DEDICATED TO MAKING A DIFFERENCE

Cement Sustainability Initiative (CSI)

CO_2 Accounting and Reporting Standard for the Cement Industry

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The Cement CO_2 Protocol

Version 2.0

World Business Council for Sustainable Development

Contents

Introduction

Preface for the revised protocol

Under the umbrella of the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD), a number of leading cement companies are collaborating to address issues related to global sustainability. One of these issues is the industry's emissions of carbon dioxide (CO_2), the main greenhouse gas (GHG) contributing to man-made global warming.

In 2001, the CSI companies agreed on a methodology for calculating and reporting CO_2 emissions: the Cement CO_2 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).

This second, revised edition of the Cement CO_2 Protocol 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 WRI / WBCSD Protocol, which was published in March 2004. A summary of the main changes compared to the original version of the Cement CO_2 Protocol is provided in Appendix 8.

Objectives

This protocol is intended as a tool for cement companies worldwide. It provides a harmonized methodology for calculating CO_2 emissions, with a view to reporting these emissions for various purposes. It addresses all direct and the main indirect sources of CO_2 emissions related to the cement manufacturing process in absolute as well as specific or unit-based terms. The protocol comprises two main elements: this guidance document, and an Excel spreadsheet. The spreadsheet is designed as a practical tool to help cement companies prepare their CO_2 inventories. An overview of the spreadsheet structure is provided in Appendix 1. The guidance document and the spreadsheet are collectively referred to as "the protocol" below.

The purpose of this guidance document is to explain the structure and rationale 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 3. Please note that in this protocol, metric tonnes are used, where 1 tonne = 1000 kg. For other abbreviations of units and numeric prefixes, see Appendix 7.

Relation to other CO_2 protocols

The basic calculation methods used in this protocol are compatible with the latest guidelines for national greenhouse gas inventories issued by the Intergovernmental Panel on Climate Change (IPCC), and with the revised WRI / WBCSD Protocol.[2] Default emission factors suggested in these documents are used, except where more recent, industry-specific data has become available.

This allows cement companies to report their CO_2 emissions to national governments in accordance with IPCC requirements. In addition, this protocol has been designed as a flexible tool that facilitates reporting under various schemes, such as:

- The European Greenhouse Gas Emissions Trading Scheme;[3]
- The Climate Leaders Program of the United States Environmental Protection Agency;[4]
- The draft greenhouse gas reporting guidelines of the Japanese Government;[5]
- The Greenhouse Challenge Program of the Australian Greenhouse Office.[6]

Appendix 6 provides a comparison of this protocol with the first three of these GHG reporting schemes.

Defining organizational and operational boundaries

Drawing appropriate boundaries is one of the key tasks in an emissions inventory process. In line with WRI / WBCSD (2004), 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. (See "Organizational boundaries", p. 22, of this protocol for guidance). 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;
- Grinding of clinker, additives and cement substitutes such as slag, both in integrated cement plants and stand-alone grinding stations;
- Fly ash beneficiation.

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.
- **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 "Direct Greenhous Gas Emissions from Cement Manufacturing" of this protocol provides detailed guidance on the different sources of direct emis-sions occurring in cement plants. Indirect emissions are addressed in Chapter "Indirect Greenhous Gas Emissions", p. 11.

In the context of operational boundaries, it is useful to recall the concept of scopes as defined in the revised WRI / WBCSD Protocol.

- Scope 1 emissions are direct emissions occurring from sources that are owned or controlled by the company.
- Scope 2 emissions are indirect emissions from the generation of purchased electricity consumed in the company's owned or controlled equipment.
- Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions.

The revised WRI / WBCSD Protocol requires that companies shall separately account for and report on scopes 1 and 2 at a minimum. The Cement CO_2 Protocol is consistent with this reporting requirement, except for some minor deviations which are summarized in "Scopes of Revised WRI / WBCSD GHG Protocol, p.3.

Principles for the CO_2 protocol

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. 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 boundary, 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 revised WRI / WBCSD Protocol. In addition, the protocol aims to meet the following principles:

1. Avoid double-counting at plant, company, group, national, and international levels;
2. Allow to distinguish between different drivers of emissions (technological improvement, internal and external growth);
3. Allow to report emissions in absolute as well as specific (unit-based) terms;
4. Reflect the full range of CO_2 abatements achieved;
5. Include performance indicators which do not distort the markets for cement and cementitious products, nor endanger fair trading;
6. 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 CO_2 taxation schemes, reporting under CO_2 compliance schemes (voluntary or negotiated agreements, emissions trading), industry benchmarking, and product life-cycle analysis.

Direct greenhouse gas emissions from cement manufacturing

Overview

Direct emissions are emissions from sources that are owned or controlled by the reporting entity. In cement plants, direct CO_2 emissions result from the following sources:

> Calcination of carbonates, and combustion of organic carbon contained in raw materials;
> Combustion of conventional fossil kiln fuels;
> Combustion of alternative fossil kiln fuels (also called fossil AF or fossil wastes);
> Combustion of biomass kiln fuels (including biomass wastes);
> Combustion of non-kiln fuels;
> Combustion of the carbon contained in wastewater.

Table 1: Parameters and proposed data sources for calculation of diret CO_2 emissions. See protocol spreadsheet for default CO_2 emissions of fuels

Emission components	Parameters	Units	Proposed source of parameters
CO_2 from raw materials:			
Calcination of clinker	Clinker produced	t	Measured at plant level
	CaO + MgO in clinker	%	Measured at plant level
	CaO + MgO in raw meal	%	Measured at plant level
Calcination of dust	Dust leaving kiln system	t	Measured at plant level
	Emission factor clinker	t CO_2/ t cli	As calculated above
	Dust calcination degree	% calcined	Measured at plant level
Organic carbon in raw materials	Clinker	t cli	Measured at plant level
	Raw meal : clinker ratio	t / t cli	Default = 1.55; can be adjusted
	TOC content of raw meal	%	Default = 0.2%; can be adjusted
CO_2 from fuel combustion:			
Conventional kiln fuels	Fuel consumption	t	Measured at plant level
	Lower heating value	GJ /t fuel	Measured at plant level
	Emission factor	t CO_2 /GJ fuel	IPCC / CSI defaults, or measured
Alternative fossil fuels (fossil AF)	Fuel consumption	t	Measured at plant level
	Lower heating value	GJ /t fuel	Measured at plant level
	Emission factor	t CO_2 /GJ fuel	CSI defaults, or measured
Biomass fuels (biomass AF)	Fuel consumption	t	Measured at plant level
	Lower heating value	GJ /t fuel	Measured at plant level
	Emission factor	t CO_2 /GJ fuel	IPCC / CSI defaults, or measured
Non-kiln fuels	Fuel consumption	t	Measured at plant levell
	Lower heating value	GJ /t fuel	PCC / CSI defaults, or measured
	Emission factor	t CO_2 /GJ fuel	IPCC / CSI defaults, or measured
Wastewater combusted	--	--	Quantification of CO_2 not required

t = metric tonne, AF = Alternative fuels, cli = clinker, TOC = Total organic carbon

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. 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.

CO_2 from raw material calcination

Calcination is the release of CO_2 from carbonates during pyroprocessing of the raw meal. Calcination CO_2 is directly linked with clinker production. In addition, calcination of cement kiln dust (CKD) and bypass dust can be a relevant source of CO_2 where such dust leaves the kiln system for direct sale, addition to cement, or for discarding as a waste.

On plant level, calcination CO_2 can basically be calculated in two ways: based on the volume and carbonate content of the raw meal consumed, or based on the volume and composition of clinker produced plus dust leaving the kiln system. The raw meal-based method is often used in the U.S. and Japan, while the clinker-based method is being suggested in the revised IPCC guidelines for national GHG inventories of 1996. The two methods are, in theory, equivalent. The CSI Task Force decided to focus on the clinker-based method in the protocol spreadsheet. Companies may nevertheless choose to apply the raw meal-based method or a combination of the two if adequate data are available. In doing so, 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.

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

(1) Clinker: Calcination CO_2 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.

In the absence of better data, a default of 525 kg CO_2/t clinker shall be used. This value is comparable to the IPCC default (510 kg CO_2/t) corrected for typical MgO contents in clinker. See Appendix 4 for details on the default emission factor.

(2) Dust: CO_2 from bypass dust or cement kiln dust (CKD) leaving the kiln system shall be calculated based on the relevant volumes of dust and an emission factor. 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.

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

CKD, as opposed to bypass dust, is usually not fully calcined. The emission factor for CKD shall be determined based on the emission factor for clinker and the calcination rate of the CKD, in accordance with Equation 1. This equation has been incorporated in the spread-sheet.

Equation (1)

$$EF_{CKD} = \frac{\frac{EF_{Cli}}{1+EF_{Cli}} * d}{1-\left(\frac{EF_{Cli}}{1+EF_{Cli}} * d\right)}$$

where:

EF_{CKD} = emission factor of partially calcined cement kiln dust (t CO_2/t CKD)

EF_{Cli} = plant specific emission factor of clinker (t CO_2/t clinker)

d = CKD calcination rate (released CO_2 expressed as a fraction of the total carbonate CO_2 in the raw meal)

The calcination rate d of the CKD shall preferably be based on plant-specific data. In the absence of such data, a default value of 1 shall be used. This value is conservative, i.e. it will in most cases lead to an overstatement of CKD-related emissions, because CKD is usually not fully calcined, with calcination rates often being closer to zero than one. See Appendix 4 for details on Equation 1 and the calcination rate d.

In the absence of plant-specific data on dust volumes, the IPCC default for CO2 from discarded dust (2% of clinker CO_2, see Appendix 4) shall be used. It should be noted, however, that this default 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.

CO_2 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 CO_2 during pyroprocessing 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 CSI Task Force indicate that a typical value for TOC in the raw meal is about 0.1 – 0.3% (dry weight). This corresponds to CO_2 emissions of about 10 kg /t clinker, representing about 1% of the typical combined CO_2 emissions from raw material calcination and kiln fuel combustion.[7]

CO_2 emissions from organic carbon in raw materials shall be quantified and reported to ensure completeness of the inventory (See “Materiality thresholds”, p. 31). Since their contribution to overall emissions is small, however, 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%)

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 CO_2 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.

CO_2 from conventional kiln fuels

Conventional kiln fuels are fossil fuels including e.g. coal, petcoke, fuel oil and natural gas. The preferred approach is to calculate CO_2 from conventional kiln fuels (but also alternative and non-kiln fuels, (See sections “CO_2 from alternative kiln fuels” and “CO_2 from non-kiln fuels”, p. 8) based on fuel consumption, lower heating values, and the matching CO_2 emission factors. Fuel consumption and lower heating values of fuels are routinely measured at plant level. 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). The default for petcoke is based on analyses compiled by the CSI Task Force (see Appendix 5 for details).

Companies are encouraged to use plant- or country-specific emission factors if reliable data are available. 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 to account for incomplete combustion of fossil fuels.[8] In cement kilns, however, this effect is negligible, due to very high combustion temperatures and long residence time in kilns and minimal residual carbon found in clinker. Consequently, carbon in all kiln fuels shall be treated as fully oxidized.

CO_2 from alternative kiln 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 include fossil fuel-based fractions, such as waste tires, waste oil and plastics, and biomass fractions, such as waste wood and sewage sludge. AF serve as a substitute for conventional fossil fuels.

IPCC 1996 guidelines for national GHG inventories require the following:

> **CO_2 from biomass fuels** is considered climate-neutral, because emissions can be compensated by regrowth of biomass in the short term. CO_2 from biomass fuels is reported as a “memo item”, but excluded from the national emissions totals. The fact that biomass is only really climate-neutral if sustainably harvested, is taken into account in the “Land use change and forestry” sections of the national inventories, where CO_2 emissions due to forest depletion are reported.

> **CO_2 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 conventional waste disposal (landfilling, incineration) are reported in the “waste management” category.

To ensure consistency with the guidelines of IPCC as well as WRI / WBCSD, there is thus a need for transparent reporting of the direct CO_2 emissions resulting from AF combustion in cement plants. Therefore, this protocol requires reporting as follows:

> Direct CO_2 from combustion of biomass fuels (including biomass wastes) shall be reported as a memo item, but excluded from emissions totals. The IPCC default emission factor of 110 kg CO_2/ GJ for solid biomass shall be used, except where other, reliable emission factors are available.[9]

> Direct CO_2 from combustion of **fossil** AF shall be calculated and included in the total of direct CO_2 emissions (**gross emissions total**). CO_2 emission factors depend on the type of AF 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 compiled by the CSI Task Force.

> Indirect **GHG savings** achieved through the utilization of AF, and resulting **net emissions** from AF, shall be accounted for in a separate step. This is further described in “Emissions and emissions rights”, p.13.

Some AF, for example used tires and impregnated saw dust, contain both fossil and biomass carbon. Ideally, a weighted emission factor should be calculated here, based on the share of the fossil carbon in the fuel's overall carbon content. However, this share is difficult and costly to measure, and very variable for some fuels. Therefore, companies are advised to use a conservative approach where carbon from such fuels is assumed to be of 100% fossil origin, until more precise data become available.

CO_2 from non-kiln fuels

Overview

Non-kiln fuels include, for instance, fuels for thermal process equipment (e.g. dryers), auto-production of power, plant and quarry vehicles, and room heating. Cement companies shall ensure the complete reporting of CO_2 emissions from non-kiln fuels combusted on site. These emissions are accounted for in the spreadsheet as follows:

> CO_2 from non-kiln fuels 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
- raw material drying (including mineral
- components such as slag or pozzolana)
- on-site power generation

Note that fuels consumed for drying of kiln fuels are included in the kiln fuel section.

> CO_2 from off-site transports by company-owned fleets is currently excluded from the spreadsheet (see details below).

> Carbon in non-kiln fuels is assumed to be fully oxidized, i.e. carbon storage in soot or ash is not accounted for. The resulting overestimation of emissions will usually be small (approx. 1%). Companies wishing to account for incomplete oxidation of carbon in non-kiln fuels shall do so in accordance with the WRI / WBCSD tool for stationary fuel combustion.

See also Table 7 on page 34 regarding the process steps which need to be covered to ensure complete reporting according to this protocol.

CO_2 from transports

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 “Indirect greenhouse gas emissions”, p. 11 for details.

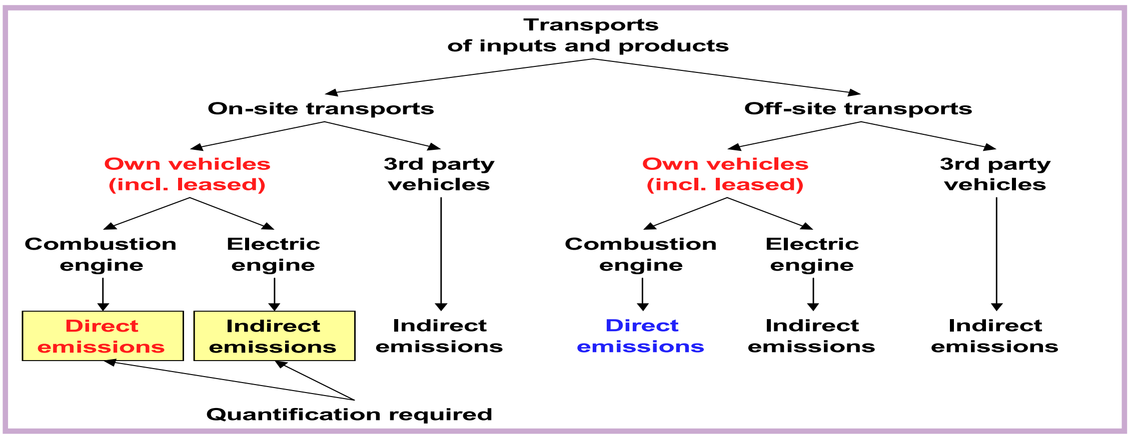
Figure 1 provides a breakdown of transport types related to cement production. This protocol requires that companies account for energy consumption and associated emissions of on-site transports carried out with own vehicles (including leased vehicles). Examples include the fuel consumption of quarry 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.

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

> On-site transports carried out by third parties (i.e. vehicles are not owned or controlled by the reporting entity);
> All off-site transports, e.g. of fuels, intermediates and finished products, irrespective of whether the transports are carried out by third parties or by company-owned fleets.

The reasons for these exclusions are that the associated emissions are typically small compared to kiln emissions, and often difficult to quantify in a consistent manner. Please note, however, that the complete exclusion of off-site transports can represent a deviation from the requirement of WRI / WBCSD to report the emissions from all owned and controlled sources. Companies aiming to comply with this WRI / WBCSD requirement have to report the emissions of their owned and controlled fleets, both for on- and off-site transports.

Figure 1: Breakdown of transports by type, and coverage of this protocol



CO_2 from wastewater

Some cement plants inject wastewater in their kilns, for example as a flame coolant for control of nitrogen oxides (NO_x). The carbon contained in the wastewater is emitted as CO_2. This protocol does not require cement companies to quantify their CO_2 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 CO_2 emissions;[10]
- 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 demonstrate with approximate calculations that their consumption of waste water has no material impact on their overall CO_2 emissions.

Non-CO_2 greenhouse gases

Emissions of methane (CH_4) from cement kilns are very small due to the high combustion temperatures in the kilns. CH_4 emissions are typically about 0.01% of kiln CO_2 emissions on a CO_2-equivalent basis.[11] Likewise, data compiled by the CSI Task Force indicate that emissions of nitrous oxide (N_2O) from cement kilns are typically small, but these data are currently too limited in scope to allow for generalized conclusions.[12] The other GHG covered by the Kyoto Protocol (PFC, HFC, SF_6) are found not to be relevant in the cement context.

This protocol does not require cement companies to quantify their non-CO_2 GHG emissions from kilns. Besides the relative insignificance of these gases, the main underlying reason is that most voluntary and mandatory reporting schemes are currently restricted to CO_2

Relevant emissions of CH_4 and N_2O 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 WRI / WBCSD calculation tool for stationary fuel combustion (See *www.ghgprotocol.org*).

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. Key examples include the CO_2 emissions from:

- External production of electricity consumed by cement producers;
- Production of clinker bought from other producers and inter-ground with own production;
- Production of clinker bought from other producers and inter-ground with own production;
- Production and processing of conventional and alternative fuels by third parties;
- Transport of inputs (raw materials, fuels) and outputs (cement, clinker) by third parties.

Data on indirect emissions can be useful to assess overall environmental performance of an industry. To this end, cement companies shall calculate and report two of the above four categories of indirect emissions:

- **CO_2 from external electricity production** shall be calculated based on the measured consumption of grid electricity and, preferentially, emission factors obtained from the electricity supplier. Alternatively, an average emission factor for the country may be used (see Appendix 2). In accordance with requirements of the revised WRI / WBCSD Protocol (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.

- **CO_2 from production of bought clinker** shall be calculated based on the net clinker purchases (bought clinker minus sold clinker) of the reporting entity, and the default emission factor of 862 kg CO_2 /t clinker. The latter represents an average of several companies in 2003 as determined by the CSI Task Force.
  Using net clinker purchases – as opposed to all (= gross) clinker purchases – offers the benefit that company-internal clinker transfers between plants cancel out when a company's operations are consolidated. This allows to avoid the problem of double-counting emissions related to clinker transferred within a company. The netting of bought and sold clinker volumes for the purpose of calculating associated emissions is automatically done by the spreadsheet. (See "Internal clinker transfers", p. 24 for details).

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 transports (see "CO_2 from non-kiln fuels", page 8 for details).

The approaches for calculating these 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 transports (see "CO_2 from non-kiln fuels" p. 8 for details).

Table 2: Parameters and data sources for calculation of indirect CO_2 emissions as required by this protocol

Emission	Parameters	Units	Source of parameters
CO_2 from external power production (indirect emission)	Power consumption Emission factor excl. T&D losses	GWh t CO_2 /GWh	Measured at plant level Supplier-specific value or country grid factor (see Appendix 2)
CO_2 from clinker bought (indirect emission)	Net clinker imports Emission factor	t cli t CO_2 /t cli	Measured at plant level (bought minus sold clinker) Default factor = 862 kg CO_2 /t cli

CO_2 emissions associated with the production of clinker- or cement-substituting mineral components (MIC) shall not be considered an indirect emission of the cement industry if these emissions are the result of another industrial process. This applies, in particular, for slag produced by the steel industry, and for fly ash produced by power plants. The CO_2 emissions of the facilities generating these by-products are associated with the intended main product – steel and power – and not with the by-product. The utilization of these by-products by the cement industry does not cause additional CO_2 emissions in the steel or power production.

Emissions and emission rights

A company or some of its subsidiaries can be subject to more than one CO_2 reporting and compliance system at the same time. For example, a cement company may have adopted a world-wide corporate voluntary reduction target, its European Union subsidiaries will be subject to the mandatory cap and trade scheme and its US operations may be part of the US EPA Climate Leaders program. These schemes may differ regarding the required emission reduction (i.e., the number of emissions rights allocated), as well as regarding the types of credits or other emission rights that are eligible for achieving compliance. The company will then need to report separately for each scheme, using the relevant reporting criteria.

Key objectives of this protocol are to ensure that cement companies can report the full range of emission reductions they achieve and that this will be done in a transparent, consistent and unambiguous way. Especially the reporting of emission reductions that occur outside the organizational boundaries of the reporting entity, i.e. so-called offsets, must be precisely standardized to guarantee accuracy and transparency.

With this aim this protocol uses the concepts of “Emission Rights”, “Emissions Balance”, and “Gross and Net Emissions” as defined below.

Cement companies with a voluntary corporate CO_2 reporting system or emissions target who wish to account for offsets or any other emission rights shall do so in accordance with the rules laid out in this protocol, and shall use the definition of gross and net emissions as defined in this protocol.

Cement companies that do not wish to account for offsets or other emission rights shall report only gross emissions and do not have to use the emissions balance approach.

Balance of emissions and emission rights

In the context of corporate GHG reduction targets and flexible market instruments such as emissions trading and CDM, emission assets play a crucial role. Examples of emission assets include allowances allocated and traded in cap and trade schemes, emission rights defined by voluntary targets, and offsets or “credits” for emission reductions achieved outside the organizational boundaries of the company. Such assets are collectively called emission rights in this protocol. Emission rights can, but do not have to be tradable.

Companies wishing to account for their emission rights shall do so in accordance with the rules laid out in this protocol. They shall account for emissions and emission rights separately, in order to ensure transparency in their GHG reporting. A company’s total emissions can then be balanced with its total emission rights for a given period to determine compliance with its target, if applicable (often called the “Net CO_2 Position”). The principle of this “balance sheet approach” is illustrated in Figure 2.

Figure 2: Balance sheet approach for separate accounting of emissions and emission rights. See "Gross vs net emissions", below for definition of "Initial" and "Acquired" emission rights

Emissions	**Emission rights**
CO_2 from raw materials CO_2 from conventional fossil fuels CO_2 from alternative fossil fuels (fossil wastes) CO_2 from non-kiln fuels	Initial Emission Rights: > Allowances obtained from regulator Acquired Emission Rights: > Allowances bought (+) or sold (-) in market > Project-based credits bought (+) or sold (-): CER, ERU, domestic credits[13] > Credits for using waste fuels > Other credits (e.g., for heat exports)
Total direct emissions	Total emission rights

Memo items
CO_2 from biomass fuel Indirect CO_2 (bought electricity & clinker)

Gross vs. net emissions

Objective and definition

One key objective of this protocol is to ensure that cement companies can report, and use for compliance purposes where eligible, the full range of emission reductions they achieve, irrespective of whether these reductions occur within or outside the organizational boundaries of the company. This is basically in line with emissions trading schemes and other flexible market mechanisms, which give companies flexibility with respect to where they want to achieve emission reductions.

To this end, this protocol defines an indicator for a company's net CO_2 emissions, as follows:

- **Gross emissions** are the total direct CO_2 emissions from a cement plant or company in a given period. Gross emissions include CO_2 from alternative fossil fuels, but exclude CO_2 from biomass fuels, since the latter is treated as a memo item.

- **Acquired emission rights** are all emission rights acquired by a company in a given period, except initial emissions allowances obtained from the regulator. The rationale of this definition is explained further below.

- **Net emissions** are the gross emissions minus the acquired emission rights.

Net CO_2 Emissions = Gross CO_2 Emissions - Acquired Emission Rights

Net emissions as defined here are an indicator for a company's net carbon footprint. They reflect a company's direct emissions as well as indirect emission reductions achieved, for example, by purchasing emissions allowances in the market. See "Corporate environmental reporting", p. 33 for the reporting requirements with respect to net emissions.

Defining acquired emission rights

The definition of what qualifies as an "acquired emission right" is crucial for the correct understanding of the net emissions indicator. This protocol groups the total emission rights which a company obtains in a given period into initial and acquired emission rights:

- **Initial emission rights** are allowances obtained from a regulator in the context of an emissions target or initial allocation process. In a mandatory cap and trade system, such as the EU ETS, the initial emission rights are the allowances allocated by the Competent Authority of each Member State. In case of a company's voluntary emissions target, the company's management acts as the regulator and the reduction target defines the quantity of initial emission rights. Initial emission rights are not reflected in the net emissions indicator because they do not represent emission reductions, but rather a title to emit a defined amount.

> **Acquired emission rights** include emissions allowances and credits purchased and sold in the market (with a negative sign for sales), plus any credits awarded by the regulator for emission reductions achieved outside the organizational boundaries of the company. The latter could include, for example, credits for the use of waste fuels and for exports of waste heat.

What qualifies as an acquired emission right depends on the rules of the CO_2 compliance and reporting scheme. As a result, different net emission indicators could theoretically exist. In practice, however, the main use of the net emissions indicator is for a company's voluntary GHG target and reporting. Consequently, this protocol defines only a single net emissions indicator:

Net CO_2 Emissions = Gross CO_2 Emissions – Acquired Emission Rights
With Acquired Emission Rights =
Allowances bought (+) or sold (-)
Project-based credits bought (+) or sold (-): CER, ERU, domestic credits*
*Offsets related to use of wastes as alternative fuels***

* *If credits are generated by the company itself for sale, they should be accounted for as indicated in Table 3 below.*

** *Offsets from AF use may be converted to credits if externally certified.*

Avoiding double-counting of emission reductions

When calculating acquired emission rights, it is important to avoid double-counting of emission reductions that are already reflected in a company's gross emissions, or in its indirect emissions. This is particularly true for CDM projects, where certified emission reductions (CERs) may be issued to a cement company for achieved reductions, which can then be sold to a buyer. To this end, companies shall calculate their acquired emission rights according to Table 4.

Table 3 implies, for example, that if a company reduces its own fuel consumption in a CDM project and keeps the resulting carbon credits (CERs), these credits should not be counted as acquired emission rights because the same reduction will already reflect in its gross CO_2 emissions. If the company sells the same credits, however, they should be deducted from the acquired emission rights (i.e., counted with a negative sign).

Table 3: Acquired emission rights:

Type of emissions reduced or reduced	Sign under *Acquired emission rights*		Comment
	If ER generated for own use	If ER generated for sale	
Own direct emissions	0	-	Reduction reflected in company's gross emissions
Own indirect emissions (e.g., reduced electricity imports from grid)	0	0	Reduction reflected in company's indirect emissions
Other emissions (e.g., emissions from conventional disposal of waste fuels by landfilling or incineration)	+	0	Reduced emissions were not result of company's operation

Table 4: Acquired emission rights: How to treat different types of emission reductions (ER

+ Emission reduction to be counted as acquired emission rights (positive sign)

- Emission reduction to be counted as sold emission rights (negative sign)

0 Emission reduction not to be counted as acquired emission rights

Emissions and emissions rights

Indirect emission reductions related to utilization of wastes as AF

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

Increased utilization of AF can have an influence on the direct CO_2 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.

In addition to these direct effects, utilization of AF by the cement industry typically results in GHG emission reductions at landfills and incineration plants where these wastes would otherwise be disposed. These indirect emission reductions can be equal, higher or lower than the direct CO_2 emissions from AF combustion at the cement plant, depending on the type of waste and the displaced disposal path. 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. IEA 1998).

The requirements regarding the reporting of CO_2 emissions from fossil fuel-based AF (also called “fossil AF” or “alternative fossil fuels”) vary widely between different schemes. The balance sheet approach described above provides a flexible frame-work for reporting under different schemes while still ensuring completeness, rigor and transparency of reporting:

> Direct CO_2 emissions resulting from the combustion of fossil AF must always be included in the company’s gross emissions, in accordance with Section “CO_2 from alternative kiln fuels”.

- Credits for indirect emission reductions can be reported under "Acquired Emission Rights", depending on and in compliance with the rules of the scheme under which the reporting is taking place.

- The resulting net emissions, being the gross emissions minus the acquired emission rights, reflect the emissions according to the rules of the reporting scheme under consideration.

For example:

- The United Kingdom's Climate Change Levy Agreements and the Swiss CO_2 Law require to report net emissions excluding CO_2 from fossil AF. Companies reporting under these schemes in accordance with this protocol shall calculate their gross emissions including the CO_2 from any fossil AF utilized, and apply an emissions credit equal to the direct emissions from these AF in the Acquired Emission Rights section. The resulting net emissions are exactly what the UK and Swiss reporting schemes require.

- The Monitoring Guidelines of the European ETS require reporting of gross emissions – including the CO_2 from use of fossil AF – as defined in this protocol. Moreover, the ETS rules do not foresee any generalized allocation of emission rights or credits in exchange for the use of AF by the cement industry. Therefore, utilization of AF will usually not result in any acquired emission rights under this scheme. In some EU Member States, however, utilization of AF may qualify for project-based credits, for example under the Joint Implementation (JI) mechanism of the Kyoto Protocol. Such JI credits would be counted as acquired emission rights of the cement company, provided that they are not sold to a third party. This would have an influence on the company's compliance state (i.e., the overall balance of emissions and emission rights), but not on its reporting of gross emissions under the ETS.

- Some global cement companies have voluntarily committed to their own group-wide CO_2 reduction targets, including the convention that the use of AF is considered a means to reduce global emissions (i.e., CO2 from both fossil and biomass AF is considered effectively climate-neutral). These companies will apply a credit equivalent to their CO_2 emissions from fossil AF under "Acquired Emission Rights". Since those companies will report both gross and net emissions, full transparency of information is guaranteed.

Regarding the last example, the CSI Task Force emphasizes that companies shall apply a "default" credit for fossil AF only for their voluntary corporate environmental reporting. Whenever reporting under a regulated scheme, companies shall respect the provisions of that scheme in relation to AF. Detailed instructions for voluntary environmental reporting are provided in "Recommendations for reporting", p.33.

Other indirect emission reductions

Utilization of Waste Energy

Some cement plants export waste heat to external consumers as a substitute for conventional energy sources. In analogy to the indirect effects related to the use of AF, a cement company may account for the indirect GHG emission reductions resulting from such waste heat exports by applying a credit under "Acquired Emission Rights", provided that the rules of the relevant reporting schemes allow such crediting. The credit for waste heat export will influence the company's net emissions, but not its gross emissions which fully reflect the direct CO_2 emissions associated with the production of the heat.

Similar credits may be applied for other forms of waste energy utilization, for example for on-site power generation from waste heat. However, 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 generating cement company may be considered questionable in this case.

Re-carbonization of cement as a CO_2 sink

When poured concrete is curing, it reabsorbs some CO_2 from the atmosphere. Re-absorption is however small compared to the emissions from cement production[14] and is not under control of the legal entity that reports emissions from cement manufacturing. More CO_2 is absorbed throughout the lifetime of the concrete product, but very slowly. Consquently, re-carbonization of cement is not included as a CO_2 sink in this protocol.

Emissions and emissions rights

Performance indicators

Introduction

The CO_2 Protocol aims to provide a flexible basis for CO_2 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, CO_2 compliance regimes and emissions trading, industry benchmarking, etc. System boundaries for such reporting depend largely on conventions, 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.

Denominator for specific, unit-based emissions

From a sustainable development and business point of view, the reporting of CO_2 efficiency – the specific or unit based emission – is at least as important as the reporting of absolute emissions. This raises the question how the numerator and denominator of the specific emissions should be defined. In particular, how should direct clinker sales and clinker substitutes be taken into account?

The CSI Task Force decided that companies shall calculate their specific emissions as follows (see also Figure 3):

- **Numerator**: direct gross or net emissions of the reporting company, as applicable;
- **Denominator**: all clinker produced by the reporting company for cement making or direct clinker sale, plus gypsum, limestone, CKD[15] and all clinker substitutes consumed for blending, plus all cement substitutes produced. For this denominator, the term **cementitious**

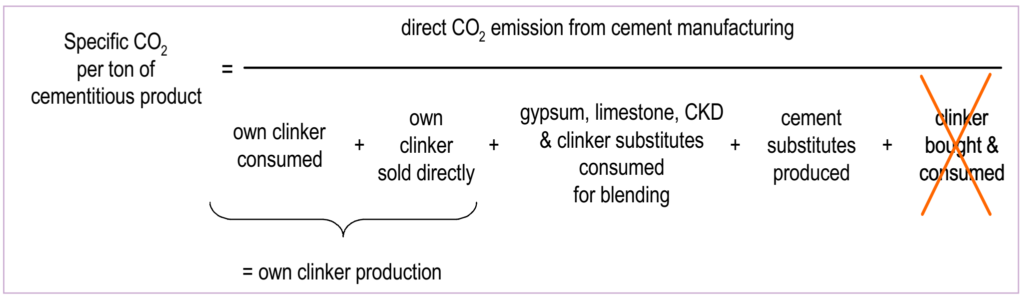


Figure 3: Definition of specific (= unit-based) CO_2 emission. The denominator is based on clinker production, hence sold clinker is included and bought clinker is excluded.
See "Dealing with stock changes", p. 21 for guidance.

products or binders is 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.

This denominator is considered the most appropriate basis for monitoring emissions performance and calculating national cement industry benchmarks. It is important to note that the denominator excludes the following:

- Bought clinker, used for cement production;
- Granulated slag which is sold to and ground by another company;
- Cement volumes which are traded without any processing.

The denominator is consequently not necessarily equal to total cement sales. It is in line with the criteria specified in “Principles for the CO_2 Protocol”, p. 4:

- It fully rewards use of clinker and cement substitutes as a CO_2 emission reduction option.
- Intergrinding of mineral components with clinker to make blended cements (i.e. clinker substitution) or using the mineral components as a binder (i.e. cement substitution) are equally rewarded; i.e. there is no bias against any type of cement.
- Bought clinker does not reduce specific emissions; i.e. there is no incentive to dislocate clinker production to less regulated countries, and there is no unfair distortion of the clinker market.

Alternative options which include bought clinker in the denominator of specific emissions do not meet the basic criteria listed on p. 4:

- If bought clinker were included in the denominator instead of the own clinker sales, clinker markets would be distorted: net sellers of clinker would be punished because their (apparent) specific emissions would increase, endangering their compliance with specific CO_2 targets. On the other hand, targets could easily be met by increasing the share of bought clinker, without any real benefit for the global climate.
- Including both bought and sold clinker in the denominator is not a feasible option because it results in double-counting between companies.

Alternative options which exclude clinker substitutes or cement substitutes from the denominator do not reflect the CO_2 efficiency improvement resulting from product substitution.

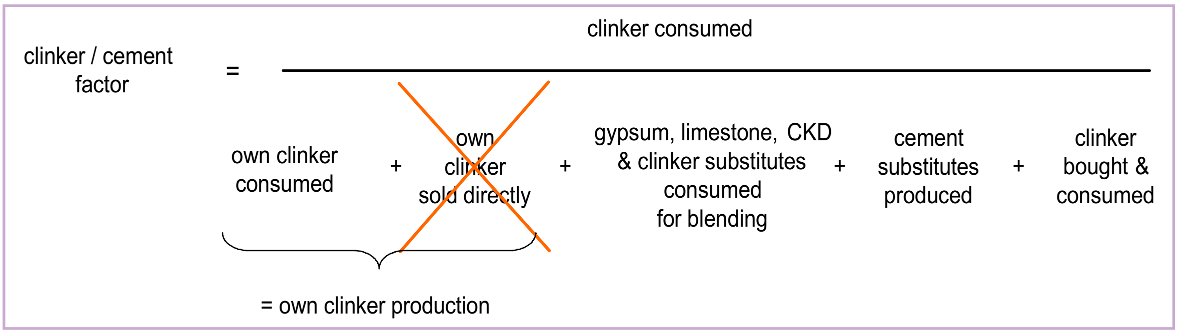


Figure 4: Definition of clinker / cement factor.
Sold clinker is excluded from the denominator, bought clinker is included.
Additions to clinker stocks can be positive (stock increase) or negative (decrease).

Denominator for other ratio indicators

For selected ratio indicators which do not use CO_2 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 cement production. The proposed clinker / cement factor is shown in Figure 4. It has also been implemented in the protocol spreadsheet.

Dealing with stock changes

Direct CO_2 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 or taken from stock. 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.

Organizational boundaries

Which installations should be covered?

CO_2 emissions result not only from kiln operations, but also from up- 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.

Voluntary reporting under this protocol, in contrast, shall cover the main direct and indirect CO_2 emissions associated with cement production as required in Chapters "Direct greenhouse gas emissions from cement manufacturing" and in "Indirect greenhouse gas emissions" 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 the section "Consolidating emissions and emissions rights" below:

> Clinker production, including raw material quarrying;

> Grinding of clinker, additives and cement substitutes such as slag, both in integrated cement plants and stand-alone grinding stations;

> Fly ash beneficiation.

Separate inventories may be established for individual facilities as appropriate, for instance if they are geographically separated or run by distinct operators.[16] The impacts of such a division will cancel out when emissions are consolidated at company or group level (See also section "Internal clinker transfers", p. 24 regarding company-internal clinker transfers). Section "Corporate environmantal reporting", p. 33 provides more guidance on voluntary environmental reporting.

Consolidating emissions and emission rights

The revised WRI / WBCSD 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 5. Text in italics denotes quotations from the revised WRI / WBCSD Protocol. For details on each approach as well as illustrative examples, please refer to Chapter 3 of the WRI / WBCSD document.

- **Equity share**: Under this approach, a company consolidates its GHG emissions according to (pro rata) the 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 revised WRI / WBCSD 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.[17]

In defining control for GHG accounting purposes, companies are advised to follow their existing rules and practices for financial reporting. Likewise, the revised WRI / WBCSD 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 revised WRI / WBCSD 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.

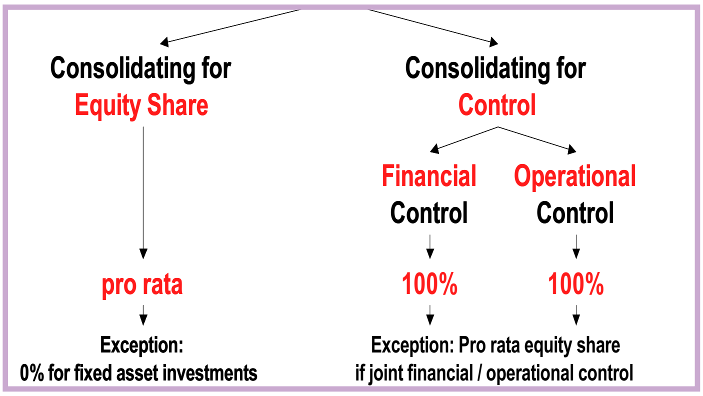


Figure 5: Options for consolidating emissions as recommended by WRI / WBCSD

With a view to the characteristics of the cement industry, the CSI Task Force 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. This approach is summarized in Table 4. See the revised WRI / WBCSD Protocol for more detailed guidance and illustrative examples for these consolidation rules.

Table 4: Key for consolidating corporate GHG emissions of cement companies, as adopted by the CSI Task Force.

Criterion for consolidation	% GHG to consolidateby 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	Relative to share ownership(see below)
Second criterion: Equity share ownership	
0% - 100% ownership	pro rata ownership

Consolidating emission rights

Companies shall consolidate their emission rights in the same way as they consolidate their emissions. When consolidating emission rights, it is important to ensure that emission rights for each plant are calculated according to the same rules across the whole area of consolidation. See pp. 13 to 17 for details on emission rights.

Internal clinker transfers

Many cement companies transfer large volumes of clinker internally, between different plants and grinding stations. How should these transfers be accounted for when preparing and consolidating CO_2 inventories for the different sites? With respect to the protocol spreadsheet, the following is noteworthy:

> At plant level, accounting for internal clinker transfers is necessary for the correct quantification of the plant's performance indicators. For example, the clinker factor of a grinding station will be distorted if a major source of clinker (internal or external) is neglected.

> At company level, clinker volumes transferred internally will cancel out when the inventories of different plants are consolidated. As a result, accounting for internal transfers is not necessary for the correct quantification of performance indicators at company level.

> Accounting for internal transfers does not lead to any double-counting at company level. The spreadsheet is designed in a way which prevents double-counting with respect to both absolute CO_2 emissions and performance indicators. This applies also for indirect CO_2 emissions related to purchased clinker, provided that all plants of a company apply the same default emission factor of 862 kg CO_2 /t clinker and report only emissions related to net volumes of purchased clinker as required in "Indirect greenhouse gas emissions" of this protocol (see pp. 11 - 12 for details).

In conclusion, this protocol allows companies to decide themselves whether they wish to account for internal clinker transfers. Accounting for internal transfers is, however, required if a company wishes to analyze CO_2 performance indicators at plant level.

Baselines, acquisitions and divestitures

CO_2 emissions performance is often measured relative to a past reference year (the “base year”). As a default, the “Kyoto base year“ 1990[18] 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 “Consolidating emissions and emissions rights”, pp. 21 - 22).

> **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 revised WRI / WBCSD Protocol.

Managing inventory quality

Summary of recommendations of revised WRI / WBCSD protocol

The revised WRI / WBCSD Protocol provides extensive guidance on the management of inventory quality. This section summarizes some key points. See the WRI / WBCSD document for details.

Implementing an inventory program

The design, updating and refinement of a company's GHG inventory is 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.

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 revised WRI / WBCSD Protocol recommends that companies should take the following seven steps in implementing quality management:

1 **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.

2 **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.

3 **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 of generic quality checking measures is provided in Table 5 below.

4 **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 (For details on uncertainty see p. 29).

5 **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 revised WRI / WBCSD Protocol and Section "Practical Experiences of companies managing inventory quality" of this document.

6 **Institutionalize formal feedback loops:** The results of the reviews in step five, 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 one, and to the persons responsible for preparing the inventory.

7 **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 5: Examples of generic quality checking measures. Source: Based on WRI / WBCSD 2004, p.51

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 criteria 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

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 CSI Task Force, is 92.8 kg CO_2/GJ with a 95% confidence interval of ± 0.2 kg CO_2/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 CO_2/GJ.

The aggregate uncertainty of an emissions estimate for a plant or company will depend on the individual uncertainties of the underlying parameters. WRI / WBCSD have 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.[19] 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 CSI Task Force recognizes that uncertainty in GHG inventories is a longer-term challenge which deserves attention. Table 6 (next page) identifies the sources of uncertainty which are typically the most relevant in a cement company, along with measures to minimize them.

Table 6: Typical major sources of uncertainty in cement sector CO2 inventories, and measures to minimize them.

* Parameters marked with an asterisk are only relevant if the raw meal based method is used for calculating CO_2 from raw material calcination.

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
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., tires and impregnated saw dust

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 revised WRI / WBCSD Protocol 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 emissions sources should be considered "immaterial". Instead, companies are encouraged to apply simplified methods for quantifying their minor sources of CO_2. This applies, for example, for CO_2 emissions from organic carbon in raw materials (See p. 7).

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:

> CO_2 emissions from off-site transports of inputs and products (See pp. 8-9) are typically small, but also difficult to quantify consistently because these transports are often carried out by third parties.

> CO_2 emissions from combustion of wastewater (See p. 10), in addition to being small, occur only in relatively few plants, and the carbon can be from biomass sources;

> CH_4 and N_2O emissions from kilns (See p. 10) are very small, but also currently outside the scope of major reporting schemes such as the EU ETS.

The exclusion of these latter emission sources is, therefore, based on several reasons and not just on a quantified materiality threshold.

Practical experience of companies in managing inventory quality

Example 1: RMC

RMC Group has set up an audit program for its CO_2 inventory submissions. Each cement plant is to be audited once per year by the Group Internal Audit Team. This gives the Group confidence in the figures being generated and should help prepare for external audits. The audit comprises of a number of tests which check the submissions against the inventory guidelines and the generic CSI spreadsheet. The audit also covers transfer of data between sheets, and comparison to data captured in other electronic and manual systems.

RMC has introduced some requirements for written procedures to support the submissions and make them more reliable and auditable. Proper documentation aids the accurate production of data and avoids key-man dependence. Examples of documentation include the frequency of stocktaking, and the frequency of laboratory tests where default values have been overridden by plant-specific data. Generally, written documentation is requested regarding:

> Sources of each piece of data, with clear data trails and supporting documents;

> Reliability of each piece of data and whether it is recorded or estimated;

> Whether any assumptions are made;
> How plant specific emissions factors and heating values are derived;

> Procedures for management and review of data, including monthly sign off by designated senior technical manager;

- Procedures for trend monitoring, and controls for quality assurance.

RMC Group requires that emission factors for raw material calcination must be quantified for each plant, rather than using the CSI default emission factor. Likewise, the calcination rate of CKD must be determined through regular analyses of CKD samples.

The representatives of each country meet, on average, once per year to be updated on developments, to discuss their queries and to be briefed on the Group-wide situation. The Group's historic data from 1990 to 2003 have been reviewed by KPMG in order to establish if they are verifiable in the eyes of an external expert.

Example 2: Italcementi

Italcementi and the other companies organized under the Italian association of cement producers have used the Cement CO_2 Protocol to quantify their CO_2 emissions. PricewaterhouseCoopers (PWC) was tasked to audit the data, with the objective of verifying the correct use of the protocol as well as the accuracy and completeness of the emissions estimates.

To simplify the task, the cement companies agreed on some common rules, such as e.g.:

- Fuel consumed for internal transports was not taken into account;
- A standard emission factor for calcination of raw materials was used (532 kg CO_2/t cli);
- Standard emission factors from the CSI Protocol had to be used for all fuels.

A key benefit of the verification exercise was the positive response of the Italian Government who gained certainty about the reliability of the submitted emissions data. On a technical level, one finding related to the importance of using site-specific lower heating values, due to the changing composition of fuels over regions and time. Other findings included:

- The documentation of data back to 1990 can be difficult due to lack of records;
- Verification requires disclosure (to the verifier) of sensitive information, for example regarding cement composition;
- Site visits of the verifiers to the plants proved not very productive in some companies because of their central organization.

Recommendations for reporting

Introduction

CO_2 emissions monitoring and reporting has multiple goals, such as e.g.: 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 "Principles for the CO_2 Protocol", p. 4. 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 CO_2 emissions, including CO_2 from fossil wastes. CO_2 from biomass fuels should be reported as a memo item.

> Reporting under CO_2 compliance and taxation schemes will have varying reporting requirements, depending on local conventions. The protocol allows to report gross and net emissions, indirect emissions and acquired emission rights, as appropriate.

Appendix 6 summarizes the reporting requirements of the EU ETS, U.S. Climate Leaders, and the Japanese GHG Reporting Scheme as well as this protocol.

This protocol does not define any threshold for excluding "immaterial" emission sources. The underlying reasons are explained in "Materiality Thresholds", p. 31. 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.

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 CO_2 emissions of the reporting entity (calcination, conventional kiln fuels, alternative kiln fuels, non-kiln fuels, with biomass CO_2 as a memo item);

> Acquired emission rights, and resulting net emissions (if applicable);

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

Reporting shall be in absolute (Mt CO_2/year) as well as specific (kg CO_2/t cementitious material) units. Reporting of net emissions alone, omitting gross emissions, is not acceptable.

In order to be complete, voluntary reporting shall include the CO_2 emissions (including indirect CO_2 emissions from consumption of grid electricity) from the different process steps as shown in Table 7 (next page). In particular, cement companies shall include the following types of activities in their voluntary reporting, to the extent that they control or own the respective installations:

- Clinker production, including raw material quarrying;
- Grinding of clinker, additives and cement substitutes such as slag, both in integrated cement plants and stand-alone grinding stations;
- Fly ash beneficiation.

Additional requirements for voluntary reporting include:

- It shall be clearly stated when CO_2 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 CO_2 Protocol Version 2.0, and any material deviations from it.

Table 7: Recommended inventory boundaries for voluntary CO2 reporting.
See rows 7a-7i of spreadsheet for background.
n.a. = not applicable.

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 "Which installations should be covered", p. 22 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 transports: ® n.a
Off-site transports	No	Reporting 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.	--

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.

Scopes of revised WRI / WBCSD GHG protocol

The revised WRI / WBCSD Protocol classifies emissions under different scopes. Table 8 shows how the emissions sources discussed in this protocol relate to the classification of WRI / WBCSD.

The revised WRI / WBCSD Protocol requires companies to separately account for and report on scopes 1 and 2 at a minimum. This Cement CO_2 Protocol provides a basis for complete reporting as required by WRI / WBCSD, with the exception of CO_2 from company-owned off-site transport fleets, CO_2 from combustion of wastewater, and CH_4 and N_2O emissions. As explained in "Materiality thresholds" (p. 31), these latter emission sources are excluded as a default for various reasons, but can be included if required.

Table 8: Reporting scopes of WRI / WBCSD, and corresponding sections of this protocol

WRI / WBCSD classification	Corresponding sections of this protocol
Scope 1: Direct GHG emissions (only if sources are owned or controlled)	
> Process emissions	§ 3.2: CO_2 from raw material calcinations § 3.3: CO_2 from organic carbon in raw materials
> Stationary combustion sources	§ 3.4 and § 3.5: CO_2 from kiln fuels § 3.6: CO_2 from non-kiln fuels § 3.7: CO_2 from wastewater
> Mobile combustion sources	§ 3.6: CO_2 from non-kiln fuels
> Non-CO_2 greenhouse gases	§ 3.8: Non-CO_2 greenhouse gases
Scope 2: Indirect GHG emissions from purchased electricity	§ 4: Indirect emissions from grid electricity
Scope 3: Other indirect emissions	§ 4: Indirect emissions from bought clinker
Optional information: Offsets	§ 5: Emission rights, and net emissions

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.

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Acronyms and glossary

Quotations from the glossary of the revised WRI / WBCSD Protocol (2004) are marked with an asterisk. See the WRI / WBCSD Protocol for an extended glossary.

Absolute emission

Absolute GHG emissions are expressed as a mass stream, for example in tonnes of CO_2.

AF

Alternative fuels used for fossil fuel substitution in clinker production. AF are derived from waste.

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.]

Annex 1

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.

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.

Bypass dust

Discarded dust from the bypass system dedusting unit of suspension preheater, precalciner and grate preheater kilns, consisting of fully calcined kiln feed material.

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.

Climate-neutral

Burning of climate-neutral fuels does not increase the GHG stock in the atmosphere over a relevant time span. Renewable AF are climate-neutral because the CO_2 emission is compensated by an equivalent absorption by plants.

CKD

Discarded dust from long dry and wet kiln system dedusting units, consisting of partly calcined kiln feed material. Extraction and discarding of bypass dust and CKD serve to control excessive circulating elements input (alkali, sulfur, chlorine), particularly in cases of low-alkaline clinker production. The term "CKD" is sometimes used to denote all dust from cement kilns, i.e. also from bypass systems.

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.

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.

GHG

The greenhouse gases listed in Annex A of the Kyoto Protocol include: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydro-fluorocarbons (HFCs) and sulfur hexafluoride (SF_6).

Indirect emissions

Indirect GHG emissions are emissions that are a consequence of the operations of the reporting company, but occur 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).

MIC

Mineral components are natural or artificial mineral materials with hydraulic properties, used as a clinker or cement substitutes (e.g. blast furnace slag, fly ash, pozzolana).

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.

Protocol

The methodology for calculating, monitoring and reporting GHG emissions.

Specific emissions

Specific emissions are emissions expressed on a per unit output basis, for instance in kg of CO_2 per tonne of cement.

UNFCCC

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

Appendix 1 - Cement CO_2 protocol spreadsheet

The protocol spreadsheet is a Microsoft Excel document. It contains the following worksheets:

1. Read Me:
This sheet explains the meaning of the different colors used in the worksheets and provides additional instructions for the user.

2. Comments:
This sheet gives a short explanation of every line of the Plants Worksheet.

3. Plants:
One worksheet for each plant of a company.

4. Company:
Consolidation to company level of the information of every plant.

5. Fuel CO_2 factors:
Default CO_2 emission factors for fuels used in cement plants.

6. Calcination CO_2:
Auxiliary sheet to calculate the CO_2 emission factor for the calcination of raw material.

Appendix 2 - Default CO_2 emission factors for grid electricity

Source: WRI / WBCSD, Calculating CO_2 emissions from stationary combustion. Automated Worksheets, Version 2.1, October 2004. The factors are based on IEA data which are updated annually. See www.ghgprotocol.org/standard/tools.htm for the latest update.
The emission factors cover all fuels used for electricity generation, including cogeneration and district heating. They do not take into account transmission and distribution losses. All values are in kg CO_2 /MWh. See the WRI / WBCSD document for emission factors by fuel (coal, oil, natural gas).

Annex I Countries	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All Annex I	..	..	..	..	425	414	418	414	429	432	433	429	426	429	429
Australia	822	837	811	814	821	806	782	776	823	822	838	824	817	845	893
Austria	173	187	242	249	206	193	206	213	229	228	201	202	186	182	207
Belarus	..	..	..	..	350	333	350	335	310	306	301	293	301	295	301
Belgium	318	329	335	332	321	334	354	347	329	300	306	270	285	272	267
Bulgaria	646	401	461	430	488	499	474	452	438	468	478	450	449	468	437
Canada	191	211	194	186	195	174	170	175	169	190	215	206	214	224	211
Croatia	..	..	..	258	325	327	250	273	253	298	323	305	302	312	356
Czech Republic	581	608	584	632	633	582	584	582	579	553	555	563	570	561	548
Denmark	498	472	475	505	469	456	471	430	468	422	390	364	339	337	332
Estonia	..	..	..	..	649	620	619	689	679	680	720	705	696	685	670
Finland	217	206	230	235	207	232	268	252	289	267	212	207	211	239	252
France	95	118	104	118	93	63	64	71	72	66	92	80	78	62	70
Germany	574	573	571	584	553	550	548	533	541	532	509	495	500	505	518
Greece	922	978	991	941	959	934	917	872	828	869	860	822	814	832	815
Hungary	465	470	468	459	483	456	439	439	432	430	426	463	410	392	390
Iceland	1	1	1	1	1	1	1	1	1	1	3	4	0	0	0
Ireland	782	768	751	752	758	745	743	731	727	719	711	713	659	675	644
Italy	543	565	574	544	535	522	518	549	527	517	518	499	507	485	509
Japan	418	410	422	420	426	408	422	405	400	387	376	391	399	402	422
Latvia	..	..	..	..	322	266	258	260	250	213	195	214	200	189	185
Lithuania	..	..	..	..	191	190	219	177	178	171	179	185	169	151	128
Luxembourg	2038	2253	2474	2365	2371	2358	1995	1237	1106	692	148	166	149	150	305
Netherlands	599	587	580	563	551	553	520	512	483	487	460	458	436	442	440
New Zealand	113	115	104	120	147	115	92	90	121	162	123	148	138	177	144
Norway	4	3	3	3	3	3	4	3	5	4	4	5	3	5	4
Poland	661	664	656	651	653	640	643	675	665	667	664	665	672	660	663
Portugal	347	578	517	519	621	546	497	570	429	467	464	536	471	434	504
Romania	478	501	538	561	410	384	456	441	444	385	351	360	395	412	412
Russia	..	..	..	..	308	291	296	292	342	328	327	327	321	322	327
Slovak Republic	387	394	336	322	399	588	504	506	491	544	435	425	370	250	215
Slovenia	384	370	352	297	351	357	319	319	300	366	373	344	335	341	370
Spain	351	436	422	423	480	418	415	453	356	389	371	427	403	381	429
Sweden	51	45	42	48	45	47	51	44	68	43	45	41	33	36	43
Switzerland	10	11	26	28	29	25	28	29	34	29	34	29	31	31	33
Turkey	426	592	588	591	582	527	583	535	539	550	558	578	600	619	537
Ukraine	..	..	..	..	359	362	351	351	323	324	333	327	326	328	321
United Kingdom	685	669	679	663	647	571	542	547	514	477	479	433	448	471	455
United States	608	584	566	556	584	587	583	567	576	600	601	593	583	599	579

Non-Annex I	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Albania	251	240	134	79	51	80	85	37	24	21	18	39	49	61	58
Algeria	814	742	695	669	661	652	681	699	671	682	706	693	686	687	697
Angola	316	296	343	260	180	131	181	177	190	244	203	342	383	380	373
Argentina	517	512	392	409	376	338	329	273	331	299	303	329	296	226	208
Armenia	..	..	..	..	400	110	126	214	220	264	258	225	236	243	153
Azerbaijan	..	..	..	..	778	857	482	504	522	533	543	633	644	631	570
Bahrain	1084	1053	1061	1076	1055	890	877	815	811	766	822	852	868	840	835
Bangladesh	614	612	572	545	573	588	601	605	561	584	588	593	595	645	611
Benin	1102	1102	1201	1097	1132	1211	661	951	733	796	679	659	602	909	853
Bolivia	279	306	328	330	378	356	441	483	387	426	451	311	298	509	470
Bosnia and Herzegovina	..	..	..	..	860	1372	166	181	253	652	778	688	740	731	653
Brazil	63	56	53	55	61	55	51	55	56	62	62	82	81	96	83
Brunei	881	883	882	874	874	891	938	841	816	817	827	794	760	763	782
Cameroon	17	14	13	13	12	9	11	10	10	10	15	11	10	16	27
Chile	264	403	450	286	183	185	251	261	348	385	418	459	331	260	262
Chinese Taipei	442	488	449	477	485	500	498	506	510	539	549	567	578	590	581
Colombia	211	182	203	216	290	213	179	194	137	192	198	119	159	168	149
Congo	11	8	6	0	7	9	10	9	7	7	9	115	0	0	0
Costa Rica	40	19	20	50	140	99	172	156	87	34	68	21	8	14	15
Cote d'Ivoire	299	219	206	245	246	287	320	275	340	420	517	414	380	394	409
Cuba	775	763	773	772	753	785	795	811	797	803	812	825	809	811	808
Cyprus	836	846	842	832	826	831	837	834	842	851	858	861	845	778	758
Democratic Republic of Congo	25	19	5	4	3	3	4	4	4	4	5	4	4	4	4
Dominican Republic	1094	1109	845	904	752	724	843	876	745	778	831	850	760	658	734
DPR of Korea	606	633	565	551	542	504	507	480	520	557	499	552	583	582	567
Ecuador	124	140	187	230	278	195	172	314	227	295	288	237	216	273	262
Egypt	613	508	521	530	530	503	467	443	433	431	457	457	422	416	419
El Salvador	124	86	71	270	252	295	380	403	257	374	369	273	288	302	310
Eritrea	0	0	0	0	1528	1396	1502	1464	1330	1004	642	659	671	765	685
Ethiopia	182	182	136	170	64	57	44	42	40	26	25	10	11	10	8
Former Yug. Rep. of Macedonia	..	..	847	864	829	814	813	839	799	729	751	685	681	778	723
Gabon	275	258	271	279	284	299	209	255	315	315	344	326	326	264	269
Georgia	..	..	..	..	367	319	273	488	166	153	162	154	193	133	52
Ghana	0	0	0	0	0	3	4	3	1	4	232	187	78	129	212
Gibraltar	624	646	939	638	595	1050	1749	1749	1745	1721	1728	1720	1743	1751	1747
Guatemala	97	75	70	87	295	281	295	306	257	239	450	338	392	421	484
Haiti	438	436	408	454	311	216	91	327	398	568	380	289	346	340	335
Honduras	23	19	12	10	40	63	138	327	236	267	382	245	282	325	277
Hong Kong [China]	828	826	826	835	819	860	871	852	805	686	707	676	678	687	695
India	876	866	864	876	907	930	895	941	984	955	931	931	943	941	927
Indonesia	723	672	701	702	648	721	620	585	610	664	638	659	643	740	717
Iraq	486	437	459	445	580	599	649	626	626	616	621	595	627	665	696
Islamic Republic of Iran	595	581	602	594	561	585	590	605	598	593	562	582	568	578	560
Israel	807	811	829	819	820	822	821	821	827	822	825	820	800	836	823
Jamaica	825	952	757	914	893	1240	836	888	828	828	831	823	821	824	803
Jordan	866	827	815	870	895	860	832	834	811	800	807	748	708	702	741
Kazakhstan	..	..	..	..	1246	1221	1476	1095	1123	1042	1132	1116	1068	1186	1157
Kenya	97	91	54	58	68	72	87	77	95	109	296	433	641	441	372
Korea	510	472	512	549	572	542	542	530	526	545	492	478	498	475	434
Kuwait	874	791	292	834	671	648	650	595	664	666	664	656	655	658	677
Kyrgyzstan	..	..	..	..	154	107	78	121	125	133	107	100	101	100	103
Lebanon	693	1101	1835	1026	653	704	668	654	706	690	783	815	733	751	722
Libya	1053	990	779	757	736	726	878	1180	1172	1183	1190	1179	1182	1183	1183
Malaysia	491	491	595	600	550	535	491	493	498	444	481	458	445	460	501
Malta	1534	1597	1591	1120	1024	1392	1164	962	979	942	937	909	868	807	888
Mexico	550	542	529	529	516	512	565	509	508	524	587	579	585	584	581
Morocco	817	784	783	814	826	893	844	832	709	694	733	762	774	768	769
Mozambique	1405	1009	242	262	214	150	65	64	41	20	3	3	1	5	3
Myanmar	662	575	510	479	441	456	484	508	577	524	601	573	457	335	288
Namibia	0	0	0	47	27	179	260	37	48	57	45	30	21	29	29
Nepal	35	0	0	29	50	58	71	26	25	73	73	35	12	7	2
Netherlands Antilles	717	719	717	715	718	718	720	717	717	719	717	719	720	720	719
Nicaragua	458	365	359	365	442	396	448	484	498	537	632	605	610	613	563
Nigeria	537	469	421	353	384	411	334	316	323	342	396	397	428	386	373
Oman	826	804	763	775	855	849	851	831	786	758	751	809	796	817	830
Other Africa	716	626	574	522	566	539	540	531	510	576	617	524	505	467	477
Other Asia	222	190	333	339	339	369	348	324	337	327	350	374	382	340	338
Other Latin America	614	612	572	545	573	588	601	605	561	584	588	593	595	645	611

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Pakistan	368	416	408	414	393	384	391	405	443	454	411	468	480	463	443
Panama	147	160	170	262	369	297	301	317	226	280	434	240	191	400	270
Paraguay	3	0	0	0	0	0	0	3	1	0	0	0	0	0	0
People's Republic of China	741	747	753	759	764	744	737	771	779	826	819	782	754	733	740
Peru	194	191	184	153	215	178	157	186	204	211	195	171	152	120	143
Philippines	488	513	435	430	483	479	519	509	514	570	591	501	498	530	479
Qatar	612	612	603	603	603	603	603	603	603	603	603	1104	1101	789	847
Republic of Moldova	..	..	..	..	708	615	578	515	710	730	689	634	743	772	744
Saudi Arabia	609	625	563	576	576	587	608	560	570	590	591	595	600	600	599
Senegal	996	995	930	887	911	939	969	903	879	905	906	938	953	699	858
Serbia and Montenegro	..	..	..	658	733	749	690	829	800	817	803	691	723	738	771
Singapore	724	698	900	800	841	1004	977	938	880	771	761	700	635	557	527
South Africa	821	827	850	833	855	881	864	878	867	870	926	889	893	850	841
Sri Lanka	65	15	2	55	191	74	64	51	232	263	204	229	417	400	426
Sudan	392	314	325	339	301	516	353	465	483	511	466	338	533	534	632
Syria	391	400	394	417	413	439	464	461	401	398	397	395	394	394	393
Tajikistan	..	..	..	..	88	65	40	50	61	46	45	41	41	41	41
Thailand	549	541	627	674	646	630	623	606	625	634	608	596	564	562	539
Togo	1200	1147	1222	1271	1286	1281	1277	1271	1222	1259	1291	1300	1271	1258	1259
Trinidad and Tobago	723	732	708	746	730	757	713	711	689	678	710	708	691	694	707
Tunisia	731	700	651	696	685	677	651	588	602	608	602	590	567	577	557
Turkmenistan	..	..	..	..	340	505	825	931	730	630	610	791	795	757	761
United Arab Emirates	747	747	747	747	746	747	747	747	747	747	762	762	788	852	902
United Republic of Tanzania	173	160	152	136	137	160	222	285	192	390	42	126	190	112	116
Uruguay	155	238	43	94	89	67	12	53	104	70	33	187	57	3	4
Uzbekistan	..	..	..	..	524	533	476	434	446	461	486	480	459	465	462
Venezuela	350	341	323	235	227	242	222	219	199	222	237	218	210	282	283
Vietnam	1135	688	537	379	303	253	292	294	319	408	468	397	421	392	424
World	496	494	490	498	467	460	465	466	481	490	491	486	484	488	489
Yemen	763	747	771	771	773	770	771	771	772	774	775	775	774	773	772
Zambia	16	16	11	10	13	11	9	7	7	10	10	7	7	6	6
Zimbabwe	742	780	714	939	1030	1036	1091	920	879	787	905	812	741	847	757

Appendix 3 - Greenhouse gas sources and abatement options in cement production

Overview of Cement Manufacturing Process
Cement manufacture includes three main process steps (see Figure 6):

1 preparing of raw materials;

2 producing clinker, an intermediate, through pyroprocessing of raw materials;

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

There are two main sources of direct CO_2 emissions in the production process: combustion of kiln fuels, and calcination of raw materials in the pyroprocessing stage. These two sources are described in more detail below. Other CO_2 sources include direct emissions from non-kiln fuels (e.g. dryers, room heating, on-site transports), and indirect emissions from e.g. external power production and transports. Non-CO_2 greenhouse gases covered by the Kyoto Protocol[22] are not relevant in the cement context, in the sense that direct emissions of these gases are negligible.

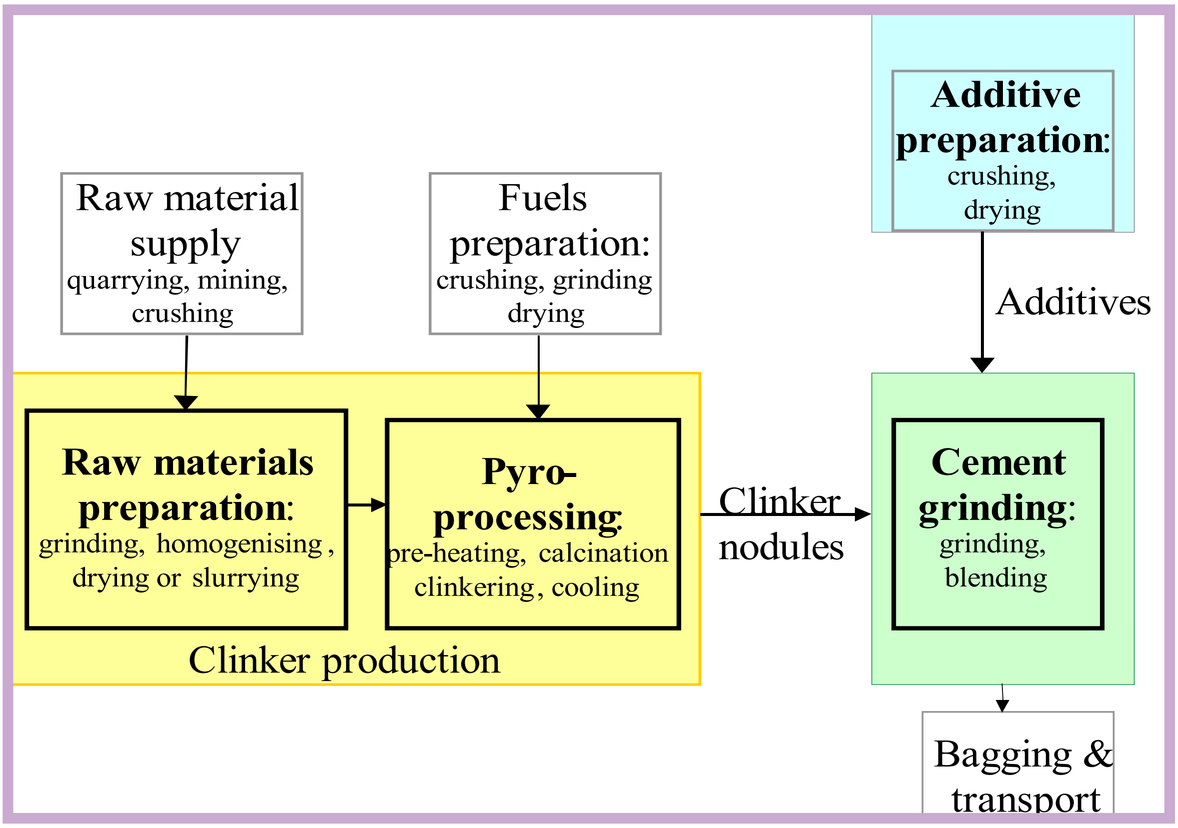

Figure 6: Process steps in cement manufacture.
Source: Ellis 2000, based on Ruth et al. 2000

CO_2 from calcination of raw materials

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

$$CaCO_3 + heat ® \; CaO + CO_2.$$

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

> CO_2 from actual clinker production;
> CO_2 from raw materials leaving the kiln system as partly calcined cement kiln dust (CKD), or as fully calcined bypass dust.

CO_2 from actual clinker production is proportional to the lime content of the clinker,[23] which in turn varies little in time or between different cement plants. As a result, the CO_2 emission factor per tonne of clinker is fairly stable (IPCC default: 510 kg CO_2/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.

CO_2 from organic carbon in raw materials

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

CO_2 from fuels for kiln operation

The cement industry traditionally uses various fossil fuels to operate cement kilns, including coal, petroleum coke, fuel oil, and natural gas. 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 tires, as well as biomass-derived fractions such as waste wood and dewatered sludges from wastewater treatment.

Both conventional and alternative fuels result in direct CO_2 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 emission reductions elsewhere, for instance from waste incineration plants or landfills.

CO_2 abatement options

CO_2 emissions in the cement industry can be tackled by different measures. The main categories of CO_2 abatement potentials include:

> use of mineral components to substitute clinker;
> fuel switching: for instance, use of natural gas or AF instead of coal;
> energy efficiency: technical and operational measures to reduce fuel and power consumption per unit clinker or cement produced;
> reduction of dust leaving the kiln system (cement kiln dust, bypass dust), where this occurs in relevant quantities.

Mineral components (MIC) are natural and artificial materials with latent hydraulic properties. Examples of MIC include natural pozzolanas, blast furnace slag, and fly ash. MIC are added to clinker to produce blended cement. In some instances, pure MIC are directly added to the concrete by the ready-mix or construction company. MIC use leads to an equivalent reduction of direct CO_2 emissions associated with clinker production, both from calcination and fuel combustion. Artificial MIC 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, indirect emissions must not be included in the cement production inventory.

Appendix 4 - Details on calcination CO_2

Summary of IPCC recommendations, and default emission factor for clinker

IPCC (1996) recommends to calculate calcination CO_2 based on the CaO content of the clinker produced (0.785 t CO_2/t CaO, multiplied with the CaO content in clinker). A default CaO content in clinker of 65% is recommended, corresponding to 510 kg CO_2/t clinker.

CO_2 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 to account for discarded dust by adding 2% to clinker CO_2 by default, acknowledging that emissions can range much higher in some instances. IPCC does not distinguish between bypass dust and cement kiln dust (CKD).

The IPCC default for clinker is similar to the recommendations of the Australian Cement Industry Federation (518 kg CO_2/t cli) and the American Portland Cement Association (522 kg CO_2/ t cli), as well as data on the Holcim Group average (524 kg CO_2/t cli). The difference may be due to the fact that IPCC neglects CO_2 from decomposition of magnesium carbonates (MgO content in clinker is usually about 2%). [24]

CSI recommends to determine the emission factors for clinker calcination on a plant-specific basis. To this end, an auxiliary worksheet 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 to use a default emission factor of 525 kg CO_2/t clinker, corresponding to the IPCC default corrected for Mg carbonates.

CO_2 from cement kiln dust: Deriving the calculation formula

Cement kiln dust (CKD) is usually not fully calcined. The CO_2 emission factor for CKD can be derived from the mass balance between CKD, raw meal and released CO_2:

1) $$CKD = RawMeal - CO2_{RM} * d$$

where:

- CKD = quantity of cement kiln dust produced (t)
- RawMeal = amount of dry raw meal consumed and converted to CKD (t)
- $CO2_{RM}$ = total carbonate CO_2 contained in the raw meal (t)
- d = CKD calcination rate (released CO_2 expressed as a fraction of the total carbonate CO_2 in the raw meal)

The CO_2 emission factor for CKD is:

2) $$EF_{CKD} = \frac{CO2_{RM} * d}{CKD} = \frac{CO2_{RM} * d}{RawMeal - CO2_{RM} * d}$$

where:

- EF_{CKD} = emission factor for CKD (t CO_2/t CKD)

Since $CO2_{RM}$ is proportional to the amount of raw meal, equation (2) can be rewritten as:

3) $$EF_{CKD} = \frac{fCO2_{RM} * d}{1 - fCO2_{RM} * d}$$

where :

> $fCO2_{RM}$ = weight fraction of carbonate CO_2 in the raw meal (--).

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

4) $$EF_{Cli} = \frac{fCO2_{RM}}{1 - fCO2_{RM}}$$

or rearranged:

5) $$fCO2_{RM} = \frac{EF_{Cli}}{1 + EF_{Cli}}$$

where:

EF_{Cli} = emission factor for clinker (t CO_2/t cli)

With the help of equation 5, equation 3 can be expressed as:

6) $$EF_{CKD} = \frac{\frac{EF_{Cli}}{1 + EF_{Cli}} * d}{1 - \frac{EF_{Cli}}{1 + EF_{Cli}} * d}$$

Equation (6) has been entered into the spreadsheet. It allows to calculate the emission factor of CKD based on (i) the emission factor of clinker, and (ii) the calcination rate of the CKD. Figure A4-1 illustrates the impact of the calcination rate. The diagonal line indicates that the assumption of a linear dependence between the CKD calcination rate and the CKD emission factor results in an overestimation of emissions by up to 50% (at low calcination rates) or up to 55 kg CO_2/t CKD.

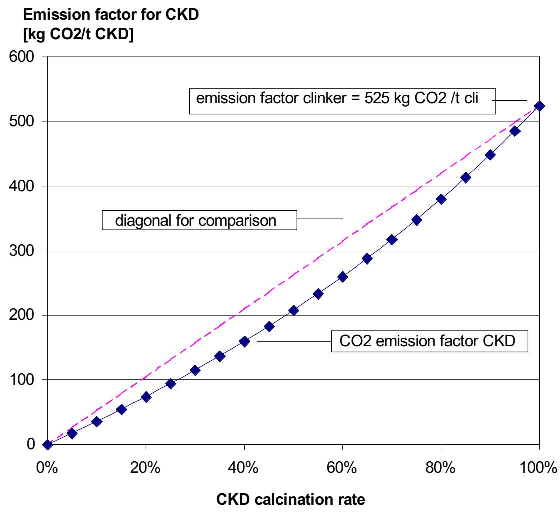

Figure A4-1: Influence of CKD calcination rate on the CO_2 emission factor for CKD, using the default clinker emission factor (525 kg CO_2/t cli) as an example.

Determining the CKD calcination rate

The CKD calcination rate d shall be calculated according to Equation (7), based on the weight fractions of carbonate CO_2 in the CKD and in the raw meal, respectively. The two input parameters $fCO2_{CKD}$ and $fCO2_{RM}$ shall be measured by chemical analysis. Possible analysis methods include, for example, a loss on ignition test or titration.

7) $$d = 1 - \frac{fCO2_{CKD} \times (1 - fCO2_{RM})}{(1 - fCO2_{CKD}) \times fCO2_{RM}}$$

where:

> $fCO2_{CKD}$ = weight fraction of carbonate CO_2 in the CKD (--)

> $fCO2_{RM}$ = weight fraction of carbonate CO_2 in the raw meal (--)

In the absence of measurement data on the composition of the CKD, 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 CKD-related emissions, because CKD is usually not fully calcined.

Appendix 4

Appendix 5 - Background material on fuel emission factors

This appendix summarizes background information on fuel emission factors collected by the CSI Task Force.

Petcoke

The CSI Task Force compiled data on the emission factor of petcoke from its member companies in 2003. The results are:

Average value: 92.8 kg CO_2/GJ
Standard deviation: 2.08 kg/GJ
No. of samples: 361

The samples were mostly taken in 1999-2003. They cover different world regions, with a focus on Europe (see Table A5-1). The resulting average of 92.8 kg/GJ replaces the former default value of 100 kg CO_2/GJ in the original version of the Cement CO_2 Protocol, which was based on preliminary estimations.

Table A5-1: Regional coverage of petcoke samples (No. of samples)

Latin America	Canada /US	Europe	Asia	Africa	Total
40	1	291	20	9	361

Alternative fuels

The CSI Task Force compiled data on the emission factors of some alternative fuels from its member companies in 2003-04. The results are shown in Table A5-2:

Table A5-2: Measurement data on alternative fuels compiled by the CSI Task Force. CO_2 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
Solvents	116	73.8	14.9
Biomass fuels:			
Animal meal	116	89.2	6.5

Appendix 5

Appendix 6 - Comparison of GHG reporting schemes

Data sources

EC 2004, Commission of the European Communities. Commission Decision of 29/01/2004 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and the Council. C(2004) 130 final. http://europa.eu.int/comm/environment/climat/emission/implementation_en.htm

EPA 2003a, United States Environmental Protection Agency. Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance: Direct Emissions from the Cement Sector. Draft for Comment through August 2003. http://www.epa.gov/climateleaders/protocol.html

EPA 2003b, United States Environmental Protection Agency. Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance: Indirect Emissions from Purchases / Sales of Electricity and Steam. December 2003. http://www.epa.gov/climateleaders/protocol.html

EPA 2004a, United States Environmental Protection Agency. Climate Leaders Greenhouse Gas Inventory Protocol: Design Principles. http://www.epa.gov/climateleaders/protocol.html

EPA 2004b, United States Environmental Protection Agency. Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance: Direct Emissions from Stationary Combustion. January 2004. http://www.epa.gov/climateleaders/protocol.html

MoE (2003), Japanese Ministry of Environment. Draft Guideline of Corporate Accounting on GHG Emissions (in Japanese). http://www.env.go.jp/earth/ondanka/santeiho/guide/pdf1_5/mat_01.pdf

WRI / WBCSD 2004, World Resources Institute & World Business Council for Sustainable Development. The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard. Revised Edition. http://www.ghgprotocol.org

Abbreviations:

- cli - clinker
- EF - emission factor
- GHG - greenhouse gas
- HHV - higher heating value (= gross calorific value)
- LHV - lower heating value (= net calorific value)
- OPC - ordinary portland cement
- TOC - total organic carbon

Appendix 6

Item	CSI Protocol, Version 2.0 (this document)	EU ETS Monitoring Guidance (EC 2004)	US Climate Leaders Program (EPA 2004a-b, 2003a-b)	Japanese GHG Reporting System (MoE 2003)
1) Coverage of sources, and parameters used for calculation:				
Clinker calcination (Process emissions)	**Clinker method** (recommended): > clinker produced- > site-specific EF, based on mass balance of CaO and MgO, or > default EF = 525 kg CO_2/t cli, if no site-specific data available Carbonate method is mentioned as a possible alternative to the clinker-based method, depending on company's preference, but is not described in any detail.	**Clinker method** (EC 2004 p.76ff): > clinker produced > Tier 2: site-specific EF, based on CaO- and MgO content in clinker and input materials (simplified formula [25]) > Tier 1 [26]: default EF = 525 kg CO_2/t cli **Carbonate method:** > raw meal consumed > EF based on carbonate content of raw meal	**Clinker method** (EPA 2003a): > same as CSI **Carbonate (or cement) method:** > cement produced > clinker to cement ratio (defaults = 0.95 for OPC and 0.75 for blended cement) > raw material to clinker ratio (default = 1.54) > $CaCO_3$ and $MgCO_3$ content of raw material (default = 0.78) > Loss on Ignition (LOI) test for measuring CO_2 release from carbonates is mentioned as possible alternative for calculating emission factors.	**Limestone method:** > limestone consumed (dry weight; default for adjusting for water content is 3.1%) > site-specific EF per t of limestone > default is 417 Kg CO_2/t lime-stone, if no site-specific data available
Dust calcination (Process emissions)	Calculated based on: > vol. of dust leaving kiln system > EF for clinker > calcination rate of dust (default = 100% calcined)	Calculated based on volume of discarded dust, plus:[27] > Tier 1: 525 kg CO_2/t dust, or > Tier 2: - EF for clinker, and - calcination rate of dust	Clinker method: Same approach as CSI. Carbonate method: Need to account for incomplete calcination of CKD is mentioned.	No calculation required. CKD generation in Japan is extremely low.
Organic carbon (TOC) in raw materials	Calculated based on: > clinker produced > raw meal to clinker ratio (default = 1.55)	Calculated like fuel emissions (but simplified method may be used, see details on precision requirements below).	Not addressed	Not addressed

Appendix 6

	> content of raw meal (default = 0.2%) Automatic calculation, input of site-specific data is possible but not required.			
Conventional kiln fuelsand non-kiln fuels	Calculated based on: > fuel consumption (site-specific) > LHV of fuels (site- or company specific) > EF of fuel (kg CO_2/GJ);CSI/IPCC defaults except if more precise EF are available Oxidation factor for carbon is 100%.	Same as CSI, except: > LHV and EF measured for each site and batch of fuel (EC 2004 p.49)	Calculated based on: > fuel consumption (site-specific) > heating values of fuels (obtained from supplier, or default HHV from list) > EF of fuel (obtained from supplier, or default EF per unit HHV from list) > oxidation factor for carbon (no default for cement kilns provided)	Calculation in accordance with WRI / WBCSD (2004): > fuel consumption (site-specific) > HHV (higher heating value is generally used in Japan) > EF of fuel (per HHV; site-specific or national defaults) Non-kiln fuels include on-site power generation and drying furnaces.
Alternative fossil kiln fuels	Same as for conventional kiln fuels	Same as for conventional kiln fuels	Same as for conventional kiln fuels	Calculated based on: > consumption of wastes (t) > default EF for different waste categories (in kg CO_2/t waste
Biomass kiln fuels	Same as for conventional kiln fuels, but: > default EF of 110 kg CO_2/GJ is used for solid biomass (IPCC 1996) > CO_2 from biomass is not included in emissions totals, but reported separately as memo item	Same as for conventional kiln fuels, but: > default EF of 0 kg CO_2/GJ is used	Same as for conventional kiln fuels, but: > default EF provided: 92 kg CO_2 /GJ LHV for wood,55 kg CO_2 /GJ LHV for landfill gas > CO_2 from biomass is not included in emissions totals, but reported separately as memo item	Quantification not required
Carbon in waste water	Quantification not required	Not explicitly addressed	Not explicitly addressed	Not explicitly addressed
Other GHG than CO_2	Quantification not required	Quantification not required, since EU-ETS is currently restricted to CO_2.	CH_4, N_2O emissions calculated from: > fuel consumption (site-specific) > default emission factors provided for different fuels Relevance of CH_4 and N_2O for cement kilns is not addressed.	CH_4 and N_2O emissions from kilns, boilers and other furnaces are calculated using default emission factors.

Indirect CO_2 from purchased clinker	Calculated based on: > purchased clinker volumes (net) > default emission factor = 862 kg CO_2/t cli	Quantification not required	Optional reporting item (EPA 2004a p.65)	Not addressed
Indirect CO_2 from purchased electricity	Calculated based on: > consumption of grid electricity > EF of grid electricity (preferentially obtained from electricity supplier, else use national default)	Quantification not required	Same as CSI, except: > if supplier-specific EF are not available, defaults should be taken from U.S. EPA eGRID database for different U.S. sub-regions (EPA 2003b p.12)	Same as CSI
Continuous emissions monitoring systems (CEMS)	Not discussed	CEMS may be used under certain conditions. Emissions measurement with CEMS must follow the relevant standards (CEN, ISO, etc.), and must be corroborated by a supporting emissions calculation as described above (EC 2004 p.18).	Emissions measurement with CEMS is mentioned as an alternative to the calculation of emissions based on fuel consumption (EPA 2004b p.6).	Not addressed
2) Emission rights and credits:				
Accounting of emission rights	Detailed instructions for accounting	Not applicable	Climate Leaders guidance on accounting for offsets is currently under development, based on the corresponding module of WRI / WBCSD protocol (EPA 2004a p.45).	Not addressed
Default for credits from alternative fossil fuels	Credits for using alternative fossil fuels must be calculated in accordance with the rules of the relevant reporting scheme. In voluntary corporate reporting, a 100% credit for CO_2 from fossil wastes may be applied if more specific data is not available.	Not applicable	Currently not addressed	Not addressed
Netting of emissions and credits	Allowed, but transparency must be maintained by reporting both gross and net emissions	Not applicable	Currently not addressed	Not addressed

3) Organizational boundaries, uncertainty and precision of estimates:				
Installations and processes covered	Emissions must be reported for the following process steps: > raw material supply > preparation of raw materials, fuel > kiln operation (pyro-processing) > cement grinding, blending > on-site power generation > room heating, cooling	Coverage of process step can vary between EU Member States. Mobile sources are usually excluded.	No guidance specific for the cement industry is provided.	Currently not addressed
Consolidation rules	Following recommendations of WRI / WBCSD protocol (2004) with minor deviations	Not applicable, since reporting is only required at installation level	Following recommendations of WRI / WBCSD protocol (EPA 2004a p.6ff)	Following primarily WRI / WBCSD. Coverage at corporate level: group basis; inclusion of overseas companies is voluntary but recommended.
Internal clinker transfers	Companies choose whether to report clinker transferred within the company, and associated emissions (see above for details on indirect emissions related to purchased clinker).	Not applicable, since guidance relates only to direct emissions.	Not explicitly addressed	Not addressed
Baseline adjustments	Following recommendations of WRI / WBCSD	Not applicable, since no consolidation of emissions is required.	Following recommendations of WRI / WBCSD protocol(EPA 2004a p.23)	Not addressed
4) Other aspects:				
Denominator for performance indicators	Different denominators are defined for specific CO_2 emissions and other performance indicators.	Not applicable	Generic guidance provided (EPA 2004a p.58)	Not addressed
Materiality thresholds	No materiality thresholds. Small emission sources shall be quantified to the extent practical, but simplified calculation methods may be applied	No materiality thresholds. Simplified "No tier"-methods may be applied to quantify minor sources jointly emitting £ 0.5 kt CO_2/a or less than 1% of the site's total emissions, whichever is higher (EC 2004 p.15).	No materiality thresholds (EPA 2004a p.2)	Currently not addressed
Precision requirements, uncertainty assessments	Precision requirements, uncertainty assessments	Detailed requirements, depending on applicable Tier, which is a function of a site's total emissions (EC 2004 p.13 and 76ff)	Not required to quantify uncertainty ranges, but recommended to identify areas of uncertainty and make effort to use most accurate data possible (EPA 2004a p.36; EPA 2004b p.17)	Currently not addressed

Appendix 7 - 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**	
CH_4	Methane	cubic metre	m^3
N_2O	Nitrous Oxide	hectare	ha
CO_2	Carbon Dioxide	gram	g
CO	Carbon Monoxide	tonne	t
NO_x	Nitrogen Oxides	joule	J
NMVOC	Non-Methane Volatile Organic Compound	degree Celcius	°C
NH_3	Ammonia	calorie	cal
CFCs	Chlorofluorocarbons	year	yr
HFCs	Hydrofluorocarbons	capita	cap
PFCs	Perfluorocarbons	gallon	gal
SO_2	Sulfur Dioxide	dry matter	dm
SF_6	Sulphur Hexafluoride		
CCl_4	Carbon Tetrachloride		
C_2F_6	Hexafluoroethane		

Source:
IPCC 1996, Revised 1996 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^3 (tech atm)	bar	0.980665
atm	bar	1.01325
mile (statue)	kilometer	1.6093
ton CH_4	ton CO_2 equivalent	21
ton N_2O	ton CO_2 equivalent	310
ton carbon	ton CO_2	3.664

Sources: International Energy Annual, 1998; http://www.eia.doe.gov/emeu/iea/convheat.html

BP Group Reporting Guidelines, 2000

Conversion factors

A8 - Main changes compared to original protocol

The revision of the Cement CO2 Protocol served to incorporate feedback obtained from many cement companies worldwide, further improve user-friendliness and adherence to the principles stated in Chapter 2, and align the protocol with the overarching Revised GHG Pro-tocol of WRI / WBCSD. In particular, the revision involved the following main changes:

Change / Item	Guidance Chapter	Spreadsheet (WS= Worksheet)
Adapted guiding principles of the protocol	2	--
Reworded section on calcination of raw materials, to improve transparency and reflect range of possible methods	3.2	--
Introduced accounting for organic carbon in raw materials	3.3	Lines 35ff; and WS *Calcination Factor*
Added section on CO_2 emissions from wastewater injected in kilns (Guidance document); changed spreadsheet accordingly	3.7	Deleted lines 29, 121, 151, 181, 231
Updated and moved section on methane and nitrous oxide	3.8	--
Extended the guidance on indirect CO_2 related to grid electricity	4	--
Introduced accounting for emission rights; changed definition of Net Emissions	5	Lines 64a-65a, 401-426
Updated section on consolidation of emissions	7	--
Added section on intra-company clinker transfers, and changed calculation of indirect CO_2 emissions from clinker imports	7.3	Lines 49a-d
Added section on management of inventory quality	8	--
Updated recommendations for corporate environmental reporting	9.2	--
Added instructions for determination of CKD calcination rate	Appendix 4	--
Added comparison of main GHG reporting schemes (cement industry perspective)	Appendix 5	WS *Fuel CO_2 Factors*
Added separate rows for the following fuels: *lignite, mixed indus-trial waste, animal bone meal, animal fat, and other biomass*	Appendix 6	Lines 107a, 137a, 167a, 217a lines 113a, 143a, 173a, 223a;lines 120-123, 150-153, 180-183, 230-233;and WS F*uel CO_2 Factors*, lines 6a, 12a, 18-21
Write-protected non-input cells	--	Whole spreadsheet
Net CO_2 emissions: Eliminated distinction between *calcination component and fuel component*	--	Deleted lines 71a, 71b, 74a, 74b, 78, 79
Added rows to allow for annual variations in CO_2 emission factors for kiln fuels	--	Added lines 185-209;changed formulas in lines 211-233 and 331-334
Changed format of input cells requiring percentage data	--	Assigned percentage format to line 24, and changed connected formulas. Analogous in WS Calcination Factor

End notes

1: Absolute emissions are expressed in tonnes of CO_2. Specific emissions are expressed in kilograms of CO_2 per unit product.

2: IPCC 1996, Revised 1996 Guidelines for National Greenhouse Gas Inventories, and IPCC 2000, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. A new methodology report (2006 IPCC Guidelines for National Greenhouse Gas Inventories) is currently being elaborated. See *www.ipcc-nggip.iges.or.jp*

3: See the monitoring and reporting guidelines of the EU-ETS (EC 2004), *http://europa.eu.int/comm/environment/climat/emission/implementation_en.htm*

4: See the climate leaders design principles (EPA 2004a) and the guidance for cement sector emissions (EPA 2003a), *http://www.epa.gov/climateleaders/protocol.html*

5: See the draft CO_2 protocol developed by the Japanese Government, *http://www.env.go.jp/earth/ondanka/santeiho/guide/pdf1_4/mat_01.pdf*

6: See the reporting guidelines of the Cement Industry Federation of Australia (CIF 1998) and subsequent documents.

7: 1.55 t raw meal /t clinker x 2 kg C /t raw meal x 3.664 kg CO_2 /kg C = 11 kg CO_2 /t clinker, under the assumption that all organic carbon is converted to CO_2. 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 is based on 43 measurements compiled by CSI Member Companies for Europe and Northern Africa.

8: Default carbon oxidation factors: 98% for coal, 99% for oil, and 99.5% for natural gas; see e.g. IPCC 1996, Vol. III, p.1.29

9: See IPCC 1996, Vol. III, p.1.13

10: 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 CO_2 emissions of about 2 kg per t of clinker or about 0.2% of a plant's typical overall CO_2 emissions (values based on data provided by several CSI member companies).

11: 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 CO_2 /GJ from fuel combustion, plus 130 – 170 kg CO_2 /GJ from raw materials calcination, totaling 186 – 270 kg CO_2 /GJ. In comparison, 1 g CH_4 /GJ corresponds to 21 g CO_2 e/GJ on a 100 year time horizon. The IPCC default is con-firmed by a small set of company data compiled by the CSI Task Force.

12: IPCC defaults for N_2O emissions from cement kilns are currently not available. A limited set of data compiled by the CSI Task Force indicates that N_2O concentrations in kiln flue gas are usually below 10 mg /Nm^3. This corresponds to about 7 kg CO_2e /t clinker, or about 0.8% of the typical CO_2 emissions associated with clinker production.

13: CER and ERU, respectively, are credits derived from projects under the Clean Development Mechanism and Joint Imple-mentation of the Kyoto Protocol.

14: See IPCC 1996, Vol. III, p.2.5.

15: Any dust volumes which leave the kiln system and are ultimately incorporated in cementitious products should be included in the denominator. Examples include CKD added to the cement mill, and direct sales of CKD as a binder. In the protocol spreadsheet, such dust volumes shall be counted under mineral components used for blending, or under mineral compo-nents used as cement substitutes. In contrast, landfilled dust should be excluded from the denominator.

16: This may be required, for instance, if installations are defined according to the European Union's IPPC directive.

17: 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.

18: 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

19: 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 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 revised WRI / WBCSD Protocol for details.

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22: Methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), and fluorinated hydrocarbons (PFCs, HFCs)

23: A second, but much smaller factor is the CaO- and MgO content of the raw materials and additives used.
24: Sources: IPCC recommendation: IPCC 2000, pp. 3.9ff; Australian average: CIF 1998, p.20; Holcim average: Lang & Lamproye 1996

25: The formula will lead to an overstatement of emissions if relevant amounts of CaO and MgO are present in the raw material.

26: Tier 1 is only applicable for very small plants (total annual emissions £ 50'000 t CO_2)

27: This approach for calculating dust emissions is based on the implicit assumption that clinker emissions are calculated using the clinker method. No guidance is provided for the calculation of dust emissions based on the carbonate method. The carbonate methode automatically accounts for dust leaving the kiln system, but not for the fact that dust may be incompletely calcined.

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