processed cement exchanged with other companies or countries" (indicator 10d) if the transfer occurs between plants located in different countries (cross-border transfer). The clinker portion should be calculated based on the clinker/cement factor or cement composition of the transferred cement and is reported with positive sign if the cement is received and with negative sign if it is sent.

At plant level, the **cement constituents from internal transfers of cement sent/received for further processing** (within the same company) shall be reported as a summarized value in a separate line: "Cement constituents from internal transfer of processed cement within country" (indicator 17a) if the transfer occurs between plants in the same country and "Cement constituents in processed cement exchanged with other companies or countries" (indicator 17b)

if it is a cross-border transfer. The amount shall be entered as a plus for received and a minus for sent.

The clinker portion and cement constituents of the transferred cement are not accounted as part of the clinker consumed and cement constituents consumed in the receiving plant for cement production (the transferred cement is not part of the cement production of the receiving plant). The reason behind is that this clinker and cement constituents conforming the transferred cement for further blending have already been accounted in the producing (sending) plant as part of its cement production. Accounting them also in the receiving plant would be double counting. The receiving plant can account for all the cement constituents that are consumed for further blending this transferred cement. As the received cement is not being accounted as cement production in the receiving plant, the total cement production of the plant as registered in its internal systems may not be exactly reflected in the production totals (20, 21, 21a) of this Protocol. Therefore, a new indicator has been created to consider it and consolidate the total cement production of the plant, including transferred cements for further blending (indicator 21c; 21ca including blending of cements in integrated Ready-mix / Precast businesses). In the same way, in order to get the clinker factor including transferred cements, a new clinker factor KPI has been also included (92b). The sending plant does not have deducted the transferred cement from their total cement production nor from its clinker factor, as negative values are not accounted for this new indicator.

At company level, internal clinker transfers, processed MICs internal transfers between cement plants, clinker portion and cement constituents from internal cement transfers are added separately for checking purposes. All these are consolidated automatically as a sum of all plants, and it should be zero at company level.

Purchased cements should also be reported only if they are purchased for further blending at the cement plant. On plant level, the clinkers portion of cement bought from other companies (external clinker) used for further blending shall be reported in a new line in Version 4.2, "Clinker portion in processed cement exchanged with other companies or countries (indicator 10d).

At plant level, the cement constituents from purchased cement sold/bought for further blending shall be reported as a summarized value in a separate line, "Cement constituents in processed cement exchanged with other companies or countries" (indicator 17b). The amount should be entered as a positive value if received and a negative value if sent.

In the same way that happens with cement internal transfers for further blending, the received cement is not being accounted as part of the cements of the plant that buys the cement, as it has already been accounted in the producing (selling)

plant. The receiving plant can account for the cement constituents used to blend this cement. The explanation related to the new indicators 21c and 92b described above is also applicable in this case.

In Version 4.2 of this Protocol, total clinker consumed results as:

Total clinker consumed = clinker production + clinker bought – clinker sold – change in clinker stock + internal clinker transfer (within country and cross-border).

In conclusion, Version 4.2 accounts for internal clinker and MIC transfers and provides additional lines to report internal cement transfers and cement purchases/sales for further blending.

6.4. Baselines, Acquisitions and Divestitures

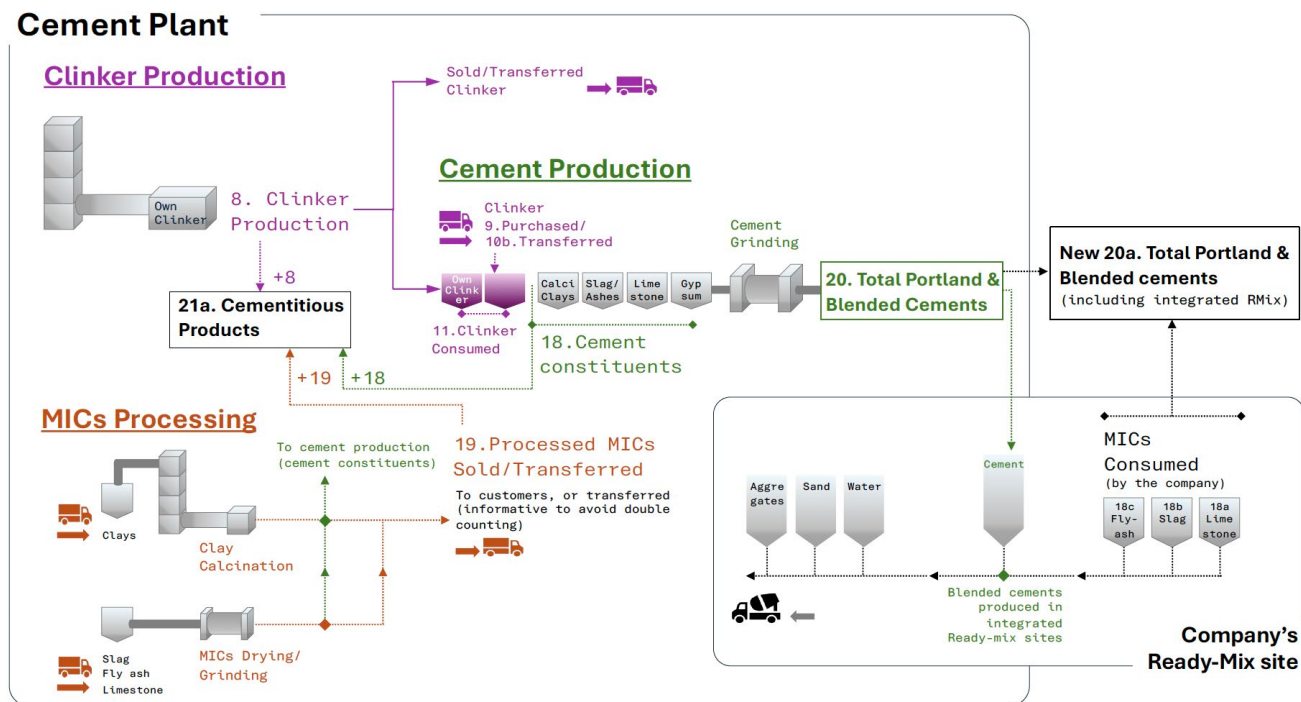
CO₂ emissions performance is often measured relative to a past reference year (the "base year"). As default, the "Kyoto base year" 1990 can be used as a reference. In many cases, however, the lack of reliable and accurate historical data justifies the use of a more recent base year, especially when compliance or emissions trading is concerned. The choice of base year will also depend on individual country regulations.

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

- **Adjust the baseline for change by acquisition and divestiture:** Consolidated emissions reported for past years shall always reflect the current amount of shares held in a company. If a company is acquired, its past emissions shall be included in the consolidated emissions of the reporting company. This shall be done either back to the base year, or back to the year the acquired company came into existence, whichever is later. If a company is divested, past emissions shall be removed from the consolidated emissions. These adjustments shall be made in accordance with the consolidation rules (see Section 7.2).
- **No baseline adjustment for "organic" change:** In case of organic growth of production due to investment in new installations, capacity expansions or improved capacity utilization, the baseline shall not be adjusted. In the same sense the baseline shall not be adjusted for organic negative growth: Closure of kilns or decrease of production shall not result in a change of the baseline.

For illustrative examples regarding choice of base year and baseline adjustment, see the GHG protocol [1]

Figure: 11 Organizational Boundary Graph



7. Performance Indicators

7.1. Introduction

The CO₂ and Energy Protocol aims to provide a flexible basis for CO₂ emissions monitoring and reporting. The calculation of individual emission components as described above is quite straightforward. The definition of emission totals and ratio indicators, in contrast, is highly dependent on the reporting context and purpose, such as input to national inventories, CO₂ compliance regimes and emissions trading, industry benchmarking, etc. System boundaries for such reporting depend largely on conventions and practical requirements, rather than on scientific arguments.

With this background, a section on performance indicators has been added to the protocol spreadsheet. It contains a number of indicators which are deemed most useful in the light of the current business and policy environment, and associated reporting requirements. Generally, the section on performance indicators is conceived as a flexible vessel where companies can introduce additional parameters according to their needs, for instance different emission (sub-) totals. A number of KPIs have been added in Version 4 compared to Version 3. A summary of the definitions of the performance indicators (KPIs) in Version 4 is presented in Appendix 7 together with a comparison to Protocol Version 3.

7.2. Denominator for Specific, Unit- Based Emissions

From a sustainable development and business point of view, the reporting of CO₂ efficiency – the specific or unit-based emission – is at least as important as the reporting of absolute emissions. This raises the question of how the denominator of the specific emissions should be defined.

Five denominators are appropriate in the cement and concrete industry:

- Clinker
- Cement equivalent (at cement plants level)
- Cementitious products (at cement plants level)
- Cement equivalent including vertically integrated businesses (at vertically integrated company level, including blending of cements in integrated Ready-Mix / Precast Businesses) – new in Version 4.2
- Cementitious products including vertically integrated businesses (at vertically integrated company level, including blending of cements in integrated Ready-Mix / Precast Businesses) – new in Version 4.2

Each of these five denominators give a different weighting to the CO₂ performance involved in different stages of cement manufacturing.

- **Clinker:**

In the context of this protocol, clinker refers to grey and white clinker used for the production of grey and white cement. The production of clinker is the main source of CO₂ in cement production.

- **Cement equivalent (at cement plants level):**

Cement equivalent (at cement plants level) is a cement production value, which is determined from clinker produced on-site applying the plant specific clinker/cement-factor. Hence, it is a virtual cement production under the assumption that all clinker produced in a plant is consumed for cement production in the same plant and applying the real plant specific clinker/cement factor.

- **Cementitious products (at cement plants level):**

Cementitious products (at cement plants level) consist of all clinker produced by the reporting company for cement making or direct clinker sale, plus all cement constituents other than clinker consumed for cement production, plus all MICs processed in a cement site or a stand-alone MIC grinding installation sold externally for the construction industry. For this denominator, the terms "cementitious products" or "binders" are used, as it is a sum of clinker and mineral components. The denominator excludes clinker bought from third parties to produce cement, since this clinker is already included in the inventory of the third party [18]. Note that the denominator excludes the following:

- Bought clinker, used for cement production;
- Granulated slag, fly ash and other pozzolans that are stored or traded/sold without any processing for changing their properties;
- Limestone and other MICs which are stored or traded/sold without any processing to change their properties;
- Limestone and other MICs which are processed, but to be sold outside the construction industry. That means that they are used for purposes other than being a cement constituent, that is, different purposes than replacing clinker for cement production (e.g. production of aggregates, backfilling, landfilling stabilization, agricultural uses, asphalts production...);
- Clinker and cement volumes bought which are traded without any further processing/blending;

There are some geographies where the use of MICs to produce blended cements is traditionally performed in the concrete/precast/blocks/mortars sites, like United Kingdom, United States, Australia... instead of in the cement sites.

There are some companies operating in these geographies performing clinker/cement production and concrete/precast/blocks/mortars production (vertically integrated companies). To correctly tackle all the cement production of these vertically integrated companies, the MICs consumed in the concrete/precast/blocks/mortars sites should be accounted for in the total company cement and cementitious production.

When calculating vertically integrated companies KPIs, double counting of the processed MICs in cement - MICs consumed in those businesses shall be avoided, by providing information of the origin of the MICs in the concrete/precast/blocks/mortar owned businesses when these MICs are internally transferred from own operations.

Note: If companies are going through assurance or audit of any kind for indicator 19bb it is important that necessary proof for validation is checked to ensure that the MICs are processed before selling externally. For rest of the indicators such as 19 a – 19b, 19 and 19y a simple validation is enough as the processed slag , fly ash are typically used in Construction Industry.

There are two different denominators applicable to those vertically integrated companies, defined as follows, and consolidated at country/company level:

- **Cement equivalent (at vertically integrated company level):**
This denominator only applies if a company has vertically integrated businesses together with its clinker/cement production sites, which includes concrete/ready-mix, precast, blocks, and mortars businesses. Cement equivalent (at vertically integrated company level) is a cement production value, which is determined from clinker produced on a company and applying the specific clinker/cement-factor at vertically integrated company level. Hence, it is a virtual cement production under the assumption that all clinker produced in a country/company is consumed for cement production in the same company and applying the real specific clinker/cement factor including MICs consumed in the company's vertically integrated businesses. MICs consumed in the cement company's vertically integrated businesses are reported in the spreadsheet at the country/company level (ReadyMixPlants.xlsx excel file).
- **Cementitious products (at vertically integrated company level):**

This denominator only applies if a company has vertically integrated businesses together with its clinker/cement production sites, which includes concrete/ready-mix, precast, blocks, and mortars businesses. Cementitious products (at vertically integrated company level) consist of all clinker produced by the reporting company for cement making or direct clinker sale, plus all cement constituents other than clinker consumed for cement production in any of the vertically integrated businesses, plus all MICs processed at cement plants that are sold externally for the construction industry. MICs consumed in the cement company's vertically integrated businesses are reported in the spreadsheet at the country/company level (ReadyMixPlants.xlsx excel file). Double counting of the MICs that are processed and transferred internally to own vertically integrated businesses is avoided at company level by reporting in line 19c of the "ReadyMixPlants" excel file the total amount of MICs received from own operations (with negative sign). For this denominator, the terms "cementitious products" or "binders" are used, as it is a sum of clinker and mineral components. The denominator excludes clinker bought from third parties to produce cement, since this clinker is already included in the inventory of the third party.

Note that the denominator excludes the following:

- Bought clinker, used for cement production.
- Granulated slag, fly ash and other pozzolans that are stored or traded/sold without any processing for changing their properties.
- Limestone and other MICs which are stored or traded/sold without any processing to change their properties.
- Limestone and other MICs which are processed but are produced/processed to be sold outside the construction industry, that means that are used for purposes other than being a cement constituent, so different purposes than replacing clinker for cement production (e.g. production of aggregates, backfilling, landfilling stabilization, agricultural uses, asphalts production...).
- Clinker and cement volumes bought which are traded without any further processing/blending.

The GCCA decided that companies shall calculate their specific (= unit-based) CO₂ emissions as follows (see also Figure 6 and 7):

Equation 8: Per ton of cement equivalent (at cement plants level). The denominator is based on clinker production, assuming that all clinker produced in a plant is consumed for cement production on site. 7.2 Denominator for Specific, Unit- Based Emissions

$$\begin{array}{c}
 \text{Specific CO}_2 \text{ emission per ton of} \\
 \text{Cement (eq.)} \quad \equiv \quad \frac{\text{Direct CO}_2 \text{ emissions from Cement} \\
 \text{Manufacturing}}{\underbrace{\text{Own clinker consumed} + \text{Own clinker sold directly}}_{\text{Own clinker production}}} \times \text{Clinker to} \\
 \text{cement} \\
 \text{(eq.)} \\
 \text{factor}
 \end{array}$$

Equation 9: Per ton of cementitious (at cement plants level). The denominator is based on clinker production, hence sold clinker is included and bought clinker is excluded and cementitious products are included. Denominator for Specific, Unit-Based Emissions

$$\begin{array}{c}
 \text{Specific CO}_2 \text{ per} \\
 \text{ton of} \\
 \text{cementitious} \\
 \text{product} \quad \equiv \quad \frac{\text{Direct CO}_2 \text{ emission from Cement Manufacturing}}{\underbrace{\text{Own clinker consumed} + \text{Own clinker sold directly}}_{\text{Own clinker production}} + \text{Gypsum, limestone, CKD \& Clinker substitutes consumed for blending} + \text{Cement substitutes produced} + \text{Clinker brought and consumed}}
 \end{array}$$

When consolidating at GCCA level, to avoid double counting of the MICs processed by one company and sold to another cement company consuming them to produce cement, the company processing the MICs shall provide details of the volumes of processed MICs sold to another cement player reporting to GNR (line 19y).

Equation 10: Per ton of cement equivalent (at vertically integrated company level). The denominator is based on clinker production, assuming that all clinker produced in a company is consumed for cement production in any of its integrated businesses.

$$\begin{array}{c}
 \text{Specific CO}_2 \text{ per} \\
 \text{ton of cement} \\
 \text{equivalent} \\
 \text{(at vertically} \\
 \text{integrated} \\
 \text{company level)} \quad \equiv \quad \frac{\text{Direct CO}_2 \text{ emission from Cement Manufacturing}}{\underbrace{\text{Own clinker consumed} + \text{Own clinker sold directly}}_{\text{Own clinker production}}} \times \text{Clinker to} \\
 \text{cement (eq.)} \\
 \text{factor (at} \\
 \text{vertically} \\
 \text{integrated} \\
 \text{company level)}
 \end{array}$$

Equation 11: Per ton of cementitious (at vertically integrated company level). The denominator is based on clinker production, hence sold clinker is included and bought clinker is excluded and cementitious products are included.

$$\begin{array}{c}
 \text{Specific CO}_2 \text{ per} \\
 \text{ton of} \\
 \text{cementitious} \\
 \text{product (at} \\
 \text{vertically} \\
 \text{integrated} \\
 \text{company level)} \\
 \hline
 \text{Direct CO}_2 \text{ emission from Cement Manufacturing} \\
 \begin{array}{l}
 \text{Own clinker consumed} + \text{Own clinker sold directly} + \text{Cement constituent consumed for blending in cement plants} + \text{Cement substitutes processed and sold at cement plant} + \text{Clinker brought and consumed} \\
 \text{Own clinker production} \quad \text{plus consumed for blending in vertically integrated business}
 \end{array}
 \end{array}$$

When consolidating at GCCA level, to avoid double counting of the MICs processed by one company and sold to another cement/concrete company consuming them to produce cement in their cement or vertically integrated businesses, the company processing and selling MICs shall provide details of the volumes of processed MICs sold to another cement or vertically integrated player reporting to GNR (line 19y).

7.3. Denominator for Other Ratio Indicators

For selected ratio indicators which do not use CO₂ in the numerator, it is appropriate to include bought clinker, and exclude sold clinker, from the denominator. This applies for:

- Specific power consumption per tonne of cementitious product, which should take into account grinding of bought clinker;
- The clinker/cement factor, which should describe the ratio between total clinker consumption and total production of cement or cementitious product. These apply to clinker/cement equivalent factor at cement plants level and at vertically integrated company level.

Clinker/cement (eq.) factor (at cement plants level)

As described in section Denominator for Specific, Unit- Based Emissions (equivalent) can be calculated from produced clinker divided by the clinker/cement (eq.) factor, which is defined as: Total clinker consumed / (own

clinker consumed plus gypsum, limestone, FD, plus MICs consumed for blending, plus clinker bought and consumed). The proposed clinker/cement (eq.) factor is shown in Figure 8.

The factor is based on Clinker Consumption. Hence, in the denominator sold clinker is excluded and bought clinker is included. MICs processed and sold are excluded. Check section, Dealing with Stock Changes and Sold and Purchased Clinker

Definition of clinker/cement (eq.) factor

$$\text{Clinker/Cement (eq.)} = \frac{\text{Clinker Consumed}}{\text{Own clinker consumed} + \cancel{\text{Own clinker sold directly}} + \text{Cement constituent consumed for blending} + \cancel{\text{Cement substitutes processed and sold at cement plant}} + \text{Clinker brought and consumed}}$$



Own clinker production

The clinker/cement (eq.) factor (at vertically integrated company level) definition is identical to the clinker/cement (eq.) factor but adding to the denominator all MICs consumed in the company's vertically integrated businesses (concrete/ready-mix, precast, blocks and mortar sites).

Clinker/cementitious factor (at cement plants level)

The proposed clinker/cementitious factor is shown below.

The factor is based on clinker consumption. Hence, in the denominator sold clinker is excluded and bought clinker is included. Furthermore, MICs are included. See section on Dealing with Stock Changes and Sold and Purchased Clinker

Definition of clinker/cementitious factor.

$$\begin{array}{c}
 \text{Clinker/Cementitious} \\
 \text{factor}
 \end{array}
 \equiv
 \frac{\text{Clinker Consumed}}{\text{Own clinker consumed} + \cancel{\text{Own clinker sold directly}} + \text{Cement constituent consumed for blending} + \text{Cement substitutes processed and sold at cement plant} + \text{Clinker brought and consumed for blending}}$$



 Own clinker production

The clinker/cementitious factor (at vertically integrated company level) is identical to the clinker/cementitious factor defined above but adding to the denominator all MICs consumed in the company's vertically integrated businesses (concrete/ready-mix, precast, blocks and mortars sites). To avoid double counting of the MICs processed and used in own vertically integrated businesses, the MICs processed and transferred to own vertically integrated businesses shall be reported in the spreadsheet to be automatically discounted.

7.4. Dealing with Stock Changes and Sold and Purchased Clinker

Direct CO₂ resulting from clinker production should be reported for the year in which it is emitted. To avoid distortion, specific emissions per tonne of cementitious product should therefore be based on the full clinker production of the same year, irrespective of whether the produced clinker is consumed, sold, or stored.

Other ratio indicators such as specific electricity consumption and clinker/cement factors, in contrast, should be based on actual amounts of clinker (plus gypsum and MIC) consumed, irrespective of whether the clinker was produced this year, taken from stock or purchased. When calculating clinker production from clinker consumption or vice-versa, changes in clinker stocks as well as sales and purchases of clinker need to be taken into account (for accounting of material transfers see also Clinker, Cement and MIC Transfers and Purchases).

7.5. New General Performance Indicators (KPIs)

A number of new KPIs have been added according to the experiences of the use of Version 3. These are: *(A summary of their definition is presented in Glossary), Acronyms and Abbreviations*

- CO₂ emission factor
- Specific Gross and Net CO₂ Emissions per Cement (equivalent) (at vertically integrated company level)

- Specific Gross and Net CO₂ Emissions per Cementitious Product (at vertically integrated company level)
- Clinker/cement (eq.) (at vertically integrated company level)
- Clinker/cementitious factor (at vertically integrated company level)
- Specific Energy Use of Carbon Capture Unit
- Specific direct CO₂ Generation
- Specific indirect CO₂ Emissions
- Specific CCUS rates

8. Further Information

Appendix 1 describes the protocol spreadsheet. The spreadsheet itself contains

- > a "Comments" sheet which provides a short explanation for every line of the main worksheet.

- > a "Frequently asked questions (FAQ)" section to provide support for questions to the different sections of the spreadsheet.

For further questions, information or comments on this protocol, please refer to the Internet Manual: www.Cement-CO2-Protocol.org or email to info@gccassociation.org

Note: Internet Manual Development work will start in 2026

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10. Glossary, Acronyms and Abbreviations

Quotations from the glossary of the Greenhouse Gas Protocol *. Quotations from the glossary of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories are marked with double asterisk**. See the Greenhouse Gas Protocol and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for an extended glossary.

Absolute (net or gross) emission

Absolute GHG emissions are expressed as a mass stream, for example in tonnes of CO₂ per year (t CO₂/yr).

AF

Alternative fuels

AFR

Alternative fuels and raw materials. This definition includes alternative raw materials, which contain a significant amount of organic matter.

Allowance*

A GHG allowance is a commodity giving its holder the right to emit a certain quantity of GHG. GHG allowances are typically allocated by a regulator to the emitters covered by a cap and trade system.

Alternative fuels

Fuel materials or products used as a source of thermal energy and not classified as traditional fuel. In the cement industry wastes such as plastics, solvents, waste oil, end-of-life tires, etc. and different types of mixed or pure biomass fuels are used.

Annex I

Annex I to the UNFCCC lists the developed country Parties which have special responsibilities in meeting the objective of the Convention. They include the OECD countries (excl. Mexico and Korea), the countries of Eastern Europe, Russia, and the European Union. Under the Kyoto Protocol, Annex I Parties have accepted quantified emissions limitation or reduction commitments for the period 2008–12.

ARM

Additional raw materials, e.g. added directly to the calciner or kiln inlet, that are not part of the kiln feed, which is normally a homogenized mass flow fed to a pre-heater system.

Baseline

Reference emission level. The term is used with different meanings in different contexts. It can denote:

- the historical emission level of an entity in a reference year,

- the projected future emission level of an entity if no extra mitigation measures are taken (business-as-usual scenario),
- the hypothetical emission level against which the climate benefits of GHG reduction projects are calculated.

Biogenic carbon**

Carbon derived from biogenic (plant or animal) sources excluding fossil carbon. Note that peat is treated as a fossil carbon in these guidelines as it takes so long to replace harvested peat.

Biomass**

Organic matter consisting of / recently derived from living organisms (especially regarded as fuel) excluding peat; includes products, by-products and waste derived from such material.

Bypass dust

Discarded dust from the bypass system dedusting unit of suspension preheater, precalciner and grate preheater kilns, normally consisting of kiln feed material which is fully calcined or at least calcined to a high degree.

Cap and trade*

A system that sets an overall emissions limit, allocates emissions allowances to participants, and allows them to trade allowances and emission credits with each other.

Cement

A building material made by grinding clinker together with various mineral components such as gypsum, limestone, blast furnace slag, coal fly ash, calcined clays and natural volcanic material. It acts as the binding agent when mixed with sand, gravel or crushed stone and water to make concrete. While cement qualities are defined by national standards, there is no worldwide, harmonized definition or standard for cement. In the WBCSD – CSI Protocol and the "Getting the Numbers Right" database, "cement" includes all hydraulic binders that are delivered to the final customer, i.e., including all types of Portland cements, composite cements and blended cements, but excluding direct sales of pure clinker". See Section 6.3

Cement constituents (other than clinker)

Main and minor additional materials other than clinker used to produced cements, including gypsum, FD, limestone and other MICs consumed **plus calcium sulphates and additives in cement.**

Cement (eq.)

Cement (equivalent) is a cement production value which is determined from clinker produced on-site applying the plant specific clinker/cement-factor. Hence

it is a virtual cement production under the assumption that all clinker produced in a plant is consumed for cement production in the same plant and applying the real plant specific clinker/ cement factor.

Cementitious products

All clinker produced by the reporting company for cement making or direct clinker sale, plus gypsum, limestone, FD and all MICs consumed for blending, plus all MICs processed in a cement site or a stand-alone MIC grinding station sold externally for the construction industry. For this denominator, the terms "cementitious products" or "binders" are used, as it is a sum of clinker and mineral components. The denominator excludes clinker bought from third parties for the production of cement, since this clinker is already included in the inventory of the third party.

cem eq.

Cement (eq.)

cem prod

Cementitious products

Climate-neutral biomass fuel

Burning of climate-neutral fuels does not increase the GHG stock in the atmosphere over a relevant time span. CO₂ emission from renewable biomass contained in alternative fuels is climate-neutral because they are compensated by an equivalent absorption by plants.

Clinker

Intermediate product in cement manufacturing and the main substance in cement. Clinker is the result of calcination of limestone in the kiln and subsequent reactions caused through burning.

FD

Filter dust, relevant for complete CO₂ reporting is especially the partly calcined FD leaving the kiln system, i.e. discarded dust from long dry and wet kiln system dedusting units, consisting of partly calcined kiln feed material (see also 'dust return'). Extraction and discarding of FD and bypass dust serve to control excessive circulating elements input (alkali, sulphur, chlorine), particularly in cases of low-alkaline clinker production. The term "FD" is sometimes used to denote all dust from cement kilns, i.e. also from bypass systems.

cli

Clinker

Credit*

GHG offsets can be converted into GHG credits when used to meet an externally imposed target. A GHG credit is a convertible and transferable instrument usually bestowed by a GHG program.

CSI

Cement Sustainability Initiative: The CSI was a global effort by 24 major cement producers with operations in more than 100 countries who believe there is a strong business case for the pursuit of sustainable development. The CSI work has been transferred to the GCCA under strategic partnership with the WBCSD.

Direct emissions

Direct GHG emissions are emissions from sources that are owned or controlled by the reporting entity. Examples include the emissions from cement kilns, company-owned vehicles, quarrying equipment, etc.

Dust return

Part of the kiln feed which is not consumed for clinker production or to form bypass dust, but which is returned to a dust cycle. The cycle often involves the raw mill and a dust filter system.

Relatively small amounts of filter dust (FD) leaving the kiln system originate from this dust cycle and dust return.

EF

Emission factor, here normally CO₂ emission factor per mass for materials or per heat for fuels.

EU ETS

The CO₂ emissions trading scheme of the European Union started in 2005. The EU ETS covers CO₂ emissions from most significant industrial sources. From 2013, also other GHG will be included. For further information see http://ec.europa.eu/climate/policies/ets/index_en.htm

Fossil carbon**

Carbon derived from fossil fuel or other fossil source.

GCV

Gross calorific value (see higher heat value, HHV)

GHG

The greenhouse gases listed in Annex A of the Kyoto Protocol include: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulphur hexafluoride (SF₆).

GNR

"Getting the Numbers Right" or "GCCA in Numbers" Project and GCCA's global cement database covering over 800 plants around the world belonging to GCCA member companies as well as GCCA partner associations.

Gross CO₂ emissions

Total direct CO₂ emissions (excluding on-site electricity production) originating from fossil carbon, i.e. excluding CO₂ emissions from biomass, which are considered climate-neutral. As of Protocol Version 3, the CO₂ emissions originating from the biogenic carbon content of mixed fuels are not accounted for.

GWP**

Global Warming Potentials are calculated as the ratio of the radiative forcing of one kilogramme greenhouse gas emitted to the atmosphere to that from one kilogramme CO₂ over a period of time (e.g., 100 years).

HHV

Higher heat value (see gross calorific value, GCV), often in GJ per ton of fuel. The higher heat value includes the latent heat contained in water vapor, which is released when condensing water vapor so that all water is in liquid state. Compare 2006 IPCC Guideline⁴, Vol. II, Section 1.4.1.2.

Indirect emissions

Indirect GHG emissions are emissions that are a consequence of the operations of the reporting company but occurs at sources owned or controlled by another company. Examples include emissions related to purchased electricity, employee travel and product transport in vehicles not owned or controlled by the reporting company, and emissions occurring during the use of products produced by the reporting company.

Inventory

A quantified list of an organization's GHG emissions and sources.

IPCC

The Intergovernmental Panel on Climate Change is an international body of scientists. Its role is to assess the scientific, technical and socio-economic information relevant to the understanding of the risk of human-induced climate change (www.ipcc.ch).

KF

Kiln feed

Kiln ()**

A tubular heating apparatus used in the production of clinker (2006 IPCC Guidelines 'manufacture of cement'). The calcination reaction may take place in the kiln itself, or, where so equipped, it may partly or completely take place in a preheater and/or precalciner apparatus ahead of the kiln.

Kiln feed

Raw materials, often processed as raw meal, are fed to a pre-heater or directly into the kiln system. The kiln feed often contains a certain quantity of recycled dust, which was returned from the pre-heater or kiln system (see also 'dust return').

Kiln fuel

Fuels fed to the kiln system plus fuels that are used for drying or processing of raw materials for the production of clinker and the preparation of Fuels for clinker manufacturing (See Section 3.7).

KPI

Key Performance Indicator is an industry term used for a type of Measure of Performance. KPIs are commonly used by organizations to evaluate its success or the success of a particular activity in which it is engaged.

LHV

Lower heat value (see net calorific value, NCV), often in GJ per ton of fuel. The lower heat value excludes the latent heat contained in water vapor. Compare 2006 IPCC Guideline⁴, Vol. II, Section 1.4.1.2.

Limestone Filler

Limestone Filler means a very fine grinding and means to have a blender in your concrete facility because limestone filler acts as a BINDER. This is used for applications, like self-compacting concrete and HPC (High Performance Concrete) and others.

LOI

Loss on Ignition is a test used in inorganic analytical chemistry, particularly in the analysis of minerals. It consists of strongly heating ("igniting") a sample of the material at a specified temperature, allowing volatile substances to escape, until its mass ceases to change.

MICs

Mineral components are natural or artificial mineral materials with hydraulic properties, used as a **clinker or cement substitute** in the case of concrete (e.g. blast furnace slag, fly ash, pozzolana, calcined clays, limestone, limestone filler, burnt shale).

Mixed fuels

Term used in this Guidance Document refers to fuels that are a mix of biomass and fossil fuel, i.e. fuel with a certain biogenic carbon content.

Net CO₂ emissions

Gross CO₂ emissions minus CO₂ emissions from alternative fossil fuels. This definition corresponds to the original Protocol Version 1.

Fuels for other processes

Fuels used by the company are not included in the definition of Fuels for clinker manufacturing. For instance, fuels used for plant and quarry vehicles, room heating, thermal process equipment (e.g. dryers) for the preparation of mineral components for cement grinding or in an installation separate from the kiln for on-site production of electrical power (See Section 3.8).

Nm³

Normal cubic meters (at 1013 hPa and 0 °C)

NCV

Net calorific value (see lower heat value, LHV), often in GJ per ton of fuel. The net calorific value excludes the latent heat contained in water vapor.

Offset*

GHG offsets are discrete GHG emission reductions used to compensate for (i.e., offset) GHG emissions elsewhere, for example to meet a voluntary or mandatory GHG target or cap. Offsets are calculated relative to a baseline that represents a hypothetical scenario for what emissions would have been in the absence of the mitigation project that generates the offsets. To avoid double-counting, the reduction giving rise to the offset must occur at sources or sinks not included in the target or cap for which it is used.

OPC

Ordinary Portland cement. In the Protocol, OPC refers to a common type of cement with high clinker content, consisting of over 90% ground clinker and about 5% gypsum. Note that differences exist between names and definitions of cement types in national standards. OPC is often referred to as:

'Portland cement' or 'CEM I' according to the European standard EN 197-1:2007, 'Portland cement' or 'P-I' or 'P-II' according to the Chinese standard GB175-2007, 'Portland cement Types I to V' according to the US standard ASTM C 150 and 'Portland' or 'PC' as described in the 2006 IPCC Guideline for National Greenhouse Gas Inventories. Whereas according to the Chinese standard GB175- 2007 the name

'Ordinary Portland cement' with the notation 'P·O ', and the notation

'P·C' for 'Composite Portland cements' can refer to cement types with significantly lower content of clinker.

Petcoke

Petroleum coke, a carbon-based solid derived from oil refineries.

Pozzolana

A material that, when combined with calcium hydroxide, exhibits cementitious properties.

Process emissions** Emissions from industrial processes involving chemical transformations other than combustion.

Processed MICs

Processed refers to dried, finely divided or ground material, activated by mechanical or thermal treatment. This excludes MICs processed for other purposes than replacing clinker (e.g., agricultural use or backfilling).

Protocol

The methodology for calculating, monitoring, and reporting GHG emissions.

Raw material preparation

Processes applied for converting raw materials to raw meal (e.g. grinding, homogenization, drying).

Raw meal

Raw meal consists of the grinded raw materials. The raw material processing can involve drying or the addition of water. Its composition is controlled and normally very stable, because the clinker burning process requires a defined chemical composition of the kiln feed.

Raw material

Materials used for raw meal preparation, e.g. limestone, iron ore, sand etc., before they are treated thermally, e.g. for drying.

Raw meal consumed

The part of the raw meal, which is consumed for clinker production, and the formation of calcined bypass dust. Compared to the kiln feed, the quantity of raw meal consumed excludes the part of recycled dust (see 'dust return').

RM

Raw meal

Specific emissions

Specific emissions are emissions expressed on a per unit output basis, for instance in kg of CO₂ per tonne of cement.

TC

Total carbon, the sum of TOC and TIC

TIC

Total inorganic carbon: carbon, mostly bound in the mineral matter of materials (e.g. carbonates in fuel ashes).

TOC

Total organic carbon

Traditional fuels

Fossil fuels defined by the International Panel on Climate Change (IPCC) guidelines, including mainly: coal, petcoke, lignite, shale, petroleum products and natural gas.

UNFCCC

United Nations Framework Convention on Climate Change; Parties to the UNFCCC are those nations which have signed the Convention.

WBCSD

The WBCSD is a CEO-led, global association of some 200 companies dealing exclusively with business and sustainable development. <http://www.wbcsd.org>.

WRI

The WRI is an environmental think tank founded in 1982 based in Washington, D.C. in the United States.

11. Appendices

11.1. A1 Cement CO₂ and Energy Protocol Spreadsheet

The protocol spreadsheet is a set of multiple Microsoft Excel documents. These documents are to be used in a single pack. The protocol document pack consists of following set of documents:

- a) Company Excel File: This will be used to consolidate your plant inputs
- b) Plant Excel File(s): This will be used to input your plant values. Multiple excel files present. Each plant excel sheet per plant. More plant files can be created, if needed.
- c) Ready Mix Plant Excel file: For your ready-mix/precast business
- d) Plant Monthly file: A template to facilitate monthly input of plant data which can be used for monthly monitoring.

Note: It is important that the names of the plant sheets shouldn't be changed and should be kept as it is mentioned in the zip file.

Details of each excel file present below:

- a) Company Excel File: It contains the following components:

- i. Read me: This sheet explains the meaning of the different colors used in the worksheets and provides additional instructions for the user.
- ii. Plant index: This sheet contains the links to each plant file. Once you update data in the plant file, the data is automatically taken up in the company excel file.
- iii. Company sheet: This sheet presents the consolidated Company values from your plants input files for each year.
- iv. Plant_calc : These sheets calculate the input values from Plant sheets taking into consideration the information reported in each Plant excel file

b) Plant Excel file(s): It contains the following components:

- i. Read me: This sheet explains the meaning of the different colors used in the worksheets and provides additional instructions for the user.
- ii. Plant Input (Plant_in): This sheet should be used to input plant values.
- iii. Calcination Input (Calcination_in): (Unlike V3.1 where the calcination sheets were automatically created, in V4.2 the calcination sheets are given by default)

a. Calcination Method A1 or A1: Simple Input Method (A1) for determining CO₂ emissions from raw material calcination (can be used for plants with kiln operation).

b. Calcination Method A2 or A2: Detailed Input Method (A2) for determining CO₂ emissions from raw material calcination (can be used for plants with kiln operation).

c. Calcination Method B1 or B1: Simple Input Method (B1) for determining the corrected CO₂ emission factor of clinker (can be used for plants with kiln operation).

- d. CalcB2:** Detailed Output Method (B2) for determining the corrected CO₂ emission factor of clinker (can be used for plants with kiln operation).

All the methods mentioned are present in the Calcination_in sheet and can be selected as a drop down based on the method company decide to use

- iv. Kiln Fuels Input (Kiln_fuels_in): Input for fuels used in the clinker manufacturing process (refer kiln_Fuels_in section)
 - v. Other processes Fuels Input (Other_processes_fuels_in): Input for fuels used in other processes different from clinker manufacturing (refer other_processes_fuels_in section)
 - vi. Calcined Clay Calcination Input (Calcined_Clay_Calcination_in): Input values from your Calcined Clay units
 - vii. Calculation sheets (Calc sheets): These sheets are meant to calculate the values fed in the different input sheets as mentioned above. These values are be fed into the Company excel file for further consolidation.
 - viii. Fuel CO₂ factors: Default CO₂ emission factors for fuels used in cement plants.
- c) Ready Mix Plant Excel file: This file 3 sheets:
- i. Read me: This sheet explains the meaning of the different colors used in the worksheets and provides additional instructions for the user.
 - ii. Ready Mix Input (ReadyMixPlants_in): Sheet to input the MICs consumed to produce Portland and Blended cements in the company's Ready-mix/Precast operations (for vertically integrated companies)
 - iii. Ready Mix Calculation (ReadyMixPlants_calc): Sheet with calculated values from the Input sheet
- d) Plant Monthly Input: Plant monthly monitoring template can be used to record monthly values that can be further consolidated at annual level in plant files which can as a further input to Company files.

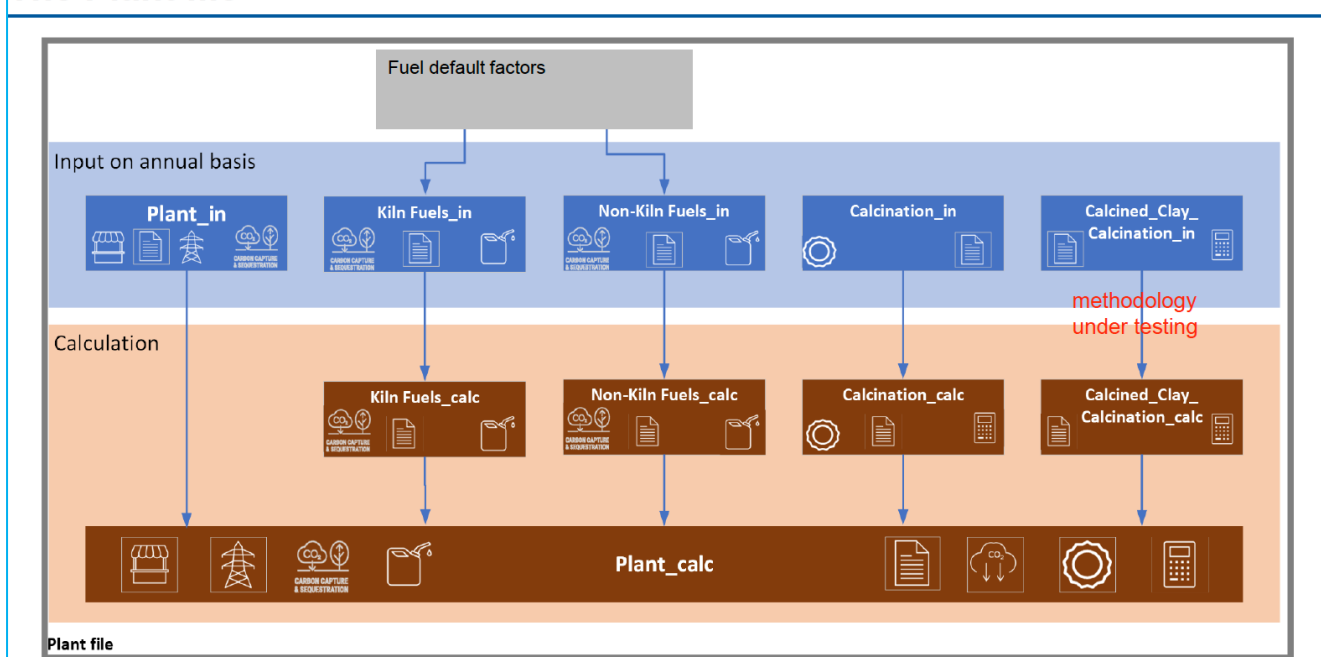
A detailed explanation for all the elements are part of Internet manual which can be accessed <https://www.cement-co2-protocol.org/en/> (Note: Internet Manual will be updated in 2026)

Attached are snapshots that provide further clarification of the enhancements implemented in the new version of protocol v4.2.

Most important changes in GCCA Protocol Version 4.0

	Version 3.1	Version 4.0
Excel version	Excel 2010	Excel Online, very high level of compatibility with Excel365, Excel 2021 and Google Sheets
Plant / company level	Both levels in one file	Separate files for plant and company
(Visible) sheets	Max. 7 per plant	1 plant file per plant with 13 sheets Input in separate sheets without any sheet protection Calculation is separated and protected in calculation sheets, removable protection allows complete analysis of calculation details + 1 ReadyMix file per company for integrated ready mix business + 1 Company file with 1 company sheet + 1 sheet per plant
Macros	Used for sheet management and validation tool	No macros used , replaced by links between sheets and files Validation range not yet available, could be amended in an additional sheet
Database links	Transfer of data and inserting DB links was possible in the special Plant sheet transfer But manual transfer required, especially calculation of company sums required user programming	Input sheets for pasting data and inserting DB links Links between sheets and files provided as far as possible Paste & Copying data from plant to company file as robust backup solution (viable solution if links between files should be lost in diverse IT systems)
Verification	Calculation cells were password protected	Copy & Paste all inputs to a fresh download of GCCA Protocol version 4 and compare calculation results

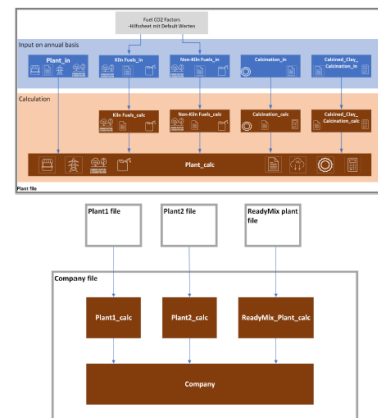
The Plant file



Get started in Microsoft Excel

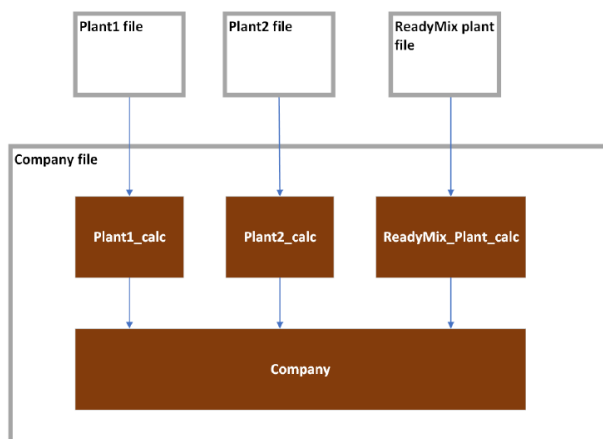
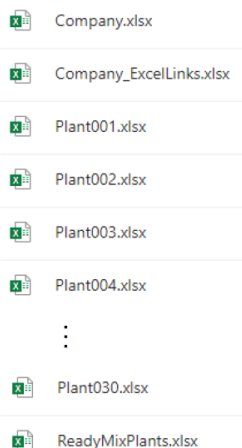
Plant001.xlsx and Company.xlsx – robust procedure

- Download [GCCA CO2 and Energy Protocol V4 00 20240502.zip](#)
- Unzip the folder
- Plant files (Plant001.xlsx to Plant030.xlsx):
Input plant data in all relevant input sheets marked "_in"
- Open **Company.xlsx**
- For each plant XXX an empty sheet "PlantXXX_calc" is prepared in company file
- **Copy & PasteValues(!)** from each PlantXXX.xlsx file the contents of the "Plant_calc" sheet onto the corresponding sheet in the company file
(Paste values only! Do not copy formulas and formats)



The Company file

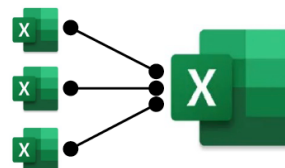
- aggregation level: National company
- integrating data from Ready Mix Plants in the National company from one special plant level file



Get started in Microsoft Excel

Company_ExcelLinks.xlsx, automatic, functioning of links is highly dependent on online/desktop work environment

- Download [GCCA CO2 and Energy Protocol V4 00 20240502.zip](#)
- Unzip the folder
- Plant files (Plant001.xlsx to Plant030.xlsx):
Input plant data in all relevant input sheets marked "_in"
- Open **Company_ExcelLinks.xlsx**
- For each plant XXX a sheet "PlantXXX_calc" is prepared in company file with relative links to plant files
- It is essential that **all plant files are located in the same folder as the company file**.
Place all files either online or at desktop.
Note: Mixed file locations risk automatic multiple extra copies of files and unclear or broken data links!
- Links are adjusted automatically to the local desktop or online folder location
- It may become necessary to replace invalid links in the company file, when data links become invalid, e.g. by deleting or moving unused plant files. Thus, it is also recommended to keep all unused plant files.



Get started in Google Sheets

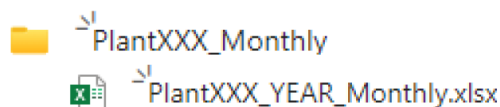
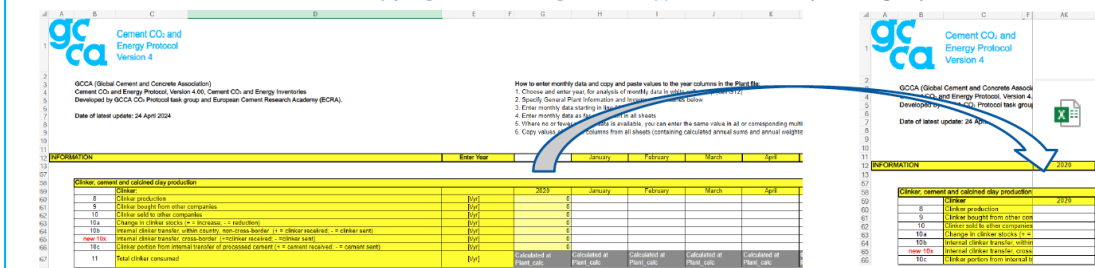
Plant001.xlsx and Company.xlsx – robust procedure

- Download [GCCA CO₂ and Energy Protocol V4 00 20240502.zip](#)
- Unzip the folder
- Upload the folder to Google Drive
- Plant files (Plant001.xlsx to Plant030.xlsx):
Input plant data in all relevant input sheets marked "_in"
- Open Company.xlsx
- For each plant XXX an empty sheet "PlantXXX_calc" is prepared in company file
- **Copy&PasteValues(!)** from each PlantXXX.xlsx file the contents of the "Plant_calc" sheet onto the corresponding sheet in the company file (Values only! Do not copy formulas and formats)



Aggregation of monthly input values

- The Plant monthly file is an optional additional level for plant and process specific data input on monthly basis.
- The PlantXXX_YEAR_Monthly.xlsx file is placed in a sub-folder and contains only dedicated input sheets with the name ending "..._in".
- Calculations of annual sums and annual weighted average values is performed in the first columns of the same input sheets.
- These columns are meant for **Copying and Pasting Values (!)** to the corresponding input sheets in the Plant file with annual data.

The screenshot displays the 'Enter Year' and 'January' to 'April' columns for data entry. The table structure is as follows:

Enter Year	January	February	March	April
2023				
2024				
2025				
2026				
2027				
2028				
2029				
2030				

11.2. A2 Greenhouse Gas Sources and Abatement Options in Cement Production

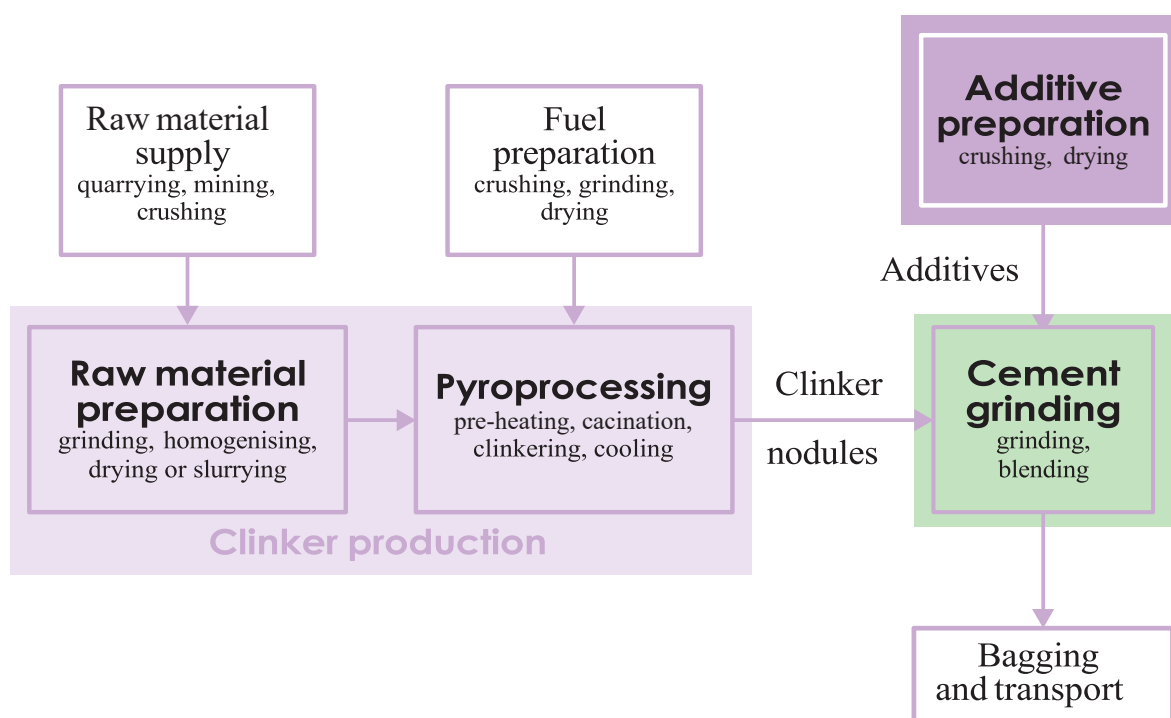
Overview of Cement Manufacturing Process

Cement manufacture includes three main process steps (see Figure A2-1):

1. Preparing of raw materials;
2. Producing clinker, an intermediate, through pyro-processing of raw materials;
3. Grinding and blending clinker with other products ("mineral components") to make cement.

There are two main sources of direct CO₂ emissions in the production process: calcination of raw materials in the pyro-processing stage, and combustion of fuels for clinker manufacturing. These two sources are described in more detail below. Other CO₂ sources include direct emissions from -fuels for other processes (e.g. dryers, room heating, CCUS, calcined clays and on-site transport), and indirect emissions from e.g. external power production and transport. Non-CO₂ greenhouse gases covered by the Kyoto Protocol are not relevant in the cement context, in the sense that direct emissions of these gases are negligible.

Figure A2-1: Process steps in cement manufacture.



CO₂ from Calcination of Raw Materials

In the clinker burning process, CO₂ is released due to the chemical decomposition of calcium carbonates (e.g. from limestone) into lime:



This process is called "calcination". It results in direct CO₂ emissions through the kiln stack. When considering CO₂ emissions due to calcination, two components can be distinguished:

- > CO₂ from raw materials actually used for clinker production, these raw materials are fully calcined in the clinker production process;
- > CO₂ from raw materials leaving the kiln system as partly calcined filter dust (FD), or as normally fully calcined bypass dust.

CO₂ from actual clinker production is proportional to the lime content of the clinker [REF 24], which in turn varies little in time or between different cement plants. As a result, the CO₂ emission factor per tonne of clinker is fairly stable (IPCC default: 510 kg CO₂/t clinker, CSI default: 525 kg CO₂/t clinker).

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.

CO₂ emissions from calcination of raw materials can be calculated based in two ways 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 Section 3.2 and Appendix 3 for details.

CO₂ 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 total organic carbon (TOC) content. Organic carbon in the raw meal is converted to CO₂ during pyro-processing. The contribution of this component to the overall CO₂ 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 company consumes large quantities of certain types of fly ash or shale as raw materials entering the kiln.

CO₂ 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. In recent years, fuels derived from waste materials have become important substitutes. These alternative fuels (AF) include fossil fuel-derived fractions such as, e.g. waste oil and plastics, as well as biomass-derived fractions such as waste wood and dewatered sludge from wastewater treatment.

Furthermore, fuels are increasingly used which contain both fossil and biogenic carbon, like, e.g. pre-treated industrial wastes (containing plastics, textiles, paper etc.) or waste tires (containing natural and synthetic rubber).

Both primary and alternative fuels result in direct CO₂ emissions through the kiln stack.

However, biomass fuels are considered "climate-neutral" in accordance with IPCC definitions. Use of alternative (biomass- or fossil-derived) fuels may, in addition, lead to important indirect emission reductions for waste treatment.

CO₂ Abatement Options

CO₂ emissions in the cement industry can be tackled by different measures. The GCCA Net zero roadmap provides a pathway to see how those can be leveraged.

The main categories of CO₂ abatement potentials include:

- > use of mineral components to substitute clinker as well as calcined clays;
- > fuel switching: for instance, use of natural gas or (biomass containing) AF instead of coal;
- > use of (partly) decarbonated raw materials;
- > energy efficiency: technical and operational measures to reduce fuel and power consumption per unit clinker or cement produced; and
- > reduction of dust leaving the kiln system (filter dust, bypass dust), where this occurs in relevant quantities.
- > use of carbon capture use and storage

Mineral components (MIC) are natural and artificial materials with latent hydraulic properties. Examples of MIC include natural pozzolana, blast furnace slag, and fly ash. 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. MIC use leads to an equivalent reduction of direct CO₂ emissions associated with clinker production, both from calcination and fuel combustion. Artificial MICs are waste materials from other production processes such as, e.g. 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. As a consequence, these indirect emissions must not be included in the cement production inventory.

11.3. A3 Details on Calcination CO₂

Reporting of CO₂ emissions from raw material calcination based on clinker output: Summary of IPCC and CSI Recommendations and Default Emission Factor for Clinker

IPCC (2006) recommends calculating calcination CO₂ based on the CaO content of the clinker produced (0.785 t CO₂/t CaO, multiplied with the CaO content in clinker). A default CaO content in clinker of 65% is recommended, corresponding to 510 kg CO₂/t clinker.

CO₂ from discarded kiln dust, according to IPCC, should be calculated separately, taking into account its degree of calcination. Where more precise data is not available, IPCC recommends accounting for discarded dust by adding 2% to clinker CO₂ by default, acknowledging that emissions can range much higher in some instances. IPCC does not distinguish between bypass dust and filter dust (FD).

Furthermore, the IPCC default value neglects CO₂ from decomposition of magnesium carbonates (MgO content in clinker is usually about 2%).

As recommended by the CSI previous task force, emission factors for clinker calcination are on a plant-specific basis. To this end, an auxiliary worksheet for the detailed output method (B2) has been included in the protocol spreadsheet, which allows to account for the specific CaO and MgO content of a plant's clinker as well as non-carbonate sources of CaO and MgO such as calcium silicates, or fly ash added to raw meal. In the absence of plant-specific data, CSI recommends using the simple output method (B1) with a default emission factor of 525kg CO₂/t clinker, corresponding to the IPCC default corrected for Mg Carbonates.

Method B2 starts with the clinker and its CaO and MgO content. Assuming that both oxides are fully carbonated in the beginning the following formula delivers a preliminary number for possible CO₂ emissions resulting from the calcination:

$$m_{CO_2}(Cli_{pre}) = \left(\frac{M_{CO_2}}{M_{CaO}} [CaO]_{cli} + \frac{M_{CO_2}}{M_{MgO}} [MgO]_{cli} \right) \times m_{cli}$$

In the next step we need to consider raw materials that contain these oxides but no or less CO₂ than expected when all the oxides are carbonated. Usually these are waste products as slags or ashes where a thermal process is reason for the missing carbon. Also gypsum, when used in the clinker production, needs to be considered. We call these materials DRM, what stands for decarbonated raw materials. The amount of CO₂ what we save is calculated as follows (we use the '*' to make clear these are avoided and not emitted amounts of CO₂):

$$m_{CO_2}^*(DRM) = \sum_i \left(\frac{M_{CO_2}}{M_{CaO}} [CaO]_i + \frac{M_{CO_2}}{M_{MgO}} [MgO]_i - [CO_2]_i \right) \times m_i$$

Unfortunately, the protocol didn't ask for residual carbon in the DRMs. For many of the materials in question this is sufficient – but some of them might contain a significant amount of carbon. In that case the reduction effect will be reduced. In a simplified approach we assume that all the carbon is part of calcium carbonate. That means the CaO will get reduced, the MgO remains the same. The reduced CaO is calculated as follows:

$$[CaO]_{reduced} = [CaO] - \frac{M_{CO_2}}{M_{CaO}} [CO_2]$$

Please note that this additional calculation needs to be done outside of the protocol.

In addition, we have to consider the ashes of the fuels we use, as they also contain the before mentioned oxides and if there was carbon associated, it is already considered in the fuel EF. We calculate this saving as follows:

$$m_{CO_2}^*(Ashes) = \sum_i \left(\frac{M_{CO_2}}{M_{CaO}} [CaO]_i + \frac{M_{CO_2}}{M_{MgO}} [MgO]_i \right) \times m_i [A_i]$$

The final clinker EF will then be:

$$EF_{Cli} = \frac{m_{CO_2}(Cli_{pre}) - m_{CO_2}^*(DRM) - m_{CO_2}^*(Ashes)}{m_{Cli}}$$

Where:

m	Quantity
EF	Emission factor
M_{CaO}	Molecular weight of the chemical compound indexed
[CaO]	Percentage of a chemical compound given in the range [0 ... 1] (equals Excel's approach when using '%')
A	Ash content

The CO₂ Emission factor for clinker determined from the specific CaO and MgO content does not account for CO₂ emissions resulting from FD leaving the kiln system and CO₂ emissions, which originate from the organic carbon content (TOC) of raw materials. Consequently, these CO₂ emissions are accounted in addition to the CO₂ emissions from calcination of raw material for clinker production. This addition is implemented for the output methods (B1 and B2) in the plant sheet (see Section 3.4).

CO₂ from Filter Dust: Deriving the Calculation Formula

Filter dust (FD) is usually not fully calcined. The CO₂ emission factor for FD can be derived from the mass balance between FD, raw meal and released CO₂:

Equation 1: $C_{FD} = \text{Raw meal} - CO2_{RM} - d$

Where,

C_{FD} = quantity of Filter dust (FD) (t)

Raw meal = here amount of dry raw meal consumed and converted to C_{fd}

$CO2_{RM}$ = total carbonate CO₂ contained in the raw meal (t)

$d = C_{FD}$ calcination rate (released CO₂ expressed as fraction of total carbonate in the raw meal)

The CO₂ emission factor for Filter dust (FD) is:

Equation 2:

$$EF_{FD} = \frac{CO2_{RM} \times d}{FD} = \frac{CO2_{RM} \times d}{\text{Raw Meal} - CO2_{RM} \times d}$$

Where,

EF_{FD} = emission factor for Filter dust (FD) (tCO₂ / tFD)

Since $CO2_{RM}$ is proportional to the amount of raw meal, equation 2 can be re-written as:

Equation 3:

$$EF_{FD} = \frac{fCO2_{RM} \times d}{1 - fCO2_{RM} \times d}$$

Where,

$fCO2_{RM}$ = weight fraction of carbonate CO₂ in the raw meal (-)

When the raw meal is fully calcined ($d=1$), EF_{fd} becomes the emission factor for clinker:

$$\text{Equation 4: } EF_{cli} = \frac{fCO2_{RM}}{1 - fCO2_{RM}}$$

Or re-arranged:

$$\text{Equation 5: } fCO2_{RM} = \frac{EF_{cli}}{1 + EF_{cli}}$$

Were,

EF_{cli} = emission factor for clinker (tCO₂/t clinker) with the help of Equation 5, Equation 3 can be expressed as:

Equation 6:

$$EF_{FD} = \frac{\frac{EF_{cli}}{1 + EF_{cli}} \times d}{1 - \frac{EF_{cli}}{1 + EF_{cli}} \times d}$$

Equation 6 has been entered into the spreadsheet. It allows calculating the emission factor of FD based on (i) the emission factor of clinker, and (ii) the calcination rate of the FD. Figure A3-1 illustrates the impact of the calcination rate. The diagonal line indicates that the assumption of a linear dependence between the FD calcination rate and the FD emission factor results in an overestimation of emissions by up to 50% (at low calcination rates) or up to 55 kg CO₂/t FD.

Determining the FD Calcination Rate

The FD calcination rate d shall be calculated according to Equation 7, based on the weight fractions of carbonate CO₂ in the FD and in the raw meal, respectively. The two input parameters fCO_{2FD} and fCO_{2RM} shall be measured by chemical analysis. Possible analysis methods include, for example, a loss on ignition test, titration or CO₂ emission analysis by infra-red (IR) detection.

Equation 7:

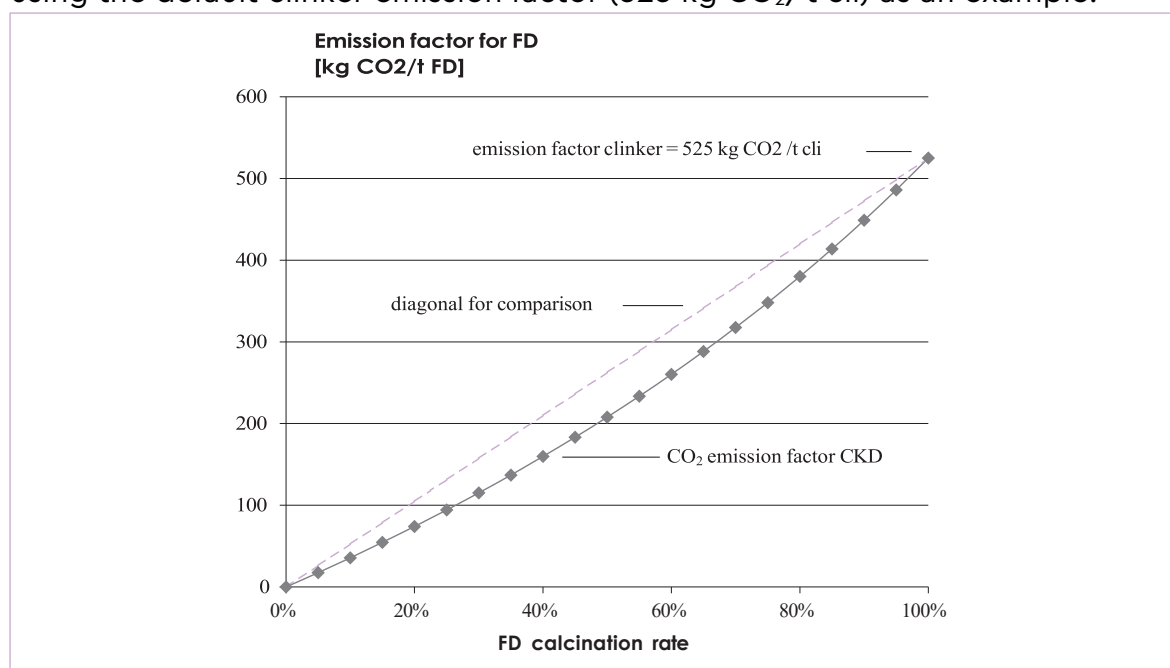
$$d = 1 - \frac{fCO_{2FD} \times (1 - fCO_{2RM})}{(1 - fCO_{2FD}) \times fCO_{2RM}}$$

Where,

fCO_{2FD} = weight fraction of carbonate CO₂ in the FD (--)

fCO_{2RM} = weight fraction of carbonate CO₂ in the raw meal (--)

Figure A3-1: Influence of FD calcination rate on the CO₂ emission factor for FD, using the default clinker emission factor (525 kg CO₂/t cli) as an example.



In the absence of measurement data on the composition of the FD, a default value of 1 shall be used for the calcination rate d . This value is conservative, i.e. it will in most cases lead to an overstatement of FD-related emissions, because FD is usually not fully calcined.

Direct determination of the CO₂ emission factor of FD from analysis of CO₂ content

For the direct determination of the CO₂ emission factor of FD, the combination of the Equations 3 and 7 yields

Equation 8:

$$EF_{FD} = \frac{fCO2_{RM} - \frac{fCO2_{fd} \times (1 - fCO2_{RM})}{(1 - fCO2_{fd})}}{(1 - fCO2_{RM}) + \frac{fCO2_{fd} \times (1 - fCO2_{RM})}{(1 - fCO2_{fd})}}$$

Equation 8 can be simplified after complementation of the left-hand term by multiplication with

Equation 9:

$$\frac{\frac{(1 - fCO2_{FD})}{(1 - fCO2_{RM})}}{\frac{(1 - fCO2_{FD})}{(1 - fCO2_{RM})}} = 1$$

As result the CO₂ emission factor of FD could equally be determined directly by the following equation:

Equation 10:

$$EF_{FD} = fCO2_{RM} \times \frac{(1 - fCO2_{FD})}{(1 - fCO2_{RM})} - fCO2_{FD}$$

In Equation 10, the terms in round brackets correct the mass reference of the CO₂ content fCO_{2RM} determined in samples of the uncalcined raw meal to the mass reference of FD, which potentially is partially calcined. The CO₂ emission factor of FD EF_{FD} is determined from the difference of the CO₂ content between the potentially partially calcined state and the hypothetical uncalcined state of FD

When using method B2 the standard (ISO 19694-3) offers an alternative method. It is described in annex A.2 of the standard and considers the accumulation of salts and sulphates in the bypass dust. For the calculation of dusts, we assume that all the oxides (CaO and MgO) were carbonated in the beginning, the therefor needed carbon equals the emissions, potential residual carbon is deducted. The emissions from the dust will be calculated as follows:

$$m_{CO_2}(FD) = \left(\frac{M_{CO_2}}{M_{CaO}} [CaO]_{FD} + \frac{M_{CO_2}}{M_{MgO}} [MgO]_{FD} - [CO_2]_{FD} \right) \times m_{FD}$$

11.4. A4 Fuel Categories & Definitions

Fossil Fuels

- **Coal + anthracite:** This class of fuel encompasses several kinds of coal. Waste coal may also be included, which is a by-product of coal processing, containing coal, along with trace minerals, dirt, and other materials.
- **Petrol coke:** Petrol coke (or petcoke) is a carbon-based solid derived from oil refineries.
- **(Ultra) Heavy fuel:** Heavy fuel is a flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights and other liquid organic compounds.
- **Diesel oil:** Standard diesel oil is assumed to consist of 100% fossil carbon. One CO₂ emission factor is defined for standard diesel oil in [line189](#).
- **Natural gas:** Note that the amounts of natural gas are reported in the unit [1000 Nm³/yr]. Nm³ refers to normal cubic meters at 1013 hPa and 0 °C.
- **Shale:** Shale is a sedimentary rock that can serve as a fuel when it has a high carbon content.
- **Lignite:** Lignite is a soft brown type of coal. It is also referred to as "brown coal". Its lower heating value (LHV) is normally smaller than the LHV of hard coal or anthracite.
- **Gasoline:** Refined liquid fuel obtained from petroleum especially used for car engines.
- **Liquefied Petroleum Gas (LPG):** mixtures of light hydrocarbons, predominantly propane and butane, that change from a gaseous to liquid state when compressed at moderate pressure or chilled. LPG is derived either as a by-product from crude oil refining or extracted from natural gas or oil production streams.
- **Other fossil fuels:** Category for all fossil fuels used in different equipment of the cement plant which are not reported in another category of the fossil fuels section.

Alternative Fuels

- **Waste Oil:** Waste oil is any mineral, petroleum-based or synthetic oil which, through use or handling, has become unsuitable for its original purpose. Examples of waste oil include oil spill clean-up, used combustion engine oils and gearbox oils, lubricating oils, oils for turbines and hydraulic oil, the bottom sediment of oil tankers after cleanout, and oil that has been contaminated through leaking containers.
- **Waste tires:** Tires here mean tires which are made of rubber and other synthetic materials. Normally, tires contain a natural rubber component. The GCCA Cement CO₂ and Energy Protocol therefore foresees a default value of 27% for their biogenic carbon content. Waste tires are no longer suitable for their intended purpose due to wear or damage. Examples: whole and shredded scrap tires, tire chips...
- **RDF:** Refuse-derived fuel (RDF) is an alternative fuel derived from wastes such industrial, commercial, or municipal solid waste (MSW). RDF consists largely of components of municipal waste such as non-recyclable plastics, and biodegradable waste. It is also referred to as solid recovered fuel (SRF). SRF is a high-quality alternative fuel produced from mainly commercial waste including paper, card, wood, textiles and plastic.
- **Plastics:** Non-recyclable 100% plastics are largely made of hydrogen and carbon, which makes them able to behave similarly to other hydrocarbon-based materials such as heating oil and gasoline. That makes them a good source of fuel and energy. Please consider that in this category, only 100% plastics are considered. Any mix of fuels containing plastics and another alternative fuels must be reported in "mixed industrial waste" or "other fossil-based wastes" as applicable.
- **Based Solvents:** Chemical solvents which consist of different types of combustible liquids.
- **Impregnated saw dust:** Composed of fine particles of wood which are a byproduct in the wood manufacturing processes but not pure wood biomass due to the impregnation.
- **Mixed industrial waste:** Different types of industrial wastes which are combustible materials. This category is used for reporting any other industrial waste different from alternative fuels reported under the RDF category.
- **Bio and mixed diesel:** Different types of diesel mixes, including blended ones with biodiesel. Biodiesel is manufactured from vegetable oils, animal

fats, or recycled grease. Note that the CO₂ emissions from bio and mixed diesel are evaluated with one common CO₂ emission factor, and biogenic carbon content.

- **Other fossil-based wastes:** Category for all fossil-based wastes and mixed fuels which are not reported in another category of alternative fuels and mixed fuels.

Biomass Based Fuels

- **Dried sewage sludge:** Sewage sludge is a result of sewage water treatment or similar processes. The sludge consists of biogenic organic materials and is normally dried for fuel use.
- **Wood, non-impregnated saw dust**
- **Paper, carton**
- **Animal waste:** Residues from the meat industry which consist of animals as source of organic carbon, bones of animals, and fat which is produced by animals.
- **Agricultural, organic, diaper waste, charcoal**
- **Biogas:** energy that is produced through the decomposition of organic materials in the absence of oxygen.
- **Other based biomass:** Category for all biomass fuels which are not reported in another category of biomass fuels. Note that the biogenic CO₂ emissions from all fuels in this category are evaluated for the memo item with one common CO₂ emission factor. A biogenic carbon content of 100% is assumed. Other liquid biomass and biofuels with 100% biomass to be reported here. 100% Ethanol based fuels are included in this category.

Hydrogen

- **Hydrogen:** Hydrogen used as fuel regardless of its production method. All types of hydrogen (black, grey, blue, green, turquoise...) are to be considered here. To be reported in metric tons.

11.5. A5 Background Material on Fuel Emission Factors

This appendix summarizes background information on fuel emission factors collected by the former WBCSD CSI Task Force and the data gathered from GCCA GNR 2023 Data for CO₂ and Energy Management.

Petcoke

The results for high-sulphur petcoke are:

Average value: 92.8 kg CO₂/GJ; Standard deviation: 2.08 kg/GJ

No. of samples: 361

Table A4-1: Regional coverage of petcoke samples (No. of samples)

Latin America	Canada / U.S.	Europe	Asia	Africa	Total
40	1	291	20	9	361

The samples were mostly taken during the period 1999–2003. They cover different world regions, with a focus on Europe (see Table A4-1). It is different from the default CO₂ emission factor of 97.5 kg CO₂/GJ, which is suggested in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

GCCA CO₂ Protocol Task Group conducted a study to understand the EF and LHV factor reported in GCCA GNR 2023 Data for CO₂ and Energy Management. Following were the results:

187_petrol_coke		
Values	Clinker production	% of production
Below 91	14,355,317	2.1%
Between 91 and 92,8	36,630,243	5.4%
Value 92,8	549,420,652	81.6%
Between 92,8 and 95,8	56,005,639	8.3%
Between 95,8 and 98,8	10,362,597	1.5%
Above 98,8	6,746,717	1.0%

Alternative Fuels

The results for alternative fuels (2003-2004) are shown in Table A4-2:

Table A4-2: Analysis data on alternative fuels compiled by the former WBCSD CSI Task Force. CO₂ emission factors were rounded to two digits in the spreadsheet

Fuel	No of Samples	CO ₂ Emission Factor Average (kg /GJ)	Standard Deviation (kg /GJ)
Fossil-based alternative fuels:			

Waste oil	90	74.2	5.6
Waste tires			
RDF			
Plastics			
Solvents based	116	73.8	14.9
Impregnated saw dust			
Mixed Industrial waste			
Bio and mixed diesel			

GCCA CO₂ Protocol Task Group conducted a study to understand the EF factor reported in GCCA GNR 2023 Data for CO₂ and Energy Management. Following were the results:

194_waste_oil		
Values	Clinker production	% of production
Below 73	6,610,467	1.0%
Between 73 and 74,2	32,215,942	5.0%
Value 74,2	582,945,339	90.4%
Between 74,2 and 77	10,258,389	1.6%
Above 77	12,685,014	2.0%

195_tyres		
Values	Clinker production	% of production
Below 82	8,626,783	1.3%
Between 82 and 85	23,311,317	3.6%
Value 85	576,786,783	87.8%
Between 85 and 88	19,166,944	2.9%
Between 88 and 91	15,477,306	2.4%
Above 91	13,267,739	2.0%

Compilation for Biomass in Tires from GCCA GNR 2023 Data for CO₂ and Energy Management

200b_biomass_in_tires		
Values	Tyres consumption	% of consumption
Between 0 and 0,24	24,326	1.0%
Between 0,24 and 0,27	68,154	2.7%
Default Value 0,27	1,728,788	68.0%
Between 0,27 and 0,28	74,849	2.9%

Between 0,28 and 0,29	62,109	2.4%
Between 0,29 and 0,3	103,110	4.1%
Between 0,3 and 0,31	74,708	2.9%
Between 0,31 and 0,32	37,153	1.5%
Between 0,32 and 0,34	69,583	2.7%
Between 0,34 and 0,35	90,509	3.6%
Between 0,35 and 0,49	99,741	3.9%
Above 0,79	110,242	4.3%

Compilation for LHV (GJ/t) in Tires from GCCA GNR 2023 Data for CO₂ and Energy Management

140_tyres		
Values	Heat consumption	% of consumption
Below 25,2	220,566	8.8%
Between 25,2 and 28,2	190,414	7.6%
Value 28,2	33,957	1.4%
Value 28,2 and 31,2	331,079	13.3%
Above 31,2	321,732	12.9%

Compilation of LHV (Gj/t) in Based solvents and impregnated saw dust

198_impregnated_saw_dust		
Values	Clinker production	% of production
Value 75 and below	596,816,171	94.4%
Between 75 and 78	13,984,746	2.2%
Between 78 and 87	7,174,314	1.1%
Above 87	13,921,559	2.2%

197_solvents		
Values	Clinker production	% of production
Below 74	17,461,337	2.8%
Value 74	582,291,369	92.7%
Between 74 and 77	6,358,025	1.0%
Between 77 and 80	6,833,142	1.1%
Between 80 and 83	7,193,337	1.1%
Above 83	7,957,199	1.3%

142_solvents		
Values	Heat consumption	% of consumption
Below 19,86	85,649	3.4%
Between 19,86 and 22,86	75,537	3.0%

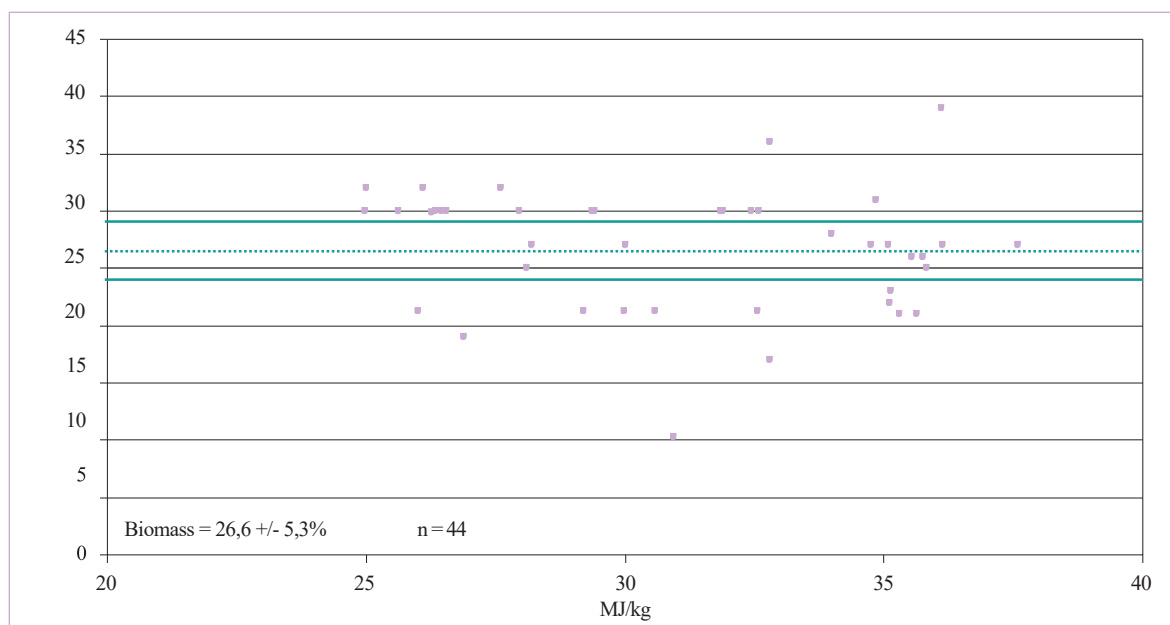
Default Value 22,86	0	0.0%
Between 22,86 and 25,86	56,000	2.2%
Above 25,86	163,411	6.5%

Biomass fuels

Fuel	No of Samples	CO ₂ Emission Factor Average (kg /GJ)	Standard Deviation (kg /GJ)
Dried sewage sludge			
Wood, non-impregnated saw dust			
Animal meal	116	89.2	6.5
Agricultural, organic, diaper waste, charcoal			
Biogas			
Other biomass-based fuels			

In 2008/2009 the former WBCSD CSI task force collected data about the biomass content of different alternative fuels in order to investigate the possibility of introducing adequate default values into the spreadsheet. As a result, only for waste tires (including shredded tires) a sufficiently consistent data base could be found (see Figure A4-1) and a default value of 27% biomass has been included. This value coincides with default values set in different European countries like Austria or Germany for the reporting within the European Emissions Trading Scheme.

Figure A4-1: Analysis data on the biomass content related to the calorific value of waste tires (including shredded tires) compiled by the former WBCSD CSI Task Force



11.6. A6 Numeric Prefixes, Units and Conversion Factors

Prefixes and multiplication factors			
Multiplication Factor	Abbreviation	Prefix	Symbol
1 000 000 000 000 000	10 ¹⁵	peta	P
1 000 000 000 000	10 ¹²	tera	T
1 000 000 000	10 ⁹	giga	G
1 000 000	10 ⁶	mega	M
1 000	10 ³	kilo	k
100	10 ²	hecto	h
10	10 ¹	deca	da
0.1	10 ⁻¹	deci	d
0.01	10 ⁻²	centi	c
0.001	10 ⁻³	milli	m
0.000 001	10 ⁻⁶	micro	μ

Abbreviations for chemical compounds		Units and abbreviations	
CH₄	Methane	cubic metre	m³
N₂O	Nitrous Oxide	hectare	ha
CO₂	Carbon Dioxide	gram	g
CO	Carbon Monoxide	tonne	t
NO_x	Nitrogen Oxides	joule	J
NMVOC	Non-Methane Volatile Organic Compound	degree Celsius	°C
NH₃	Ammonia	calorie	cal
CFCs	Chlorofluorocarbons	year	yr
HFCs	Hydrofluorocarbons	capita	cap
PFCs	Perfluorocarbons	gallon	gal
SO₂	Sulphur Dioxide	dry matter	dm
SF₆	Sulphur Hexafluoride		
CCl₄	Carbon Tetrachloride		
C₂F₆	Hexafluoroethane		

Source: IPCC 1996, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and IPCC 2006, IPCC Guidelines for National Greenhouse Gas Inventories.

Conversion Factors

To convert from	To	Multiply by
grams (g)	metric tons (t)	1×10^{-6}
kilograms (kg)	metric tons (t)	1×10^{-3}
megagrams	metric tons (t)	1
gigagrams	metric tons (t)	1×10^3
pounds (lb)	metric tons (t)	4.5359×10^{-4}
tons (long)	metric tons (t)	1.016
tons (short)	metric tons (t)	0.9072
barrels (petroleum, US)	cubic metres (m ³)	0.15898
cubic feet (ft ³)	cubic metres (m ³)	0.028317
litres	cubic metres (m ³)	1×10^{-3}
cubic yards	cubic meters (m ³)	0.76455
gallons (liquid, US)	cubic meters (m ³)	3.7854×10^{-3}
imperial gallon	cubic meters (m ³)	4.54626×10^{-3}
joule	gigajoules (GJ)	1×10^{-9}
kilojoule	gigajoules (GJ)	1×10^{-6}
megajoule	gigajoules (GJ)	1×10^{-3}
terajoule (TJ)	gigajoules (GJ)	1×10^{-3}
Btu	gigajoules (GJ)	1.05506×10^{-6}
calories, kg (mean)	gigajoules (GJ)	4.187×10^{-6}
tonne oil equivalent (toe)	gigajoules (GJ)	41.86
kWh	gigajoules (GJ)	3.6×10^{-3}
Btu / ft ³	GJ / m ³	3.72589×10^{-5}
Btu / lb	GJ / metric tons	2.326×10^{-3}
lb / ft ³	metric tons / m ³	1.60185×10^{-2}
psi	bar	0.0689476
kgf / cm ² (tech atm)	bar	0.980665
atm	bar	1.01325
mile (statue)	kilometer	1.6093
ton CH ₄	ton CO ₂ equivalent	21
ton N ₂ O	ton CO ₂ equivalent	310
ton carbon	ton CO ₂ equivalent	3.664

Sources: International Energy Annual, 1998; <http://www.eia.doe.gov/em/ef/ea/conv/heat.html>
BP Group Reporting Guidelines, 2000

Source: GHG Protocol, Guideline for Stationary Fuel Combustion www.ghgprotocol.org

11.7. A7 CO₂ Emissions from use of explosives in quarry activities

The main raw material in clinker production is limestone, which is normally found in specific areas that require excavation. The extraction process of minerals from quarries is divided into three phases: raw material extraction, transportation, and comminution. The usage of explosives takes place in the extraction phase.

The most commonly used explosive type is ANFO (Ammonium Nitrate Fuel Oil). Other explosives used in lower amounts and only for specific rock hardness are emulsions, gel, dynamite, or TNT.

ANFO consists of 94% porous ammonium nitrate (NH₄NO₃) (AN), which acts as the oxidizing agent and absorbent for the fuel, and 6% fuel oil (FO). The chemistry of ANFO detonation is the reaction of ammonium nitrate with a long-chain alkane (C_nH_{2n+2}) to form nitrogen, carbon dioxide, and water.

Depending on the explosive producer and on the chemical blend, a ton ANFO explosive detonation creates emissions between 103 and 180 kg CO₂/t of explosive. In quarry activities, on average 150 grams of ANFO explosives are required to extract 1 ton of limestone; hence, leading to no more 0.03 kg CO₂/t of limestone extracted, or 0.02 kg CO₂/t clinker produced. It is therefore justified to exclude explosives-based CO₂ emissions from the CO₂ accounting.

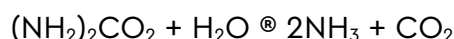
11.8. A8 CO₂ Emissions from use of urea for NO_x reduction

Aqueous urea solution $[(\text{NH}_2)_2\text{CO}]_{\text{aq}}$ is used to decompose NO_x that is present in the exhaust gas of a clinker kiln into nitrogen and water vapor. The presence of NO_x is caused by high-temperature combustion conditions during clinker production.

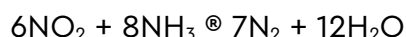
Two technologies are used for this:

- SNCR (selective non-catalytic reduction): Urea is injected at temperatures zones inside the kiln of 900-1100°C, reducing, after transformation into ammonia, NO_x without the help of a catalyst
- SCR (selective catalytic reduction): NO_x reduction is supported via a catalyst using ammonia as reducing agent at kiln temperatures of 200-400°C

When injected into the exhaust gas stream, the Urea solution decomposes into ammonia and carbon dioxide:



The ammonia then reduces NO_x according to the following reactions:



Hence, NO_x is transformed into harmless N₂ and H₂O which are released with the gas flow leaving the stack.

The resulting carbon dioxide emissions from the decomposition of urea have been derived from the total urea consumed at representative cement plants equipped with SNCR and SCR technology, respectively.

The assessments show a potential contribution of around 0.1% or less of a cement plant's total Scope 1 gross emissions. It is therefore justified to exclude Urea-based CO₂ emissions from the CO₂ accounting.

11.9. A9 SF₆ Emissions – Non-Materiality in Cement Plant

Sulphur Hexafluoride (SF₆) plays a limited yet potentially significant role in cement production. Although it is not directly involved in the core chemical reactions that create cement, understanding its usage and environmental concerns is crucial.

Limited Use as an Insulating Gas:

Unlike the primary raw materials such as limestone and clay, SF₆ is not a component of cement itself. Its primary application in cement plants is likely in specialized electrical equipment, particularly high-voltage switchgear.

SF₆'s unique properties make it an exceptional insulator in these applications:

- **Excellent Insulator:** Its high dielectric strength enables it to prevent electrical arcing, ensuring safe and efficient operation.
- **Arc-Quenching:** In the event of an arc fault, SF₆ effectively extinguishes it, minimizing damage and safeguarding equipment.

Quantity and Non-Material Classification:

In the context of cement production, sulphur hexafluoride (SF₆) is generally regarded as a non-material. This is because:

- **Function:** SF₆ is not typically involved in the chemical reactions that generate cement. Instead, it is a gas utilized in specialized industrial applications due to its insulating and arc-quenching properties.
- **Limited Use:** While SF₆ may be employed in certain equipment within cement plants, such as high-voltage switchgear for electrical insulation, its usage is typically minimal compared to the raw materials utilized in cement production (e.g., limestone, clay).

Therefore, from the perspective of cement production, SF₆ is not considered a material directly contributing to the final product (cement).

It is important to note that while SF₆ is not a direct material, it does raise environmental concerns. SF₆ is a potent greenhouse gas, and regulations may exist regarding its use, storage, and disposal within cement plants. Cement plants must implement measures to monitor leaks and have procedures in place for capturing and destroying any released SF₆.

11.10. A 10 Relevance of non-CO₂ GHG

A summary table has been provided which lists all the non-CO₂ GHGs and explains their non relevance

Sr. No	Gases Emissions	Materiality Relevance	Narrative
1	CO Emissions	Insignificant contribution hence this is not material to cement operation.	It is completely covered and accounted by calcination methods (A1, A2, B1, B2), which report emissions based on analyzing or inferring the total carbon (TC) content of materials. This is confirmed by the plant tests of the verification exercise. The contribution of CO amounts to less than 0.15 % of the direct GHG emission, which is included in the mass balances.
2	CH ₄ Emissions	Insignificant contribution hence this is not material to cement operation.	Not Relevant and not material to cement production. Methane (CH ₄) emissions in the cement industry can originate from the organic content of raw materials. Thus, their magnitude is likely site and raw material specific. *Literature values and results of the plant tests of the verification exercise indicate a maximum contribution to the total greenhouse warming potential of less than 0.04%.

3	N ₂ O Emissions	Insignificant contribution hence this is not material to cement operation.	Insignificant. In analysis of specific emission factors for the German cement industry contains a rather theoretical fuel specific emission factor for nitrous oxide (N ₂ O). This emission factor is assumed to be specified in very general terms in the German national greenhouse gas inventory for coal burning installations and it is not specific to cement plants. When converted, its contribution to the total emissions expressed as greenhouse warming potential results in 0.5% of the CO ₂ eq. The value obtained from the measurements in the plant test, in which coal was used as main fuel, is slightly smaller 0.4%. Values of the other tests in cement plants indicate a significantly smaller contribution of N ₂ O to the total greenhouse warming potential of 0.02% *
5	NO _x	Not material.	Refer A8 CO ₂ Emissions from use of urea for NO _x reduction

6	Other GHGs such as Fluorinated Hydrocarbons (HFCs, PFCs and SF ₆)	Not material.	During the plant tests of the verification exercise some other non-CO ₂ GHG have measured: sulfur hexafluoride (SF ₆), and fluorinated hydrocarbons (PFCs, HFCs). A total of six spot measurements for fluorinated GHG performed during the plant tests showed that the concentrations of SF ₆ , HFCs and PFCs were always below the limit of detection. This is confirmed by literature*.
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*Literature Link -

All verification reports of the EN 19694 Parts 2 to 6 are available on the following websites: Second Interim Report:

[https://www.vdi.de/fileadmin/pages/vdi_de/redakteure/ueber_uns/fachgesellschaften/KRdL/dateien/2nd Interim Report Mandate M 478.pdf](https://www.vdi.de/fileadmin/pages/vdi_de/redakteure/ueber_uns/fachgesellschaften/KRdL/dateien/2nd_Interim_Report_Mandate_M_478.pdf)

Final response to Mandate M/431:

[https://www.vdi.de/fileadmin/pages/vdi_de/redakteure/ueber_uns/fachgesellschaften/KRdL/dateien/CEN-TC264-WG33 final response CEN to Mandate M431.pdf](https://www.vdi.de/fileadmin/pages/vdi_de/redakteure/ueber_uns/fachgesellschaften/KRdL/dateien/CEN-TC264-WG33_final_response_CEN_to_Mandate_M431.pdf)

study report for N₂O – [Verein Deutscher Zementwerke e.V. (2009): Schlussbericht zum Forschungs- und Entwicklungsvorhaben UBA FKZ 3707 42 301, Teilvorhaben 03, TB-UBt 045/2009 , Emissi-onsfaktoren für die Zementindustrie]

11.11. A11 Table of Inclusion and Exclusion – Operational Boundaries

Sr. No	GHG Emissions	Emissions Quantified (Yes/No)	Reference Section	Scope of emission (Scope 1/2 /3)
1	Direct CO ₂ emissions from Raw material Calcination (Input methods (A1 and A2), Output method (B1 and B2))	Yes	CO ₂ from Raw Material Calcination	Scope 1
2	Direct CO ₂ emissions from Calcined Clay Production	Yes	CO ₂ from Calcined Clay Production	Scope 1
3	Direct CO ₂ emissions from Fossil Fuel Consumption in clinker and other processes	Yes	Fuels emissions accounting	Scope 1
4	Direct CO ₂ emissions from Alternative fossil fuel consumption in clinker and other processes	Yes	CO ₂ Emissions accounting Alternative Fossil Fuels, Mixed Fuels and Biomass Fuels	Scope 1
5	Direct CO ₂ emissions from Mixed fuel consumption in clinker and other processes	Yes* (fossil fraction) and No** (Biogenic fraction)	CO ₂ Emissions accounting Alternative Fossil Fuels, Mixed Fuels and Biomass Fuels	Scope 1
6	* Direct CO ₂ emissions from Mixed fuel – Fossil Fraction	Yes – Fossil fraction component of the mixed fuel shall be reported under direct emissions	CO ₂ Emissions accounting Alternative Fossil Fuels, Mixed Fuels and Biomass Fuels	Scope 1
7	** Direct CO ₂ emissions from	No – Biomass fraction component of	CO ₂ Emissions accounting Alternative	Scope 1

	Mixed fuel – Fossil Fraction	the mixed fuel shall be reported separately as a memo item and not to be included as part of the direct emissions	Fossil Fuels, Mixed Fuels and Biomass Fuels	
8	Direct CO ₂ emissions from Biomass fuels in clinker and other processes	No – Emissions from Biomass considered as climate neutral	CO ₂ from Fuels for Clinker Manufacturing	Scope 1
9	Direct CO ₂ emissions from Hydrogen fuel in clinker and other processes	No – Emissions from Hydrogen fuel considered as climate neutral	CO ₂ emissions accounting for Hydrogen	Scope 1
10	Direct CO ₂ emissions from transport on – site (company owned / leased	Yes	CO ₂ from Transport	Scope 1
11	Direct CO ₂ emissions from transport off – site (3 rd party under company management control)	No – To be accounted under Scope 3. CO ₂ emissions from off-site transports of inputs and products (Section 3.4.4) are out of scope, but also difficult to quantify consistently because these transports are often carried out by third parties. Refer relevant	CO ₂ from Transport	Scope 3 (refer GCCA Scope 3 guidance)

		sections for more details		
12	Direct CO ₂ emissions from Wastewater	No – Not material. It occurs relatively few plants, and the carbon can be from biomass sources. Refer relevant section for more details.	CO ₂ from Wastewater	--
13	Direct CO ₂ emissions from usage of Urea, explosives	No – Not material. Refer relevant section for more details	CO ₂ from use of urea for NO _x reduction	--
14	Non-CO ₂ Greenhouse gases (CH ₄ , N ₂ O, SF ₆ , PFCs, HFCs, etc.)	No – Not material. Refer relevant section for more details	Non-CO ₂ Greenhouse Gases	--
15	Indirect CO ₂ emissions from external electricity production	Yes	CO ₂ from external electricity production	Scope 2
16	Indirect emissions related to the production of Clinker and other raw materials bought from other producers and ground together with own production	No	CO ₂ from production of bought clinker	Scope 3
17	Indirect emissions related to CCUS	Yes	Indirect Greenhouse Gas Emissions	Scope 2
18	Indirect emissions related to the transport of inputs (raw material and fuel) and outputs	No	CO ₂ from production of bought clinker	Scope 3

	(cement, clinker) by 3 rd parties			
19	Indirect CO ₂ emissions from clinker purchased	Yes	CO ₂ from production of bought clinker	Scope 3
20	Other indirect emissions – Recarbonation	No – Emissions saved due to recarbonation should be deducted from the total emissions	Recarbonation of Cement - CO ₂ Sink	--
21	Other indirect emissions – Utilization of waste energy (Alternative fuel)	No – Savings/reductions due to waste heat exported to external consumer for primary energy sources should be accounted separately outside the protocol. The credit shall neither influence company's net CO ₂ emissions nor gross CO ₂ emissions	Utilization of Waste Energy	--

11.12. A12 Managing Inventory Quality

1. Summary of Recommendations of GHG Protocol

The GHG Protocol [1] provides extensive guidance on the management of inventory quality. This Section summarizes some key points. See the GHG Protocol document for details.

Implementing an Inventory Program the design, updating and refinement of a company's GHG inventory are a lasting task that should be addressed in the context of a comprehensive and systematic inventory program. Such a program will target the four basic components of a company's inventory:

- **Methods:** These are the technical and scientific approaches underlying a company's inventory. This protocol provides harmonized and robust methods for preparing a cement company's inventory. Companies are, however, encouraged to verify that these methods suit their specific requirements. In addition, companies should ensure that any methods which they devise and apply on their own accurately reflect the characteristics of their emissions sources.
- **Data:** This is the basic information on activity levels, emission factors, processes, and operations. A corporate inventory program will establish reliable collection procedures for high quality data and ensure the maintenance and improvement of these procedures over time.
- **Processes and systems:** These are the institutional, managerial, and technical procedures for preparing GHG inventories. They include the team, and the processes charged with producing and updating a high-quality inventory. Where appropriate, these processes may be integrated with other corporate data management processes.
- **Documentation:** This is the record of methods, data, processes, systems, assumptions, and estimates used to prepare an inventory. Since estimating GHG emissions is inherently technical, high quality, transparent documentation is particularly important to credibility.

2. Implementing an Inventory Quality Management System

An inventory quality management system serves to ensure and improve the quality of the four basic components of a company's inventory – methods, data, processes and systems, and documentation. The GHG Protocol recommends that companies should take the following seven steps in implementing quality management:

- **Establish an inventory quality team:** This team should be responsible for implementing a quality management system and continually improving inventory quality. The team will coordinate interactions between relevant business units, facilities, and external entities such as government agencies or verifiers.
- **Develop a quality management plan:** This plan describes the steps a company is taking to implement its quality management system. It should be incorporated in the inventory program from the beginning, although further rigor and coverage of certain procedures may be phased in over time. The plan should include procedures for all organizational levels and inventory development processes – from initial data collection to final reporting. For efficiency and comprehensiveness, companies should integrate (and extend as appropriate) existing quality management systems to cover GHG management, such as any ISO procedures. The bulk of the plan should focus on the practical measures described in steps three and four below.
- **Perform generic quality checks:** These apply to data and processes across the entire inventory, focusing on data handling, documentation, and emission calculations. A set of generic quality checking measures is provided in Table 6 below.
- **Perform source-specific quality checks:** This includes more rigorous investigations into the boundaries, assumptions and calculations for specific source categories, such as the emissions associated with individual fuels used in a cement plant. It also includes a qualitative and/or quantitative assessment of the uncertainty of emissions estimates by source category (see details on uncertainty in Section 3 below).
- **Review final inventory estimates and reports:** After the inventory is completed, an internal technical review should focus on its engineering, scientific and other technical aspects. Subsequently, an internal managerial review should focus on securing official corporate approval for the inventory. A third type of review involves an external verifier. For details on independent verification, see the GHG Protocol and the Requirements for Assurance of GCCA CO₂ data in A13 Recommendation for Reporting
- **Institutionalize formal feedback loops:** The results of the reviews in step 5, as well as the results of every other component of a company's quality management system, should be fed back via formal feedback procedures to the quality management team identified in step 1, and to the persons responsible for preparing the inventory.

- **Establish reporting, documentation, and archiving procedures:** The quality management system should contain record keeping procedures that specify what information will be documented for internal purposes, how that information should be archived, and what information is to be reported for external stakeholders.

Table 6 Examples of generic quality checking measures.

Data Gathering, Input and Handling Activities
Check a sample of input data for transcription errors
Identify spreadsheet modifications that could provide additional controls or checks on quality
Ensure that adequate version control procedures for electronic files have been implemented
Data Documentation
Confirm that bibliographical data references are included in spreadsheets for all primary data
Check that copies of cited references have been archived
Check that assumptions and criterion for selection of boundaries, base years, methods, activity data, emission factors and other parameters are documented
Check that changes in data or methods are documented
Emission Calculations
Check whether units, parameters, and conversion factors are appropriately labeled
Check that conversion factors are correct
Check the data processing steps (e.g. equations) in the spreadsheets
Check that spreadsheet input data and calculated data are clearly differentiated
Check a representative sample of calculations, by hand or electronically
Check some calculations with abbreviated calculations (i.e. back of the envelope calculations)
Check the aggregation of data across source categories, business units, etc.
Check consistency of times series inputs and calculation results

Source: Based on WRI / WBCSD 2004, p.51

3. Dealing with Uncertainty

Due to their scientific nature, the parameters required to estimate GHG emissions, such as fuel volumes, lower heating values and emission factors, are not precise point estimates, but involve an uncertainty that can be expressed as an uncertainty range or confidence interval. For example, the best estimate emission factor for petcoke, according to the results of chemical analyses of 361 samples compiled by the former WBCSD CSI Task Force (GCCA has superseded WBCSD CSI), is 92.8 kg CO₂/GJ with a 95% confidence interval of ± 0.2 kg CO₂/GJ. This means that the true emission factor for the analyzed petcoke samples falls with 95% probability within the uncertainty range of 92.8 ± 0.2 kg CO₂/GJ.

The aggregated uncertainty of an emissions estimate for a plant or company will depend on the individual uncertainties of the underlying parameters. GHG Protocol has developed a tool and guidance to help assess these uncertainties (see www.ghgprotocol.org for details).

Quantifying parameter uncertainties is demanding in terms of data and procedures. As a result, statements about the aggregate uncertainty of emissions estimates are inherently uncertain themselves and often involve a subjective component[22]. Nevertheless, there are clear incentives to assess and minimize uncertainty:

- > Companies may want to rank the sources of uncertainty in their inventory in order to identify priority areas to focus on when improving inventory quality;
- > Some GHG reporting schemes, for example the monitoring guidelines for the EU ETS, set quantitative limits for the uncertainty of key parameters used to estimate emissions from cement plants;
- > Wherever monetary values are assigned to GHG emissions, uncertainty in emissions estimates can have financial consequences.

With this background, the GHG protocol [1] recognizes that uncertainty in GHG inventories is a longer- term challenge which deserves attention. Table 7 identifies the sources of uncertainty which are typically the most relevant in a cement company, along with measures to minimize them.

Table 7 Typical major sources of uncertainty in cement sector CO₂ inventories, and measures to minimize them.

Parameter	Measures to Minimize Parameter Uncertainty
Clinker production (t/a)	Use alternative estimation methods to cross-check clinker volumes: Based on raw meal consumption and raw meal: clinker ratio Based on cement production and clinker: cement ratio, adjusted for clinker sales and purchases and clinker stock changes Based on direct clinker weighing (where applicable)

Raw meal consumption (t/a)*	Account for double counting of recycled dust by weighing devices
Calcination emission factor (kg CO ₂ /t clinker)	Calculate plant-specific emission factor based on measured clinker composition (CaO- and MgO-content), rather than using default factor Account for additions of calcined materials to the kiln via slag, fly ash, etc.
Calcination emission factor* (kg CO ₂ /t raw meal)	Calculate plant-specific emission factor based on measured composition of raw meal (carbonate content) Account for variations in raw meal carbonate content over time (e.g., additions of calcined materials)
Fuel consumption (t/a)	Use alternative methods to cross-check fuel consumption: Based on weighing at delivery, or fuel bills; account for stock changes Based on weigh-feeders (where applicable)
Lower heating values of fuels (GJ/t)	Ensure that fuel volumes and lower heating values are based on same moisture content

Parameter	Measures to Minimize Parameter Uncertainty
Emission factors of fuels (kg CO ₂ /GJ)	If using fuel mixes (e.g., coal-petcoke mix), disaggregate and apply individual emission factors, or apply weighted emission factor If using specific types of coal, use matching emission factors (see protocol spreadsheet, Comments column of Worksheet "Fuel emission factors") Measure emission factor of fuel if default factors are deemed non-representative Account for biomass carbon in, e.g., used tires and impregnated saw dust Use analysis data for biomass content in heterogeneous mixed alternative fuels like pre-treated industrial or domestic wastes, where applicable

* Parameters marked with an asterisk are only relevant if the raw meal based method is used for calculating CO₂ from raw material calcination.

4. Materiality Thresholds

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

Chapter 10 of the GHG Protocol [1] provides details on the concept of materiality in verification.

A materiality threshold should not be interpreted as a permissible quantity of emissions which a company can leave out of its inventory. For example, exclusion

of all sources which contribute less than 1% to the overall emissions of a cement plant would introduce a systematic bias which is not compatible with the guiding principle that an inventory should be complete. On the other hand, it is important to acknowledge that a company's resources available for preparing a GHG inventory are always limited, and that companies should focus on reducing the uncertainty related to their main emission sources.

With this background, this protocol does not define a minimum threshold below which an emission source should be considered "immaterial". Instead, companies are encouraged to apply simplified methods for quantifying their minor sources of CO₂. This applies, for example, for CO₂ emissions from organic carbon in raw materials (see Section 3.2).

In this context, it is useful to reiterate the reasons why this protocol does not require quantification of the following sources of direct GHG emissions:

- CO₂ emissions from off-site transports of inputs and products (Section 3.4.4) are out of scope, but also difficult to quantify consistently because these transports are often carried out by third parties.
- CO₂ emissions from combustion of wastewater (Section 3.6), in addition to being small, occur only in relatively few plants, and the carbon can be from biomass sources;
- CH₄ and N₂O emissions from kilns (Section 3.8 and 3.9) are non material.
- The exclusion of these latter emission sources is, therefore, based on several reasons and not just on a quantified materiality threshold.

Please refer A11 Table of Inclusion and Exclusion – Operational Boundaries for detailed information

11.13. A13 Recommendation for Reporting

1. Introduction

CO₂ emissions monitoring and reporting has multiple goals, such as internal management of environmental performance, public environmental reporting, reporting for taxation schemes, voluntary or negotiated agreements, and emissions trading. Additional purposes can be, for example, performance benchmarking and product life cycle assessment.

The protocol has been designed as a flexible tool to satisfy these different reporting purposes, while always meeting the criteria described in Chapter 2. The information is structured in such a way that it can be aggregated and disaggregated according to different reporting scopes. Examples include:

- Reporting to national GHG inventories should be compatible with IPCC guidelines. Hence, it should cover all direct CO₂ emissions, including CO₂ from fossil wastes. CO₂ from biomass fuels should be reported as a memo item.
- Reporting under CO₂ compliance and taxation schemes will have varying reporting requirements, depending on local conventions. The protocol allows reporting of gross and net emissions and indirect emissions, as appropriate.

This protocol does not define any threshold for excluding “immaterial” emission sources. The underlying reasons are explained in Section 3. Dealing with Uncertainty, in previous chapter.

In practice, the decision whether to include or exclude certain emission sources will also depend on the requirements of the respective reporting framework. With respect to voluntary environmental reporting, this protocol suggests specific boundaries in the next section.

2. Corporate Environmental Reporting

The objective of voluntary environmental reporting is to provide the reader with a sufficiently accurate picture of the environmental footprint of the reporting company. This implies that the reporting of cement companies shall cover all relevant emission components:

Gross direct CO₂ emissions of the reporting entity (calcination, primary fuels for clinker manufacturing, alternative fuels for clinker manufacturing, fuels for other processes, calcined clays with biomass CO₂ as a memo item);

- Net emissions (if applicable), calculated from gross emissions minus emissions from the use of alternative fuels;

- Main indirect emissions (consumption of grid electricity and bought clinker).

Reporting shall be in absolute (Mt CO₂/year) as well as specific (kg CO₂/t cementitious material) units. Reporting of net emissions alone, omitting gross emissions is not acceptable.

- In order to be complete, reporting shall include the CO₂ emissions (including indirect CO₂ emissions from consumption of grid electricity and accounting for own on-site power generation) from the different process steps as shown in Table 8.

Additional requirements for voluntary reporting include:

- It shall be clearly stated when CO₂ sources are excluded from the inventory. To this end, the protocol spreadsheet requires companies to state the boundaries of their inventory.
- Companies shall clearly state that they report according to this Cement CO₂ and Energy Protocol Version 4, and any material deviations from it.

3. Reporting Periods

Reporting GHG emissions based on financial years, rather than calendar years, can help to reduce reporting costs. From a GHG perspective, there is no problem to report based on financial years, provided that it is done consistently over time, with no gaps or overlaps. Changes in the reporting year should be clearly indicated. National regulations should be taken into account.

Table 8 : Recommended inventory boundaries for voluntary CO₂ reporting

Process Step	CO ₂ Reporting Mandatory?	Comments
Raw material supply (quarrying, mining, crushing)	Yes – unless n.a.	May require consolidating emissions of two legal entities if raw material supply is contracted out. See Section 7.1 for details.
Preparation of raw materials, fuels and additives	Yes – unless n.a.	--
Kiln operation (pyro-processing)	Yes – unless n.a.	--
Cement grinding, blending	Yes – unless n.a.	--
On-site (internal) transports	Yes – unless n.a.	CO ₂ from owned vehicles (incl. leased vehicles, excl. owner-drivers) must be reported. If third-party transport: ®n.a.
Off-site transports	No	Reporting is not mandatory. If reported, distinguish direct CO ₂ (own vehicles, incl. leased vehicles) from indirect CO ₂ (third-party vehicles)
On-site power generation	Yes – unless n.a.	Also report CO ₂ if operated only occasionally
Room heating / cooling	Yes – unless n.a.	--
Carbon Capture	Yes – unless n.a.	

n.a. = not applicable

Refer A11 Table of Inclusion and Exclusion – Operational Boundaries for more details

4. Scopes of Revised GHG Protocol

The GHG Protocol classifies emissions under different scopes. Table 9 shows how the emissions sources discussed in this protocol relate to the classification of GHG protocol.

The GHG Protocol requires companies to separately account for and report on scopes 1 and 2. The Cement CO₂ and Energy Protocol provides a basis for complete reporting as required by GHG Protocol, with the exception of CO₂ from company-owned off-site transport fleets, CO₂ from combustion of wastewater, and CH₄ and N₂O emissions. As explained in Section 4 of chapter Managing

inventory quality, these latter emission sources are excluded as a default for various reasons but can be included if required.

Table 9 Reporting scopes of GHG Protocol, and corresponding sections of this protocol

GHG classification	Corresponding sections of this protocol
Scope 1: Direct GHG emissions (only if sources are owned or controlled)	
Process emissions	Section 3.2: CO ₂ from raw material calcination Section 3.2: CO ₂ from organic carbon in raw materials
Stationary combustion sources	Sections 3.5, 3.6 and 3.7: CO ₂ from fuels for clinker manufacturing Section 3.8: CO ₂ from fuels for other processes Section 3.9: CO ₂ from wastewater
Mobile combustion sources	Section 3.8: CO ₂ from fuels for other processes
Non-CO ₂ greenhouse gases	Section 3.10: Non-CO ₂ greenhouse gases
Scope 2: Indirect GHG emissions from purchased electricity	Section 4: Indirect emissions from grid electricity
Scope 3: Other indirect emissions	Section 4: Indirect emissions from bought clinker

A14 Main Changes in the Cement CO₂ and Energy Protocol from Version 3.1 to Version 4.0

The revision of the Cement CO₂ and Energy Protocol was performed based on extended experiences with the application of the Protocol Version 3.1 and its evaluation for several years by many cement companies worldwide. The new version of the protocol has updates in the following areas:

- Mineral Components (MICs) (Aligned definition and updated accounting related to internal MIC transfer)
- Calcined Clay (new section to accommodate latest technique via Cement production using Calcined Clay) – see Section 3.3
- CCUS (new section added) – see Section 3.5
- Urea and Explosives non-materiality (new section added in the guidance) – see Section 3.8
- Fuels for clinker manufacturing and other processes (Auxiliary module for fuel related CO₂ emissions accounting fuels quantities, calorific value, CO₂ emissions factor)
- Alignment with ISO/DIS 1964 – 3: Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries
- Power Balance (improved accounting method to accommodate various modes of accounting) – see Section 4
- Recarbonation (new section added for recarbonation) – see Section 5.4

Main changes for the Protocol Version 4.0 were made regarding the following issues:

- MICs accounting and clinker transfers/purchases:

Inconsistencies present in the protocol Version 3.1 when calculating plant level KPIs if MICs are processed and transferred internally have been amended.

The MICs list is adapted to current practice and to account for all the SCMs in the company value chain:

- Alignment of the definition in the guidelines with the title in the protocol for KPIs 9 and 10; separation of cross-border internal transfers from the clinker purchased from 3rd parties.

- Correction of erroneous calculations of plant level KPIs when MICs are processed for internal transfer and changes in consolidation to avoid double counting.
 - Accounting limestone and other cementitious materials processed and sold to 3rd parties as a MIC.
 - Inclusion of MICs consumed in own Ready-Mix/Precast businesses as part of the clinker-to-cement ratio actions across company value chain for vertically integrated companies. Creation a whole new set of performance KPIs associated with the inclusion of these MICs for vertically integrated companies.
 - At plant level, the clinker and MICs portion of a cement transferred internally or exchanged with other companies shall be reported only if this cement is further blended to produce another cement type. The clinker portion and cement constituents shall be reported in the dedicated lines for that purpose (10c, 10d, 17a and 17b). The clinker portion should be calculated based on the clinker/cement factor or cement composition of the transferred cement. For more information about this point, please refer to section 6.3 Clinker, Cement and MIC Transfers and Purchases.
- Calcined Clay Accounting:

With the emergence of calcined clays, it is necessary to include the accounting of related emissions in the Protocol. A new dedicated section is added to the protocol accounting sheet as well as in the guidance document to provide all the necessary details for accounting. The section has its own performance indicators (suitable for both stand-alone and integrated Calcined Clay production plants). All the necessary details are explained in the Calcined Clay section.
 - Carbon Capture Utilization and Storage:

This new section is added with the sole aim to align with the ongoing deployment of CCUS and its expected essential role in reaching our net zero target. The respective section defines how to account for captured emissions as well as for (additional) emissions from auxiliary equipment related to CO₂ capture. The new added section clearly explains the rules for accounting of the negative emissions specifically in the situation of partial capture, use and storage. This new section has its own set of performance indicators which can be explored in KPIs section (Appendix 13.12)

- Urea and Explosives non-materiality:

This topic was explored as the Urea is used in NO_x reduction and explosives are used in quarries. Both activities generate carbon emissions. A detailed study was conducted by the members of GCCA CO₂ protocol task group, and it was concluded that the emissions generated by Urea and Explosives are non-material in Nature. Explanation is provided in Annex A7 and A8, respectively.

- Fuels for clinker manufacturing and other processes:

Fuel types used have evolved over the last decade, hence there was a need to review fuels categories and emissions factors to align with current industry practices. Also, the addition of new sections – Calcined Clay and CCUS – required updating of this section. Main changes are as follows:

- Auxiliary module for fuel related CO₂ emissions accounting added (fuels quantities, calorific value, CO₂ emissions factor)
- Additions, breakdowns, merges and renaming of fuel categories
- Emission Factors for actual and new fuels reviewed and adjusted
- Clarification of definitions in guidelines
- Accounting for calcined clays production and CCUS fuel related CO₂ emissions

Table below explains key changes in the fuels:

Type of change	Type of fuel	Current Status	Change to
Addition	Primary fossil fuels	-	Liquefied Petroleum Gas (LPG)
Inclusion	Primary fossil fuels		Gasoline
Addition	Primary fossil fuels	-	Other fossil fuels
Inclusion	Alternative fossil fuels	-	bio and mixed diesel
Naming	Alternative fossil fuels	Tires	Waste tires
Naming	Alternative fossil fuels	Solvents	Based solvents
Disaggregation	Alternative fossil fuels	RDF including plastics	RDF
Addition	Alternative fossil fuels	RDF including plastics	Non-recyclable plastics (100%)
Merge	Biomass fuels	Animal meal	animal waste (animal meal, animal bone
		Animal bone meal	

		Animal fat	meal and animal fat)
Naming	Biomass fuels	Biomass	Based biomass
Addition	Biomass fuels	-	Biogas
Inclusion	Biomass fuels	-	Biomass content from Alternative fuels
Addition (new category)	Hydrogen	-	Hydrogen

- Alignment with ISO/DIS 1964 - 3: Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries

In 2021, ISO/ DIS 19694 Series specifically ISO/ DIS 19694-3: Cement was published. It is generally aligned with the GCCA CO₂ and Energy Protocol thanks to industry input. Nevertheless, on a few topics, the ISO standard, being more recent, contains additional information or clarification which should be implemented into the new GCCA CO₂ and Energy Protocol version. The following changes are made to ensure full alignment of this protocol Version 4.0 with newly adopted ISO standards:

- ISO topic 1 - CO₂ emissions categories versus scope: In the protocol we only consider direct GHG emissions (Scope 1) and indirect GHG emissions from imported energy (Scope 2). Indirect emissions from transportation; indirect emissions from the products used by the organization; indirect emissions associated with the use of products from the organization and indirect emissions from other sources are part of Scope 3 accounting.
- ISO topic 2 - Other GHG emissions: There are several other GHG emissions which are insignificant/irrelevant to our business. Thus, it is proposed to refer to the ISO/ DIS 19694-3 validation document which provides a detailed list of the other GHG emissions which can be neglected. The reference to those other GHG emissions from the ISO document is added to the guidance document.
- ISO topic 3 - FD, Bypass dust and Filter dust: Following changes are proposed:
 - **Using clarified and adjusted terminology** which is in alignment with EN (ISO DIS) 19694-3:
Adjusted terminology: filter dust + bypass dust = FD (EN/ISO terms and definitions 3.5, 3.9 and 3.16)

- Amending additional calculation pathways for filter dust partial calcination
- **Adding the missing method** for bypass dust partial calcination in output method B2 in line with EN (ISO DIS) 19694-3
- ISO topic 4 - Determination of CO₂ emissions from raw material calcination: In the Version 3.1 of the Cement CO₂ and Energy protocol there was no provision for the determination of CO₂ emissions from raw material calcination. Thus, we aligned to ISO FDIS 19694-3, which considers an additional input mass flow for the "Additional raw materials fed to calciner or kiln inlet".
- ISO Topic 5 - Fuels and raw material with high ash content: Detailed additional guidance from ISO FDIS 1964-3 has been added for fuels and raw materials with high ash content which was missing from V3.1.
- ISO Topic 6 – Consideration of Biomass: Accounting of the carbon emission from Biomass being used as a replacement for fossil energy or process feedstock is now aligned with ISO FDIS 19694-1 and ISO 14064-1.
- Power Balance: The updated changes as follows:
 - For total power production from separate on-site power generation, following lines have been added:
 - Power delivered to Calcined clay unit
 - Power delivered to CCUS unit
 - Power delivered to the hydrogen production unit
 - Total renewable power generated
 - For power production from waste heat recovery:
 - a. Power from the waste heat recovery delivered to Calcined clay unit
 - b. Power from the waste heat recovery delivered to CCUS unit
 - For the external power purchased, following lines have been added:
 - a. % renewables in grid mix (market based and location based)
 - Reference added for market-based approach while considering grid emission factor for external electricity purchased
 - New lines added for:

- a. External power delivery – One for Calcined clay unit and other for CCUS unit
 - b. For indirect CO₂ emission for the biomass used as a fuel in the production of power (self-generation)
- Two new KPIs added for % renewables consumed in power consumption (including self-generation and power purchased) and %waste heat mix in the power generation
- Recarbonation: a line in the CO₂ protocol for natural recarbonation potential which is related to the volume of clinker produced.

The natural recarbonation potential = $\text{Clinker produced} \times 20\% \times 525$
(kgCO₂/tonne clinker) / 1000

This calculation method is in line with the [IPCC compliant IVL Tier 1 methodology](#)

- A9.1 Changes from V2 to V3.0 (Historic Changes) – This can be found in V3.1 of the protocol, which is available at GCCA members area [GNR 2.0 - GCCA in Numbers : GCCA](#)

A15 Performance Indicators (KPIs) in the Cement CO₂ and Energy Protocol Version 4.0

Please note: The column "line in Version 4.2" will be updated after internet manual development which is due in 2027/early 2028

Performance indicators in protocol Version 4 (Line number, name, unit, comment and definition)			Comparison of protocol Version 3 to 4.2			
New and adjusted performance indicators (KPIs) are marked by bold numbers and names. See comparison on the right-hand side for more details			Line numbers are listed without the prefix "line" in the equation that define the KPIs and where the necessary unit conversions are specific in square brackets, e.g. [1000kg/t]			
Absolute Direct CO ₂ emissions			Line in V4.2	Comment		
Absolute gross CO ₂ generation including CO ₂ from on-site power generation	[t CO ₂ /yr]	Total Direct Emissions from raw materials, Kiln fuels and non-kiln fuels including CO ₂ from on-site power generation	39+43+46	No Change	To be updated after internet manual development which is due in 2027/early 2028	
CO ₂ Storage and Use						
CO ₂ stored and used (fossil and Biogenic)	[t CO ₂ /yr]	New 34C	----	- - - -		
- fossil part stored and used (reducing direct fossil CO ₂ emissions, scope 1)	[t CO ₂ /yr]	New 59DE – new 59DH		- - -		
- biogenic part captured stored and used	[t CO ₂ /yr]			- - -	New KPI	

- fossil part stored	[t CO ₂ /yr]			- - - -	New KPI	
- biogenic part stored (carbon removals - reducing direct fossil CO ₂ emissions, scope 1)	[t CO ₂ /yr]			- - - -	New KPI	
- fossil part used with permanent storage	[t CO ₂ /yr]			- - - -	New KPI	
- biogenic part used with permanent storage	[t CO ₂ /yr]			- - - -	New KPI	
CO ₂ used for products with > 10 years lifecycle (fossil and biogenic, related to assessment of other indirect CO ₂ emissions, Scope 3) - fossil part used > 10 year lifecycle	[t CO ₂ /yr]			- - - -	New KPI	
CO ₂ used for products with > 10 years lifecycle (fossil and biogenic, related to assessment of other indirect CO ₂ emissions, Scope 3) - Biogenic part used > 10 year lifecycle	[t CO ₂ /yr]			- - - -	New KPI	
Absolute direct CO ₂ Emissions						
Absolute gross CO ₂ Emissions, including CO ₂ from separate on-site power generation, excluding CO ₂ stored or used permanently	[t CO ₂ /yr]	Total Direct Emissions from raw materials, Kiln fuels and non-kiln fuels excluding				

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		CO ₂ from on-site power generation				
Gross CO ₂ Emissions (=direct fossil CO ₂ excluding CO ₂ from separate on-site power generation)						
Absolute gross CO ₂	[t CO ₂ /yr]					
- Calcination Component	[t CO ₂ /yr]					
- Fuel Component	[t CO ₂ /yr]					
- stored or used, incl. biogenic part stored	[t CO ₂ /yr]					
- share of gross CO ₂ stored or used, incl. biogenic part stored	%					
Net CO ₂ Emissions (= gross CO ₂ minus alternative fossil fuels CO ₂ ; excluding CO ₂ from on-site power generation)						
Absolute net CO ₂	[t CO ₂ /yr]					
Biomass CO ₂ emissions (memo item)						
Absolute CO ₂ from biogenic sources (including biomass content of mixed fuels, related to assessment of other indirect CO ₂ emissions, Scope 3)	[t CO ₂ /yr]					
Calcined Clay						
Absolute gross CO ₂ of calcined clay	[t CO ₂ /yr]					
Specific Gross and Net CO ₂ Emissions per Clinker produced						
Specific gross CO ₂ per tonne of clinker produced	[kg CO ₂ /t cli]					
- Calcination Component	[kg CO ₂ /t cli]					
- Fuel Component	[kg CO ₂ /t cli]					

To be updated after internet manual
development which is due in 2027/early
2028

- per tonne of Clinker Produced	[kg CO ₂ /t cli]					
Specific Net CO ₂ per tonne of Clinker Produced	[kg CO ₂ /t cli]					
Specific Gross CO ₂ Emissions per Calcined Clay produced						
Specific gross CO ₂ of calcined clay produced	[kg CO ₂ /t calcined Clay]					
Specific Gross and Net CO ₂ Emissions per Cement (equivalent)						
Specific gross CO ₂ per tonne of cement (equivalent)	[Kg CO ₂ /t Cement Eq.]					
- Calcination Component	[Kg CO ₂ /t Cement Eq.]					
- Fuel Component	[kg CO ₂ /t Cement Eq.]					
Specific net CO ₂ per tonne of Cement (eq)	[kg CO ₂ /t Cement Eq.]					
Specific Gross and Net CO ₂ Emissions per Cementitious Product						
Specific gross CO ₂ per tonne of Cementitious Product	[kg CO ₂ /t cementitious produced]					
- Calcination Component	[kg CO ₂ /t cementitious produced]					
- Fuel Component	[kg CO ₂ /t cementitious produced]					
Specific net CO ₂ per tonne of cementitious product	[kg CO ₂ /t cementitious produced]					
Improvement rate - net CO ₂ per tonne of cementitious product	[% relative to base yr]					
Specific Gross and Net CO ₂ Emissions per Cement (equivalent) (including Integrated Ready-Mix/Precast Businesses)						

To be updated after internet manual development which is due in 2027/early 2028

Specific gross CO ₂ per tonne of Cement (eq)	[kg CO ₂ /t cement Eq.]					
- Calcination Component	[kg CO ₂ /t cement Eq.]					
- Fuel Component	[kg CO ₂ /t cement Eq.]					
Specific net CO ₂ per tonne of Cement (eq)	[kg CO ₂ /t cement Eq.]					
Specific Gross and Net CO ₂ Emissions per Cementitious Product (including Integrated Ready-Mix/Precast Businesses)						
Specific gross CO ₂ per tonne of cementitious product	[kg CO ₂ /t cementitious produced]					
- Calcination Component	[kg CO ₂ /t cementitious produced]					
- Fuel Component	[kg CO ₂ /t cementitious produced]					
Specific net CO ₂ per tonne of Cementitious product	[kg CO ₂ /t cementitious produced]					
Improvement rate - net CO ₂ per tonne of cementitious product	[% relative to base yr]					
Specific indirect CO ₂ Emission						
Specific indirect CO ₂ from external power generation per tonne of cement (eq.) of cementitious product	[kg CO ₂ /t cement Eq.]					
Specific indirect CO ₂ from external power generation per tonne of cementitious product	[kg CO ₂ /t cementitious produced]					
Specific indirect CO ₂ from net clinker imports (+) / exports (-) per tonne	[kg CO ₂ /t cement produced]					

To be updated after internet manual development which is due in 2027/early 2028

Specific indirect CO ₂ Emissions (including integrated ready-mix/precast businesses)						
Specific indirect CO ₂ from external power generation per tonne of cement (eq.)	[kg CO ₂ /t cement Eq.]					
Specific indirect CO ₂ from external power generation per tonne of cementitious product	[kg CO ₂ /t cementitious produced]					
Specific indirect CO ₂ from net clinker imports (+) / exports (-) per tonne of cementitious product	[kg CO ₂ /t cementitious produced]					
General Performance Indicators						
Net outbound clinker per net clinker consumption	[%]					
Clinker/cement (eq.) factor* ¹	[%]					
Clinker/cementitious factor* ²	[%]					
Calcined clay/cementitious factor* ²	[%]					
Specific heat consumption of clinker production	[MJ/t Cli]					
Specific heat consumption of calcined clay production	[MJ/Calcined Clay]					
Primary fossil fuel rate (kiln fuels)	[%]					
Alternative fossil fuel rate (kiln fuels)	[%]					

To be updated after internet manual development which is due in 2027/early 2028

Biomass fuel rate (kiln fuels)	[%]					
CO ₂ emission factor for kiln fuel mix	[kg CO ₂ /GJ]					
Total primary fossil fuel rate at plant level	[%]					
Total alternative fossil fuel rate at plant level	[%]					
Total biomass fuel rate at plant level	[%]					
Total hydrogen (as a fuel) rate at plant level	[%]					
Specific total power consumption* ³	[kWh/t cem prod]					
Specific total power consumption* ³ (including Integrated Ready-Mix /Precast Businesses)	[kWh/t cem prod]					
Specific power consumption of clinker production	[kWh/t cli]					
Specific power consumption of CO ₂ capture process	[kWh/t cli]					
Specific power consumption of calcined clay production	[kWh/t calcined clay]					
Specific power consumption of cement production* ³	[kWh/t cem prod]					

To be updated after internet manual development which is due in 2027/early 2028

Specific power consumption of cement production* ³ (including Integrated Ready-Mix /Precast Businesses)	[kWh/t cem prod]					
National energy conversion factor	[MJ/kWh]					

To be updated after internet manual development which is due in 2027/early 2028

*1 Clinker/cement (eq.) factor: The clinker/cement (eq.) factor is defined as: Total clinker consumed / (own clinker consumed plus gypsum, limestone, FD plus clinker substitute consumed for blending plus clinker bought and consumed). Definition of clinker/cement (eq.) factor as in Protocol Guidance Document Version 3, Section 6.3. The factor is based on clinker consumption. Hence, in the denominator sold clinker is excluded and bought clinker is included. Cement substitutes are excluded. See also the equation for its calculation in the 5th column.

*2 Clinker/cementitious factor: Definition of clinker / cementitious factor as in Protocol Guidance Document Version 3, Section 6.3. The factor is based on clinker consumption. Hence, in the denominator sold clinker is excluded and bought clinker is included. Furthermore, cement substitutes are included. See also the equation for its calculation in the 5th column.

*3 Specific power consumption: In this KPI the power consumption is related to the processing of cementitious products. Hence, it is referenced to cements and substitutes produced. In the denominator, sold clinker is excluded and bought clinker is included. See also the reference to line 21 in the equation for its calculation in the 5th column. Note: The reference is different from the

A16 Requirements for Assurance of GCCA CO₂ Data

In order to establish a standard assurance method and increase transparency, reliability and accuracy of reporting of CO₂ and other Climate Change KPIs to stakeholders, these KPIs must be independently assured in accordance with the following requirements:

Item	Requirement
Assurance Level	Assurance must be, at least, a Limited Assurance done at company level.
Assurer Reputation	The assurer must be a recognized, independent third-party assurance practitioner.
Scope of Assured Data	Assurance must include all agreed GCCA CO ₂ and Energy Protocol KPIs.
Frequency of Assurance	Assurance must be carried out at least once every two years at company level, assuring data from both years.
Coverage of Sites	Assurers must decide the number and location of sites to be visited to check the accuracy and quality from representative source data.
Sampling Plan	Plants assured under other schemes (e.g. EU ETS, CDM) must be counted as samples for GCCA CO ₂ assurance, to avoid double verification.
Assurance Standard	Assurance must be conducted following guidelines from the GCCA CO ₂ and Energy Protocol and from ISAE 3000, ISO 14064-3 or a similar standard.
Materiality Threshold	Data can only be considered material if any difference/inconsistency found in one or more of CO ₂ Inventory KPIs is less than 5%.
Assurance Statement	The assurer must provide to the GCCA Member an assurance statement summarizing the conclusions about the CO ₂ Inventory KPIs and explicitly mentioning the use of the GCCA CO ₂ and Energy Protocol Guidelines and the number of sites visited, and corresponding % of CO ₂ emissions covered.
Deadline	Data must be verified and reported: Old plants/ new plants/ acquisitions – two years at most New GCCA members – four years at most

4.2. End Notes

1. The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard. Revised Edition. <http://www.ghgprotocol.org>
2. This protocol and related activities shall be compliant with all applicable legal requirements, including competition laws and regulations, whether related to information exchange or to other competition law requirements, guidelines, or practices
3. Absolute emissions are expressed in tonnes of CO₂. Specific emissions are expressed in kilograms of CO₂ per unit product.
4. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. <http://www.ipcc-nggip.iges.or.jp>
5. See the Monitoring and Reporting Guidelines (MRG) of the EU ETS (EC 2007), http://ec.europa.eu/clima/policies/ets/monitoring_monitoring_en.htm
6. See "Act on promotion of global warming countermeasures", <http://www.env.go.jp/earth/ghg-santeikohyo/manual/chpt2.pdf>
7. Act on the Rational Use of Energy", <http://www.enecho.meti.go.jp/topics/080801/kinyuyouryou.pdf>
8. ISO 14064-1: 2006-03. Greenhouse gases. Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals. International Organization for Standardization, Switzerland.
9. See IPCC 2006, Vol. III, 2.2.1.1
10. $1.55 \text{ t raw meal /t clinker} \times 2 \text{ kg C /t raw meal} \times 3.664 \text{ kg CO}_2 \text{ /kg C} = 11 \text{ kg CO}_2 \text{ /t clinker}$, under the assumption that all organic carbon is converted to CO₂. The latter is conservative since a part of the organic carbon will usually be emitted as VOC or CO. The TOC content of 2 kg /t raw meal was determined based on 43 measurements compiled by CSI Member Companies for Europe and Northern Africa and has now been checked by collecting and analysing more than 100 analyses from different raw materials from cement plants all over the world

11. Compare IPCC 2006, Vol. II, Section 1.4.2.1 and IPCC 1996, Vol. III, p.1.29, Default carbon oxidation factors: 98% for coal, 99% for oil, and 99.5% for natural gas;
12. See IPCC 1996, Vol. III, p.1.13
13. If a plant uses wastewater, the volume consumed is typically about 10 kg per t of clinker. At a typical carbon content in the wastewater of 5% by weight, this corresponds to CO₂ emissions of about 2 kg per t of clinker or about 0.2% of a plant's typical overall CO₂ emissions (values based on data provided by several CSI member companies).
14. IPCC (1996, Table I-17) provides a default emission factor of approx. 1 g CH₄ /GJ for cement kilns, which corresponds to about 0.01% of the total CO₂-equivalent emissions per GJ fuel use. Assumptions: Direct CO₂ from cement plants is 56 – 100 kg CO₂ /GJ from fuel combustion, plus 130 – 170 kg CO₂ /GJ from raw materials calcination, totaling 186 – 270 kg CO₂ /GJ. In comparison, 1 g CH₄ /GJ corresponds to 21 g CO₂ e/GJ on a 100 year time horizon. The IPCC default is confirmed by a small set of company data compiled by the Former WBCSD CSI Task Force.
15. IPCC defaults for N₂O emissions from cement kilns are currently not available. A limited set of data compiled by the Former WBCSD CSI Task Force indicates that N₂O concentrations in kiln flue gas are usually below 10 mg /Nm³. Limited experience shows that this also remains value if SNCR technology is used for NO_x abatement. This corresponds to about 7 kg CO₂e /t clinker, or about 0.8% of the typical CO₂ emissions associated with clinker production.
16. See IPCC 1996, Vol. III, p.2.5
17. Any dust volumes which leave the kiln system and are ultimately incorporated in cementitious products should be included in the denominator. Examples include FD added to the cement mill, and direct sales of FD as a binder. In the protocol spreadsheet, such dust volumes shall be counted under mineral components used for blending, or under mineral components used as MICs. In contrast, landfilled dust should be excluded from the denominator.
18. This denominator has been considered in the earlier versions of the protocol as the most appropriate basis for monitoring emissions performance and calculating national cement industry benchmarks.
19. This may be required, for instance, if installations are defined according to the European Union's IPPC directive.

20. The case of joint operational control is not explicitly addressed in the revised WRI / WBCSD Protocol but is inferred here by analogy from the joint financial control case.
21. Some Annex 1 countries with economies in transition have chosen other years than 1990 as their base year or base period (e.g., Bulgaria and Romania: 1989, Poland: 1988, Hungary: 1985-87). In addition, all Annex 1 countries can choose 1995 as their base year for hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.
22. Besides the uncertainty of parameters, there are other error sources that can contribute to the uncertainty of emissions estimates. These include model uncertainty – i.e. the question how precisely a mathematical model reflects a specific context – and scientific uncertainty, for example related to the global warming potentials used to aggregate different greenhouse gases. In designing the protocol spreadsheet, the Former WBCSD CSI Task Force aimed to reduce the model uncertainty inherent in cement company inventories to minimal levels. Addressing scientific uncertainty, on the other hand, is clearly beyond the scope of corporate inventories. See Chapter 7 of the GHG protocol
23. Methane (CH₄), nitrous oxide (N₂O), sulfur hexafluoride (SF₆), and fluorinated hydrocarbons (PFCs, HFCs)
24. A second, but much smaller factor is the CaO- and MgO content of the raw materials and additives used.
25. Sources: PCC recommendation: IPCC 2000, pp. 3.9ff; GNR average: Cement Sustainability Initiative. Global Cement Database on CO₂ and Energy Information (<http://www.wbcsdcement.org>)

FDFDMICs

About the GCCA

The GCCA, a distinguished voice for the global cement and concrete industry, represents more than 80% of global production outside China, we have key Chinese players and a significant number of international members. We champion evidence-based advocacy, striving to cultivate a resilient and sustainable future for the industry and the world.

Our Vision: A world where concrete serves as a cornerstone of sustainable economic, social, and environmental progress, indispensable for a flourishing-built environment.

Our Mission: To guide the cement and concrete industry towards a net-zero emissions trajectory by 2050, aligning with the imperative of a 1.5°C climate pathway. www.gcca.org

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