

**Technical Support Document for  
Process Emissions from Cement: Proposed Rule for  
Mandatory Reporting of Greenhouse Gases**

Office of Air and Radiation  
U.S. Environmental Protection Agency

January 28, 2009

## Contents

1.	Industry Description .....	3
2.	Total Emissions .....	3
2.1	Process Emissions .....	3
2.1.1	Calcination Process .....	4
2.1.2	Raw Materials .....	4
2.2	Combustion Emissions .....	5
3.	Review of Existing Programs and Methodologies .....	5
3.1	2006 IPCC Guidelines .....	6
3.2	U.S. National Inventory Report 2008 Method .....	8
3.3	WRI / WBCSD Protocol (Cement Sustainability Initiative) .....	9
3.4	California AB32 .....	9
3.5	California Climate Action Registry (CCAR) .....	9
3.6	Department of Energy’s 1605(b) Voluntary Reporting Program .....	9
3.7	EPA Climate Leaders .....	10
3.8	EU ETS .....	10
3.9	New Mexico Mandatory GHG Reporting Program .....	11
3.10	The Climate Registry .....	11
4.	Options for Reporting Threshold .....	12
4.1	Options Considered .....	12
4.1.1	Emissions-based Threshold .....	12
4.1.2	Clinker Production Capacity-based Threshold .....	12
4.1.3	All Clinker Production Facilities .....	13
4.2	Analysis of Emissions and Facilities Covered Per Option .....	13
4.2.1	Emissions-based Threshold .....	13
4.2.2	Clinker Production Capacity-based Threshold .....	14
4.2.3	All Clinker Production Facilities .....	16
5.	Options for Monitoring Methods .....	16
5.1	Option 1: Direct Measurement (Annual Reporting) .....	17
5.2	Option 2: Hybrid Method (Annual Reporting) .....	17
5.3	Option 3: Simplified Emission Calculation Method .....	19
6.	Options for Estimating Missing Data .....	19
6.1	Direct Measurement .....	19
6.1.1	Continuous Emissions Monitoring System (CEMS) .....	19
6.1.2	Stack Testing .....	20
6.2	Facility-specific Emission Calculation .....	21
7.	QA/QC Requirements .....	21
7.1	Direct Measurement .....	21
7.2	Facility-specific Emission Calculation .....	22
8.	Types of Emissions Information to be Reported .....	23
8.1	Additional Data to be Retained Onsite .....	24
9.	References .....	25

## 1. Industry Description

In 2006, there were 113 cement plants in 37 U.S. States and 2 cement plants in Puerto Rico. Total cement production capacity was approximately 115 million metric tons. About 94 million metric tons of portland cement and 6 million metric tons of masonry cement were produced (USGS 2007).

EPA developed a Draft Cement Database (EPA Draft Cement Database; EPA 2007), based on Portland Cement Association's (PCA's) 2004 plant level summary data that contained 115 cement plants, excluding Puerto Rico (PCA 2006). It includes 107 integrated cement plants that house both kilns for producing clinker and mills for grinding cement from clinker, and 8 fine grinding-only plants that do not produce clinker and house only grinding mills for producing cement from purchased clinker. Grinding-only facilities use purchased clinker and other additives, are generally operated using purchased electricity, and have very limited on-site combustion emissions. Plant level threshold and emissions coverage analysis reported subsequently in this document were developed from this database.<sup>1</sup> Since there are *no onsite process-related GHG emissions* from the grinding-only facilities and their onsite combustion emissions are very limited, grinding only facilities will not be discussed further in this document.

U.S. clinker production (including Puerto Rico) totaled 88,453 thousand metric tons (EPA 2008a) from an industry capacity of almost 95,000 thousand metric tons (based on EPA Draft Cement Database) in 2006. Imports of clinker were also higher due to higher demand. The 6 leading cement producing states (i.e., Texas, California, Pennsylvania, Florida, Michigan, and Alabama) accounted for 48% of U.S. production in 2006 (USGS 2007).

The process-related emissions of CO<sub>2</sub> from 2006 cement production were estimated to be 45.7 MMTCO<sub>2</sub> (EPA 2008a). This is equivalent to 0.52 metric tons of process CO<sub>2</sub> per metric ton of clinker and accounts for more than half of total GHG emissions (comprising both combustion and process-related) from cement industry.

## 2. Total Emissions

Total combustion and process-related GHG emissions from 2006 cement production, including CH<sub>4</sub> and N<sub>2</sub>O emissions from fossil fuel combustion based on plant-specific characteristics in the EPA Draft Cement Database, were estimated to be 86.8 MMTCO<sub>2</sub>e (EPA 2007). This is equivalent to 0.98 metric tons of CO<sub>2</sub>e per metric ton of clinker, of which 0.46 metric tons are attributable to fuel combustion.

### 2.1 Process Emissions

Process-related CO<sub>2</sub> emissions from cement production are the second largest source of industrial CO<sub>2</sub> emissions in the United States (EPA 2008a). Cement production process comprises the following two steps: (i) clinker production and (ii) finish grinding. Process-related

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<sup>1</sup> Although this database was used for performing threshold analysis, the names and locations of individual cement plants and their production capacities included in this database have been withheld from reporting in this document due to non-disclosure copyright information contained in PCA (2006).

GHG emissions from cement production are mainly CO<sub>2</sub> emissions that arise during the clinker production process. There are no CO<sub>2</sub> emissions from the finish grinding process, during which clinker is ground finely with gypsum and other materials to produce cement.

Predominant sources of process-related CO<sub>2</sub> emissions arise from calcination of carbonates that formed clinker and from calcination of carbonates that formed clinker kiln dust (CKD). Additional process-related CO<sub>2</sub> emissions may arise from non-carbonate, total organic carbon contained in the raw materials consumed for clinker production. The CO<sub>2</sub> generation process during cement production is described below.

### **2.1.1 Calcination Process**

During the cement production process, first, calcium carbonate or calcite (CaCO<sub>3</sub>) (common sources of which include limestone and chalk) is heated in a cement kiln at a temperature of about 1,450 °C (2,400 °F) to form lime (i.e., calcium oxide or CaO) and CO<sub>2</sub> in a process known as calcination or calcining (EPA 2008a). The lime then reacts with silica-containing materials (such as sand and shale) and iron oxide and alumina in the raw materials to produce clinker, which is an intermediate product. Very small amounts of carbonates other than CaCO<sub>3</sub>, such as magnesite (or magnesium carbonates), and non-carbonate organic carbon may also be present in the raw materials fed to the kiln (these raw materials are discussed in the next section). The other carbonates and non-carbonate organic carbon also contribute to generation of additional CO<sub>2</sub> during the calcination process (IPCC 2006). CO<sub>2</sub> generated during the calcination process as a by-product is released to the atmosphere.

Clinker typically contains a large fraction of CaO and may contain a very small fraction of MgO (magnesium oxide), which is formed during the calcination process from magnesite in the raw materials. The CaO and MgO contents of clinker are controlled to tight specifications (IPCC 2006). The clinker is then cooled and is mixed with a small amount of gypsum, and other materials, such as slag. The mixture, whose composition is varied depending on the type of portland cement that needs to be produced, is then ground together in a fine-grinding mill to make portland cement. Portland cement is used both as an end-use product and also as an intermediate product in producing different types of blended cement (FHWA 2008).

During clinker production, some of the clinker precursor materials instead of forming clinker, form partially or fully calcinated cement kiln dust (CKD) (EPA 2008a). CKD is entrained in the hot flue gases and is carried out the feed end of the kiln and eventually removed by fabric filtration or electrostatic precipitation. Depending on the chemical makeup of the CKD, especially its alkalinity, CKD may be recycled back to the kiln, added to the cement at the finishing end, or disposed of on-site or off-site. Because CKD represents product, the emphasis is on using it rather than wasting it. Additional process-related CO<sub>2</sub> emissions are generated in the kiln with the formation of partially or fully-calcined CKD.

### **2.1.2 Raw Materials**

Cement production requires a major source of calcium and smaller sources of silicon, aluminum and iron (PCA 2008). In the United States, limestone is the predominant source of calcium in cement production. Other sources of calcium used in cement production include marl and chalk.

Silicon sources include sand, shale, clay, and fly ash. The iron and aluminum are added in the form of iron ore and bauxite, or recycled metals, if not contained in the silicon source added. Several other raw materials are added and/or supplemented to provide specific properties. A wide range of raw materials are used in cement kilns for clinker production. In some cases, raw materials serve both as raw materials and an energy source, such as in the case of hazardous wastes that have CaO (van Oss 2004). Examples of the raw materials used in the U.S. cement kilns are listed in Table 2.1 (PCA 2006).

**Table 2.1 Example Raw Materials for U.S. Cement Kilns**

<ul style="list-style-type: none"> <li>• Limestone</li> <li>• Alumina Corrective</li> <li>• Alumina Sludge</li> <li>• Aluminum Oxide</li> <li>• Bauxite</li> <li>• Biosolids</li> <li>• Blast Furnace Slag</li> <li>• Bottom Ash</li> <li>• Clay</li> <li>• Copper Slag</li> </ul>	<ul style="list-style-type: none"> <li>• Filter Cakes</li> <li>• Fly ash</li> <li>• Foundry Sand</li> <li>• Foundry Sludge</li> <li>• Iron Dross</li> <li>• Iron Fines</li> <li>• Iron Ore</li> <li>• Iron Sludge</li> <li>• Iron Waste</li> <li>• Marl</li> </ul>	<ul style="list-style-type: none"> <li>• Mill Scale</li> <li>• Petroleum Contaminated Soil</li> <li>• Sand</li> <li>• Sandblast Grit</li> <li>• Shale</li> <li>• Silica Gel</li> <li>• Spent Catalyst</li> <li>• Waste Aluminum</li> </ul>
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## 2.2 Combustion Emissions

Combustion emissions include CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> emissions that result from the combustion of carbon-based fuels in the cement kiln and other onsite combustion equipment. The cement kiln is the most significant of these combustion units and typically is fueled with coal. Other fossil fuels are generally too expensive to be used for kiln fuel, however carbon-based wastes are commonly combusted in the kilns. These wastes include solvents, oils and tires. The three primary types of kilns used in the U.S. are wet kilns, simple dry kilns, and dry kilns equipped with a preheater and precalciner; with the latter kiln being the most efficient. The other sources of combustion equipment at cement plants consist of transportation equipment used in the mining and transport of raw and finished materials

## 3. Review of Existing Programs and Methodologies

This section first summarizes the Tier 1, Tier 2 and Tier 3 methods recommended by the 2006 IPCC Guidelines for National GHG Inventories, followed by the method adopted in the Inventory of U.S. GHG Emissions and Sinks 1990-2006 (EPA 2008a) for calculating process-related emissions from cement production. Other emissions calculation methods under existing reporting programs and protocols are described further in this section. Most of these programs and protocols essentially apply IPCC Tier 2 and Tier 3 approaches with some degree of flexibility (EPA 2008b). These programs include:

- World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) Cement Sustainability Initiative,

- California’s Global Warming Solutions Act under Assembly Bill No.32 (also simply referred to as *California AB32*),
- California Climate Action Registry,
- DOE/EIA’s Voluntary Reporting of Greenhouse Gases Program under Section 1605(b) of the Energy Policy Act of 1992,
- EPA Climate Leaders,
- European Union Emission Trading System (EU ETS),
- New Mexico’s Mandatory Reporting Program, and
- The Climate Registry.

In addition, three alternative approaches are discussed based on EPA’s review of these existing programs and current practices within the cement industry.

### 3.1 2006 IPCC Guidelines

The IPCC Guidelines recommend three different Tiers for calculating cement emissions.

#### *Tier 1 Method*

Under this method, process-related CO<sub>2</sub> emissions are calculated based on clinker production estimates, derived from cement production data, after adjusting for imports and exports of clinker, and a default CO<sub>2</sub> emission factor (of 0.52 metric tons of CO<sub>2</sub> per metric ton of clinker). It is adjusted for CO<sub>2</sub> from CKD. The default emission factor assumes that the clinker contains 65 percent CaO, all of which is assumed to be from carbonate sources; it also assumes that all carbonate sources are calcined 100 percent in the kiln. It is generally accepted that this is not a preferred approach for facility level emissions estimation due to large uncertainty associated with the CO<sub>2</sub> emission estimates associated with this approach.

$$CO_2 \text{ Emissions} = [ \sum_i (M_{ci} * C_{cli}) - Im + Ex ] * EF_{clc}$$

Where:

CO<sub>2</sub> Emissions = emissions of CO<sub>2</sub> from cement production (metric tons)

M<sub>ci</sub> = weight (mass) of cement produced of type i (metric tons)

C<sub>cli</sub> = clinker fraction of cement type i (fraction)

Im = imports for consumption of clinker (metric tons)

Ex = exports of clinker (metric tons)

EF<sub>clc</sub> = emission factor for clinker in the particular cement, (metric tons of CO<sub>2</sub> per metric ton of clinker). The default clinker emission factor (EF<sub>clc</sub>) is corrected for CKD.

### **Tier 2 Method**

Under this method, process-related emissions are calculated directly from clinker production data and a CO<sub>2</sub> emission factor, determined by the CaO content of clinker. Usually, the CaO content of clinker falls within the range of 60 to 67 percent and the CaO content of clinker within a facility remain relatively stable (i.e., with a minimal 1 to 2 percent variation). For example, not accounting for CKD, the CO<sub>2</sub> emission factor is 0.51 metric tons of CO<sub>2</sub> per metric ton of clinker, when the CaO content is 65 percent; the emission factor falls within the range of 0.47 metric tons of CO<sub>2</sub> per metric ton of clinker (for 60 percent CaO content of clinker) and 0.53 metric tons of CO<sub>2</sub> per metric ton of clinker (for 67 percent CaO content of clinker).

However, if a facility derives significant amount of CaO from non-carbonate source such as steel slag or fly ash, this fraction of CaO should be subtracted from the CaO content of clinker and the CO<sub>2</sub> emission factor based on clinker production must be adjusted accordingly. For example, if 5 percent of CaO in a 65 percent CaO clinker is from slag, the CaO from carbonate is 60 percent and accordingly, the adjusted CO<sub>2</sub> emission factor is 0.47 metric tons of CO<sub>2</sub> per metric ton of clinker, instead of 0.51 metric tons of CO<sub>2</sub> per metric ton of clinker that has 65 percent CaO, all from carbonate sources. This method does not adjust for CO<sub>2</sub> emissions attributable to calcination of carbonates in forming MgO content of clinker.

Process-related CO<sub>2</sub> emissions attributable to calcined CKD not recycled to the kiln are added to the clinker production based CO<sub>2</sub> estimates by using a CKD adjustment factor of 1.02 (or 2% of CO<sub>2</sub> emissions attributable to clinker production). Under this method, CO<sub>2</sub> emissions can be calculated as follows.

$$CO_2 \text{ Emissions} = M_{cl} \cdot EF_{cl} \cdot CF_{ckd}$$

Where,

CO<sub>2</sub> Emissions = process-related emissions of CO<sub>2</sub> from cement production (metric tons)

M<sub>cl</sub> = weight (mass) of clinker produced (metric tons)

EF<sub>cl</sub> = emission factor for clinker (metric ton of CO<sub>2</sub> per metric ton of clinker)

This clinker emission factor (EF<sub>cl</sub>) is not corrected for CKD.

CF<sub>ckd</sub> = emissions correction factor for CKD

### **Tier 3 Method**

This method requires full accounting of carbonates in the raw materials. Under this method, process-related CO<sub>2</sub> emissions are calculated using data on the type, composition, quantity and the emission factors of the carbonates consumed for clinker production. In addition, any organic carbon and/or carbon residues in the raw materials (such as limestone, shale and fly ash) will also need to be accounted for in estimating the CO<sub>2</sub> emissions from clinker production accurately. IPCC (2006) recommends accounting for CO<sub>2</sub> emissions from organic carbon (or kerogen) content in raw materials, if it accounts for more than 5 percent of the total heat used in the kiln. IPCC (2006) recommends facilities to perform chemical analyses with sufficient frequency to estimate the carbonate contents of raw materials used in clinker production at the facility level and derive a facility-specific emission factor to estimate CO<sub>2</sub> emissions based on clinker production. The Tier 3 method includes an adjustment factor for subtracting the carbon in

the uncalcined carbonate within CKD not reused in the kiln. The following formula facilitates calculating facility-specific CO<sub>2</sub> emissions from clinker production (IPCC 2006):

$$CO_2 \text{ Emissions} = \sum_i (EF_i * M_i * F_i) - [M_d * C_d * (1 - F_d) * EF_d] + \sum_k (M_k * X_k * EF_k)$$

Where,

CO<sub>2</sub> Emissions = process-related emissions of CO<sub>2</sub> from cement production (metric tons)

EF<sub>i</sub> = emission factor for the particular carbonate *i* (metric ton of CO<sub>2</sub> per metric ton of carbonate)

M<sub>i</sub> = weight or mass of carbonate *i* consumed in the kiln, (metric tons)

F<sub>i</sub> = fraction calcination achieved for carbonate *i*

M<sub>d</sub> = weight or mass of CKD not recycled to the kiln (metric tons)

C<sub>d</sub> = weight fraction of original carbonate in the CKD not recycled to the kiln

F<sub>d</sub> = fraction calcination achieved for CKD not recycled to kiln

EF<sub>d</sub> = emission factor for the uncalcined carbonate in CKD not recycled to the kiln, (metric ton of CO<sub>2</sub> per metric ton of carbonate)

M<sub>k</sub> = weight or mass of organic or other carbon-bearing non-fuel raw material *k* (metric tons)

X<sub>k</sub> = fraction of total organic or other carbon in specific non-fuel raw material *k*

EF<sub>k</sub> = emission factor for other carbon-bearing non-fuel raw material *k* (metric ton of CO<sub>2</sub> per metric ton of carbonate)

### 3.2 U.S. National Inventory Report 2008 Method

In the Inventory, the process-related CO<sub>2</sub> emissions from cement manufacturing process for 2006 were calculated by multiplying a CO<sub>2</sub> emission factor (in tons of CO<sub>2</sub> released per ton of clinker produced) and the total amount of clinker produced. The emission factor used in this analysis was derived by assuming an average 65 percent lime fraction in clinker and a constant reflecting the mass of CO<sub>2</sub> released per unit of lime. The CO<sub>2</sub> emission factor for clinker production is calculated as follows:

$$\begin{aligned} EF \text{ Clinker} &= 0.65 \text{ CaO} \times [44.01 \text{ g/moleCO}_2 / 56.08 \text{ g/moleCaO}] \\ &= 0.51 \text{ metric tons CO}_2 \text{ per metric ton of clinker} \end{aligned}$$

The process-related CO<sub>2</sub> emissions calculated using the above specified clinker production emission factor do not include the incremental CO<sub>2</sub> emissions attributable to the calcinated portion of the CKD.

Therefore, consistent with the 2006 IPCC Guidelines, the additional process-related CO<sub>2</sub> emissions attributable to CKD are estimated as two percent of the total process-related CO<sub>2</sub> emissions calculated from clinker production (IPCC 2006). Total process-related CO<sub>2</sub> emissions from cement manufacturing thus include the CO<sub>2</sub> emissions arising from both clinker production and CKD generation.

This method is similar to the 2006 IPCC Tier 2 method in the sense that process-related CO<sub>2</sub> emissions are calculated based on clinker production and CO<sub>2</sub> emissions factor associated with clinker production and CKD. However, because the estimates are developed at the national level, this method uses default emission factors (as the representative emission factors) for calculating



process-related CO<sub>2</sub> emissions from clinker production and from CKD. These emission factors are consistent with the IPCC Tier 1 emission factors.

### **3.3 WRI / WBCSD Protocol (Cement Sustainability Initiative)**

Under this protocol, corporate- or facility-level emissions can be calculated using either of the following two approaches—based on corporate or facility-level clinker production data or based on corporate or facility-level cement production data and facility-specific or recommended default emission factors for CO<sub>2</sub> from clinker production. This protocol takes into account both CaO and MgO content of clinker and associated CO<sub>2</sub> emissions in the clinker production data-based approach. The default emission factor for clinker is 0.525 metric tons per metric ton of clinker. This emission factor is consistent with the IPCC Tier 1 emission factor for clinker production, which also includes emissions attributable to CKD. The protocol also includes a more detailed methodology for calculating facility-specific clinker and CKD emission factors.

### **3.4 California AB32**

Under the California Mandatory GHG reporting program, facility level process-related CO<sub>2</sub> emissions from clinker production must be calculated based on the volume and composition of clinker produced and the amount of CKD discarded during the manufacturing process. Each facility is required to calculate facility-specific clinker and CKD emission factors. This method requires taking into account the CaO and MgO content of clinker and the fraction of this CaO and MgO that is non-carbonate based, in calculating the facility level emissions. In addition, this program also requires calculating CO<sub>2</sub> emissions associated with organic carbon in raw materials based on the weight of raw material consumed and the assumption that two tenth of 1 percent (=0.2%) total organic carbon is contained in raw materials.

### **3.5 California Climate Action Registry (CCAR)**

CCAR recommends corporate entities and preferably, facilities and sources, to calculate and report their process-related CO<sub>2</sub> emissions from cement manufacturing based on the amount of clinker produced, CaO and MgO content of clinker, non-carbonate CaO and MgO, and the total amount of CKD not recycled to the kiln. The clinker and CKD emission factors can be derived based on the company-(or facility-/ source-) specific data collected on these factors. In the absence of company-specific data to calculate emission factors, use of a default emission factor is permitted. Process-related CO<sub>2</sub> emissions from total organic carbon in raw materials is calculated by assuming the raw materials contain 0.2% of total organic carbon.

### **3.6 Department of Energy's 1605(b) Voluntary Reporting Program**

Three methods for calculating CO<sub>2</sub> emissions are prescribed under this program. In the case of the A-rated method (i.e., the best method), process-related CO<sub>2</sub> emissions are calculated by multiplying clinker production by the respective CaO and MgO emission factors, based on measured CaO and MgO contents of clinker. In this method, facility-specific emission factors are calculated. The B-rated method uses default emission factors or IPCC-recommended default CaO and MgO contents of clinker and clinker production to calculate CO<sub>2</sub> emissions. The C-

rated method is based on calculating CO<sub>2</sub> emissions by applying a default CO<sub>2</sub> emission factor to total cement production. For calculating CO<sub>2</sub> emissions from CKD, the program's guidelines prescribe A, B and C-rated methods, in the descending order of their stringency and preference ranking.

### **3.7 EPA Climate Leaders**

The Climate Leaders Program recommends 3 approaches for calculating and reporting corporate level process-related CO<sub>2</sub> emissions from cement manufacturing. The first approach involves calculating and reporting CO<sub>2</sub> emissions based on clinker production, bypass dust produced, and CKD produced, and carbon containing non-fuel raw materials consumed. This method, similar to the WRI/WBSCD Cement Sustainability Initiative, also takes into account both facility-specific CaO and MgO contents of clinker and CO<sub>2</sub> emissions associated with calcination of carbonates that generated both these chemical compounds.

The second approach is the cement production-based approach, which takes into account the amount of cement produced by type, adjusts for imports and exports and uses data on the clinker and carbonate fractions, if data are available, in developing the process-related CO<sub>2</sub> emissions. This is not a preferred approach due to large uncertainty associated with the CO<sub>2</sub> emission estimates associated with this approach.

The third approach calculates process-related CO<sub>2</sub> emissions based on carbonate inputs, non-carbonate carbon containing non-fuel raw materials, and CKD, and corresponding default emission factors. This method also takes into account both CaO and MgO content of clinker and CO<sub>2</sub> emissions associated with calcination of carbonates attributed to these.

### **3.8 EU ETS**

In the EU ETS protocol the recommended CO<sub>2</sub> calculation methodology for cement differs by the two reporting periods. All facilities that have the production capacity of greater than 500 metric tons of cement per day are required to report their facility level process-related CO<sub>2</sub> emissions using one of the recommended approaches.

#### ***First Reporting Period***

Under Method A (also referred to as the carbonate consumption based approach), the process-related CO<sub>2</sub> emissions are calculated by measuring the amount of carbonates in process inputs and multiplying those with the default emission factors for carbonates consumed. These emissions are adjusted to account for unreleased CO<sub>2</sub> in the uncalcined carbonates. This method accounts for CO<sub>2</sub> emissions from calcination of calcium and magnesium carbonates. The EU ETS protocol recommends two tiers for measuring carbonates in inputs using metering. While Tier 1 method allows for a maximum of -5% to +5% uncertainty, Tier 2 method allows for a maximum uncertainty range of -2.5% to +2.5% in the metered amount of pure carbonates contained in the process inputs. Default emission factors can be used under both tiers.

Under Method B (also referred to as clinker production based approach), process-related CO<sub>2</sub> emissions from clinker production and CKD production are first calculated and the CKD emissions are added to the clinker-production based CO<sub>2</sub> emissions. This method includes three tiers of activity data measurement stringency. In the case of clinker production, the maximum permissible uncertainty surrounding the amount of clinker in process output metered is -5% to +5% under Tier 1, -2.5% to +2.5% under Tier 2, and is -1.5% and +1.5% under Tier 3. In the case of CKD production, the maximum permissible uncertainty surrounding the amount of CKD in process output metered is -10% to +10% under Tier 1 and -5% to +5% under Tier 2. Default emission factor can be used under Tier 1 and emission factors are calculated using WRI/WBCSD formula.

### ***Second Reporting Period***

Under Method A (also referred to as Kiln Input approach), the process-related CO<sub>2</sub> emissions are calculated by measuring the process input and multiplying it with the CO<sub>2</sub> emission factor for carbonates and conversion factors, which are factors that account for the fraction of carbon in the raw materials that are not converted to CO<sub>2</sub>. Three tiers exist for estimating inputs to kiln, each with varying degrees of maximum permissible uncertainty range. The maximum permissible uncertainty range associated with measurement of inputs to kiln is -7.5% to +7.5% under Tier 1, -5% to +5% under Tier 2 and -2.5% to +2.5% under Tier 3. It recommends calculating an emission factor for each relevant kiln input and provides two tiers of conversion factors.

Under Method B (also referred to as Clinker method), the process-related CO<sub>2</sub> emissions are calculated by adding CO<sub>2</sub> emissions associated with calcination of CKD and bypass dust, CO<sub>2</sub> emissions attributable to non-carbonate raw materials and CO<sub>2</sub> emissions from clinker production. The two tiers of uncertainty associated with measurement of clinker production are: -5% to +5% under Tier 1 and -2.5% and +2.5% under Tier 2. Non-carbonate raw materials are measured with maximum possible uncertainty of -15% to +15% under Tier 1 and -7.5% and +7.5% under Tier 2. Stringency of calculating emissions and conversion factors also differ by the different tiers: it ranges from using default emission factors to adopting best industry practice for calculation to using country-specific and facility-specific emission and conversion factors.

## **3.9 New Mexico Mandatory GHG Reporting Program**

Under this reporting program, two approaches are recommended for measuring facility-level process-related CO<sub>2</sub> emissions from cement production. The first approach recommends measuring CO<sub>2</sub> emissions using CEMS. The second method is the production based approach, under which the production process related CO<sub>2</sub> emissions are calculated as the sum of clinker production based emissions, CKD production based emissions and total organic carbon content in raw materials.

## **3.10 The Climate Registry**

Under the reporting guidelines of the Registry, facility level process-related CO<sub>2</sub> emissions from cement production can be calculated using either clinker method or carbonate method. The clinker method involves adding CO<sub>2</sub> emissions from calcination of carbonates attributable to

clinker and CKD production and from non-carbonate, total organic carbon content in the raw materials consumed. Facility-specific or default emission factors for clinker production and CKD production can be used. Default value of total organic carbon content of 0.2% of raw material by weight can be used in the calculations. The carbonate method is similar to the Tier 3 IPCC method, described above, but incorporates Registry-specific default values for emission factors.

For additional information on all of the programs listed above, please refer to the Review of Existing Programs memorandum (EPA-HQ-OAR-2008-0508-053).

## **4. Options for Reporting Threshold**

Several alternative emission and capacity threshold options for reporting facility-level GHG emissions from the cement industry were analyzed. This section describes the reporting options considered and associated emissions and the coverage of cement production facilities under each option.

### **4.1 Options Considered**

Three different threshold options were evaluated for purposes of this analysis: an emission-based threshold, a clinker-based threshold, or no threshold. Although the main focus of this document is to analyze the process-related CO<sub>2</sub> emissions from cement production, (i) because combustion accounts for nearly half of the total GHG emissions from the cement production facilities, (ii) because the affected facilities will be required to report all their total emissions, and (iii) because the emission threshold will be calculated based on the total emissions rather than process-related emissions only, the emissions threshold and coverage analyses for the cement industry included in this section correspond to total GHG emissions (comprising both process and combustion related emissions), unless explicitly specified otherwise. Note also that a cement production plant may contain one cement kiln or multiple cement kilns. For the purposes of this threshold analysis, the entire cement production plant (including all of the collocated cement kilns) is considered a single facility.

#### **4.1.1 Emissions-based Threshold**

An option is to require all facilities that exceed a total, annual on site emission-based threshold to report. The threshold would be based on total emissions, including both production process and combustion-related emissions. For this analysis the standard thresholds examined for all source categories under the GHG rulemaking were analyzed: 1,000 metric tons of CO<sub>2</sub>e, 10,000 metric tons of CO<sub>2</sub>e, 25,000 metric tons of CO<sub>2</sub>e and 50,000 metric tons of CO<sub>2</sub>e and 100,000 metric tons of CO<sub>2</sub>e.

#### **4.1.2 Clinker Production Capacity-based Threshold**

Another option is to require facilities that exceed a given clinker production capacity threshold to report. Two types of clinker production capacity threshold can be established: (a) Daily production capacity-based threshold; and (b) Annual production capacity-based threshold.

Four annual clinker production capacity thresholds were analyzed for this study, based on the clinker production rates that correspond to the standard CO<sub>2</sub> emission thresholds discussed above: 10,000 metric tons per year, 25,000 metric tons per year, 50,000 metric tons per year or 100,000 metric tons per year. Similarly, four daily clinker production capacity thresholds that generally correspond to the annual thresholds were analyzed for this study: 250 metric tons per day, 500 metric tons per day, 750 metric tons per day and 1,000 metric tons per day.

#### **4.1.3 All Clinker Production Facilities**

Another option might be to require all integrated cement facilities to report their plant level emissions. The EPA Draft Cement database contains 107 integrated cement facilities.

### **4.2 Analysis of Emissions and Facilities Covered Per Option**

This section reports the results of the cement plant industry analysis for each of the following reporting threshold option specified:

- Emissions-based threshold
- Clinker production capacity-based threshold
- All clinker production facilities

Tables 2.1 through 2.4 illustrate the results of the data analyses in support of these alternative options. In these tables, a facility corresponds to a cement manufacturing plant; the number of emissions sources (i.e., kilns) located within the cement manufacturing plants has not been taken into account.

#### **4.2.1 Emissions-based Threshold**

Table 4.1 summarizes the number of cement facilities that will be affected under alternative facility-level total (production process- and combustion-related) annual emission-based threshold and the corresponding industry emission coverage, based on 2006 facility-level emission estimates. Covered emissions include both combustion- and process-related emissions. The results of the analysis indicate that all 107 integrated cement facilities will be covered under the program if the emission threshold is 50,000 metric tons of CO<sub>2</sub>e or below, accounting for all of the total GHG emissions from cement manufacturing.

By increasing the annual emission threshold to 100,000 metric tons of CO<sub>2</sub>, only one integrated cement plant, whose 2006-emissions accounted for over 90,000 metric tons of CO<sub>2</sub>e and approximately one-tenth of one percent of the cement industry emissions in 2006, will not be covered under this program; the remaining 106 integrated cement plants, accounting for 99.9 percent of the emission will be covered by this threshold.

**Table 4.1 Summary of the Impact of Various Total Annual Facility Level Emissions Thresholds on the Effectiveness of the Reporting Rule.\***

	Threshold – Total Annual Facility Level CO <sub>2</sub> e Emissions				
	1,000 metric tons of CO <sub>2</sub> e	10,000 metric tons of CO <sub>2</sub> e	25,000 metric tons of CO <sub>2</sub> e	50,000 metric tons of CO <sub>2</sub> e	100,000 metric tons of CO <sub>2</sub> e
Number of cement facilities exceeding the threshold	107	107	107	107	106
Total Cement Industry Emissions covered (million metric tons of CO <sub>2</sub> e)	86.83	86.83	86.83	86.83	86.74
% of Total CO <sub>2</sub> e Emissions Covered by the facilities exceeding the threshold	100.0%	100.0%	100.0%	100.0%	99.9%
Total Clinker Production Capacity (1,000 metric tons)	94,385	94,385	94,385	94,385	94,283
% of Total Clinker Production Capacity	100.0%	100.0%	100.0%	100.0%	99.9%

Note: \* Includes both combustion and process-related GHG emissions. Includes CH<sub>4</sub> and N<sub>2</sub>O emissions from stationary fossil-fuel combustion in the cement plants. Clinker production capacity was based on 2004 plant level data published by Portland Cement Association. Emissions coverage corresponds to 2006 emissions calculated by scaling 2005 clinker production and emissions developed in the EPA Draft Cement Database.

Source: Summarized from EPA Draft Cement Database (2007).

#### 4.2.2 Clinker Production Capacity-based Threshold

Table 4.2 illustrates the number of affected facilities under alternative daily clinker production capacity threshold, based on the EPA’s 2005 Draft Cement Plant Database (2007) and associated sector-wide CO<sub>2</sub> emissions coverage in 2006. The results indicate that at the production capacity of 750 metric tons of clinker per day or below, over 99 percent of the 2006-total cement industry GHG emissions and 96 percent of the total integrated cement facilities will be covered at this threshold. If the threshold is increased to 1,000 metric tons of clinker production per day, over 97 percent of the 2006-emissions and about 91 percent of the total integrated cement facilities will be covered. To put this in context, EU ETS recommends a production capacity threshold of 500 tons/day.

**Table 4.2 Summary of the Impact of Various Daily Clinker Production Capacity Thresholds on the Effectiveness of the Reporting Rule**

	Threshold clinker production capacity			
	250 metric tons / day	500 metric tons / day	750 metric tons / day	1,000 metric tons / day
Number of cement facilities exceeding the threshold	107	104	103	97
Total Daily Clinker Production Capacity (metric tons/day) of facilities exceeding the threshold	287,537	286,610	285,862	280,332
Equivalent Total Annual Clinker Production Capacity (1,000 metric tons/year) of facilities exceeding the threshold	94,385	94,074	93,814	92,002
% of Clinker Production Capacity covered by facilities exceeding the threshold	100.0%	99.7%	99.4%	97.5%
% of Total CO <sub>2</sub> e Emissions covered by the facilities exceeding the threshold	100.0%	99.6%	99.3%	97.2%

Note: Clinker production capacity was based on 2004 plant level data published by Portland Cement Association.

Source: Summarized from EPA Draft Cement Database (2007).

Table 4.3 below illustrates the number of facilities exceeding the annual clinker production capacity threshold levels of 10,000 metric tons, 25,000 metric tons, 50,000 metric tons and 100,000 metric tons and associated clinker production and emissions coverage in 2006. The results indicate that even at 100,000 metric tons of clinker production capacity per year threshold, nearly all of the integrated facilities will be reporting and that nearly all of industry emissions will be covered.

**Table 4.3 Summary of the Impact of Various Annual Clinker Production Capacity Thresholds on the Effectiveness of the Reporting Rule**

	Threshold annual clinker production capacity			
	10,000 metric tons / year	25,000 metric tons / year	50,000 metric tons / year	100,000 metric tons / year
Number of cement facilities exceeding the threshold	107	107	107	106
Total Clinker Production Capacity (1,000 metric tons / year) by facilities exceeding the threshold	94,385	94,385	94,385	94,288
% of Clinker Production Covered by facilities exceeding the threshold	100.0%	100.0%	100.0%	99.9%
% of Total CO <sub>2</sub> e Emissions Covered by the facilities exceeding the threshold	100.0%	100.0%	100.0%	99.9%

Note: Clinker production capacity was based on 2004 facility level data published by Portland Cement Association. Emissions coverage corresponds to 2006 emissions calculated by scaling 2005 clinker production and emissions developed in the EPA’s Draft Cement Database. They include both combustion and process related emissions and CH<sub>4</sub> and N<sub>2</sub>O emissions.

Source: Summarized from EPA Draft Cement Database (2007).

### 4.2.3 All Clinker Production Facilities

Table 4.4 illustrates the number of integrated cement facilities and the total emissions and clinker production capacity attributable to these facilities in 2006. All of these facilities and their associated emissions would be included under a rule requiring all clinker production facilities to report emissions.

**Table 4.4 Summary of the Impact of Including All Clinker Production Facilities on the Effectiveness of the Reporting Rule**

Facility Type	Integrated Cement Facilities
Number of integrated cement facilities	107
Total Annual Clinker Production Capacity (1,000 metric tons / year)	94,385
Process-related CO <sub>2</sub> e Emissions covered by the Integrated Facilities (million metric tons of CO <sub>2</sub> e)	45.7
Total CO <sub>2</sub> e Emissions covered by the Integrated Facilities (million metric tons of CO <sub>2</sub> e)*	86.8
% of Total Annual Clinker Production Capacity covered by these facilities	100%
% of process related CO <sub>2</sub> Emissions covered by these facilities	100%
% of Total CO <sub>2</sub> e Emissions covered by the Integrated Facilities*	100%

Note:\* Includes both combustion and process-related GHG emissions. Includes CH<sub>4</sub> and N<sub>2</sub>O emissions from stationary fossil fuel combustion in the cement facilities. Clinker production capacity was based on 2004 facility level data published by Portland Cement Association. Total emissions and emissions coverage correspond to 2006 emissions calculated by scaling 2005 production and emissions developed in the EPA’s Draft Cement Database. The process related emission estimate was obtained from the U.S. GHG Inventory, referenced below.

Source: (1) Based on EPA Draft Cement Database; (2) *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*, Final. U.S. Environmental Protection Agency, Washington, DC. April 15, 2008.

## 5. Options for Monitoring Methods

This section includes review of existing CO<sub>2</sub> emission estimation and monitoring methodologies, recommended by relevant reporting programs for monitoring / measuring CO<sub>2</sub> emissions from cement production processes.

Three common CO<sub>2</sub> emissions estimation methods emerge from the review of various monitoring and measurement protocols for calculating and reporting process-related CO<sub>2</sub> emissions from cement production. They are: (i) cement-production based method, (ii) clinker-production based method and (iii) non-fuel raw material-consumption based method. The cement production based method tends to introduce a large amount of uncertainty in the CO<sub>2</sub> emission estimates calculated. This method is not consistent with *good practice* (IPCC 2006). The other two methods that are consistent with *good practice* (IPCC 2006) and have relatively lower level of uncertainty are:

- *Calculation of process-related CO<sub>2</sub> emissions based on clinker-production, after adjusting for CO<sub>2</sub> emissions attributable to CKD. Some protocols extend this IPCC (2006) Tier 2 method by adjusting for the CO<sub>2</sub> emissions attributable to bypass dust and total organic carbon in raw materials.*



- *Calculation of process-related CO<sub>2</sub> emissions based on the quantity, type and composition of raw material consumed (including their carbonates content) and the extent of uncalcined carbonates leaving the kiln. This is similar to IPCC (2006) Tier 3 method.*

The stringency of CO<sub>2</sub> monitoring methods varies across the existing monitoring programs reviewed, depending on the method adopted for calculating emission factors and the stringency of activity data measurement.

At the facility-level, process-related CO<sub>2</sub> emissions from cement production can be monitored directly using emission measurement equipment or using one of the calculation methods specified above. For purposes of this reporting program, the following three alternative emission monitoring / measurement options were analyzed.

### **5.1 Option 1: Direct Measurement (Annual Reporting)**

In cement facilities, where process emissions and/or combustion GHG emissions are contained within a stack or vent, direct measurement constitutes either measurements of individual GHG concentration in the stack gas and the flow rate of the stack gas using a Continuous Emissions Monitoring System (CEMS), or periodic measurement of the individual GHG concentration in the stack gas and the flow rate of the stack gas using periodic stack testing. Under either a CEMS approach or a stack testing approach, the emissions measurement data would be reported annually.

Elements of a CEMS include a platform and sample probe within the stack to withdraw a sample of the stack gas, an analyzer to measure the concentration of each GHG pollutant (e.g., CO<sub>2</sub>) in the stack gas, and a flow meter within the stack to measure the flow rate of the stack gas. The emissions are calculated from the concentration of the specific GHG pollutant in the stack gas that is monitored using the concentration monitor for that pollutant and the flow rate of the stack gas. The CEMS continuously withdraws and analyzes a sample of the stack gas and continuously measures each of the individual GHG pollutant concentration and flow rate of the stack gas.

For direct measurement using stack testing, sampling equipment would be periodically brought to the site and installed temporarily in the stack to withdraw a sample of the stack gas and measure the flow rate of the stack gas. Similar to CEMS, for stack testing the emissions are calculated from the concentration of GHGs in the stack gas and the flow rate of the stack gas. The difference between stack testing and continuous monitoring is that the CEMS data provide a continuous measurement of the emissions while a stack test provides a periodic measurement of the emissions.

### **5.2 Option 2: Hybrid Method (Annual Reporting)**

Under a hybrid method, facilities that already have CEMS installed for other purposes could be required to configure their CEMS to monitor CO<sub>2</sub> from their stacks. Facilities that have CEMS

installed for measuring NO<sub>x</sub> and/or SO<sub>2</sub>, could also be required to install a CO<sub>2</sub> monitor and test, quality assure and operate the system as required under Part 75, Continuous Emissions Monitoring rule, in Volume 40 of the Code of Federal Regulations (CFR). Facilities that already have CO<sub>2</sub> CEMS could be required to test, quality assure and operate the system as required under Part 75.

Under a hybrid approach, facilities that do not have CEMS could calculate their process-related emissions using a facility-specific non-fuel raw material input consumption-based approach. This mass-balance approach is conceptually similar to the Tier 3 method of the 2006 IPCC Guidelines and Method A (Kiln Input Approach) recommended under the EU ETS for the second reporting period. Under this method, cement facilities would calculate their raw material specific carbonate contents, total organic carbon (TOC) content and emission factors. Cement facilities again readily assess carbonate contents of raw material inputs with every batch.

Under this approach, facilities would establish facility-specific weighted average annual emission factors, carbonates content, and non-carbonate carbon content, based on the weighted average of sample chemical analysis conducted specified number of times (such as on a quarterly basis) during the year. Cement facilities may, however, analyze these factors more frequently either on a daily basis or every time the batch of raw material mix changes.

The CO<sub>2</sub> emissions attributable to uncalcined carbonate within CKD not reused in the kiln would be subtracted from the CO<sub>2</sub> attributable to carbonates contained in the raw materials consumed. This would require developing facility-specific CKD emission adjustment factor or using a default factor of 1, which assumes that 100% of all carbonates in CKD is calcined. To establish a CKD adjustment factor, facilities could conduct chemical analysis with sufficient frequency to estimate the facility-specific fraction of uncalcined carbonate in CKD that is not recycled to the kiln.

### *Techniques for measuring inputs and clinker*

In the laboratories of cement facilities, chemical analysis is regularly performed as a quality control tool to ensure the clinker, and in turn, resulting cement, meets the required standards (Cement Americas 2001). In order to maintain the desired composition of clinker output, the carbonate contents and non-carbonate total organic carbon content in the raw materials are monitored and controlled within appropriate ranges. Clinker that does not meet the specified standard cannot be used for cement production, but must be recycled back to the kiln or discarded. X-ray Fluorescence (XRF) analysis is the most widely used technique for determining the chemical composition of raw materials and products (such as clinker). Further, for other environmental considerations, facilities may also use thermal analysis to screen raw materials and kiln feed to evaluate their potential to contribute to volatile organic compounds and particulate matter emissions (Cement Americas 2001).

### ***Method used to measure CKD***

CKD production depends on kiln configuration, raw materials and fuel(s) used in clinker production, and process characteristics (Gebhardt 1999). CKD primarily consists of raw materials contaminated with volatile organic compounds, such as sulfur, alkalis and chlorides (Kessler 1995). Depending on its composition, some CKD is recycled back to the kiln, some CKD is recycled into cement, and some CKD must be discarded. However to the extent possible, the CKD is recycled. As a quality control measure, cement facilities measure the composition of their CKD on a regular basis. However, for purposes of calculating CO<sub>2</sub> emissions using the non-CEMS method, facility-specific uncalcined carbonate content in CKD that is not recycled back to the kiln can be estimated through chemical analysis.

### ***Method used to measure TOC***

The CO<sub>2</sub> emissions from the non-carbonate total organic carbon (TOC) in the raw materials entering the kiln can be determined using chemical analysis. Alternatively similar to other protocols (California AB32), a default factor can be used in the place of chemical analysis to determine the non-carbonate TOC in the raw materials. An example default factor might be two-tenth of one percent of the total raw material weight.

## **5.3 Option 3: Simplified Emission Calculation Method**

This method requires measuring the clinker production and CKD production, something cement facilities do as a part of regular business operations.

## **6. Options for Estimating Missing Data**

Procedures for estimating missing data provide reporting facilities methods to use substitute data that are close to the actual values. These procedures differ by the type of monitoring method adopted. Appropriate missing data procedures are described below.

### **6.1 Direct Measurement**

Alternative direct emissions measurement methods include measuring CO<sub>2</sub> emissions using CEMS and through stack testing. The missing data procedures for these two measurement options are described below.

#### **6.1.1 Continuous Emissions Monitoring System (CEMS)**

For direct measurement of CO<sub>2</sub> flow rates or direct measurement of CO<sub>2</sub> emissions using CEMS, Part 75 establishes procedures for substituting missing data. In general, missing data from operation of the CEMS may be replaced with substitute data to determine the CO<sub>2</sub> flow rates or CO<sub>2</sub> emissions during the period in which CEMS. Two different missing data procedures—“initial” and “standard” routine—are described in Part 75. For both the initial and missing data procedures, the appropriate substitute values are calculated and applied automatically by the

Data Acquisition and Handling System (DAHS), which is a component of the CEMS (EPA 2005a).

The initial missing data procedures are used until a certain number of quality assured CEMS data are obtained. For CO<sub>2</sub>, initial missing data procedures are applicable during the initial 720 hours of operation of the CEMS unit after the initial certification at the site. The initial procedures are simple procedures, such as average of the measured CEMS data before and after the period during which the data were missing, or arithmetic average of historic data for similar operating conditions.

Under Part 75, standard missing data procedures must be applied (i) after the initial 720 hours of quality assured CEMS data have been obtained (prior to the lapse of three year period) after obtaining initial certification or (ii) after the lapse of three year period after obtaining initial certification, even if 720 hours of quality assured CEMS data have not been obtained. The standard missing data procedures are nearly identical to initial missing data procedures even after 720 hours of operation of the CEMS, if the percent monitor data availability (PMA), which the ratio of total number of hours of quality assured CEMS data to the total number of hours the monitor operated, is 95 or more (i.e.,  $\geq 95\%$ ) and the period during which the data are missing does not exceed 24 hours. These substitution data procedures are as close to the actual data as possible (without any punitive component). PMA estimates are calculated hourly by the DAHS.

As a part of 2002 revisions to Part 75, EPA added new provisions that allow sources to implement the standard missing data procedures for purpose of obtaining more representative substitute data values. For example, affected sources burning different types of fuels are given the option to separate their historical CEM data according to fuel type and to apply the standard missing data procedures on a fuel-specific basis. Part 75 also accommodates using substitute data value for each missing data hour, based on the appropriate operational characteristics of that time.

In the case of a mandatory GHG reporting program, however, it would be necessary to ensure that the missing data procedures are as accurate as a possible to the actual missing data and that they are neither conservative nor liberal. The missing data procedures from Part 75 described above are consistent with the objective of the mandatory reporting program, which seeks to develop accurate inventory of GHG emissions from each affected facility.

Some of the missing data procedures established in Part 75 are, however, not consistent with the objective of the mandatory GHG reporting program. For example, for PMAs less than 95%, the standard missing data procedures under Part 75 become increasingly conservative to ensure that emissions are not under-reported in a cap-and-trade program. These conservative emission reporting procedures result in over estimates of emissions and, therefore, are not consistent with a non-cap-and-trade, mandatory GHG reporting program.

### **6.1.2 Stack Testing**

For measuring CO<sub>2</sub> emissions using stack testing, missing data procedures are not generally anticipated. EPA's Clean Air Act National Stack Testing Guidance (EPA 2005b) document

contains the quality assurance guidance for collecting appropriate data based on pre-established site-specific test plan. For more details, refer to EPA 2005b.

## 6.2 Facility-specific Emission Calculation

Procedures for estimating missing data do not apply to CO<sub>2</sub> process emissions calculated based on clinker production and plant specific emission factors. If the carbonate content analysis required to calculate the plant specific emission factor are missing or invalid, facilities could undertake a new chemical analysis. Similarly, missing or invalid CKD analysis or organic carbon analysis could be replaced by new analysis.

There is no reason for a plant to be missing information on clinker production. Clinker production is measured with redundant systems at multiple locations within the plant; for example at the clinker cooler exit, at the inlet to the clinker storage silos, and /or between the storage silos and the finish mill. The blending of clinker and other feed materials to manufacture cement and the dispatch of finished cement is also tightly monitored and can be used to accurately measure the production of clinker.

## 7. QA/QC Requirements

Facilities could perform quality assurance and quality control (QA/QC) procedures and self data verification procedures of the measurement of actual emissions and/or of all the input and output data used in the calculation of emissions.

As part of the data verification requirements, the owner or operator could submit a detailed explanation of how company records of measurements are used to quantify all sources of carbon input and output within receipt of a written request from EPA or from the applicable State or local air pollution control agency.

Monitoring method-specific QA/QC and verification procedures are described below.

### 7.1 Direct Measurement

In the case of CEMS being used for monitoring emissions, the applicable QA/QC procedures prescribed under Part 75 that are related to ensuring the accuracy of the CO<sub>2</sub> concentration monitor, the flow meters that measure the flue gas flow rate, and the DAHS that record the CEMS measurements and compute the emissions, heat rate and other relevant information could be adopted. In the case of stack testing, the QA/QC procedures described in the EPA's Clean Air Act National Stack Testing Guidance document (EPA 2005b) could be followed.

Part 75 established specific tests and testing frequency for the individual components of the CEMS systems to quality assure the data obtained by CEMS. Examples of these checks include:

- Daily *calibration error test* and daily *interference check* for flow monitors
- Quarterly *leak check* for differential pressure-type flow monitors

- Annual or Semi-annual *Relative Accuracy Test Audit (RATA) and Bias test* for flow monitors and for pollution concentration monitors
- *Primary elemental visual inspection* once every three years for Orifice and nozzle

See Part 75 for details on test specification, test acceptance criteria, and exceptions for the various types of QA checks recommended.

Some of the key good practice QA/QC and data verification procedures for maintenance of direct emissions measurement equipment, based on Acid Rain and other relevant programs, are summarized below.

- Conduct regular maintenance of monitoring equipment, such as CO<sub>2</sub> concentration monitors, flow meters and sampling probes
- Keep a written record of procedures needed to maintain the monitoring system in proper operating condition and of a schedule for implementing those maintenance procedures. In other words, develop a facility and equipment specific maintenance procedure manual(s) and regular maintenance implementation schedule(s).
- Keep a maintenance log to record of all testing, maintenance, or repair activities performed on any monitoring system or component in a location and format suitable for inspection. The maintenance log must include: date, time, and description of any testing, adjustment, repair, replacement, or preventive maintenance action performed on any monitoring system and records of any corrective actions associated with a monitor's outage period. Further, details of any resultant changes to the system's ability to record and report emissions data (such as changes to the flow monitor, changing of temperature and pressure coefficients and dilution ratio settings) must be recorded and maintained at the facility, long with written explanations of the procedures used to make the adjustment(s).

## 7.2 Facility-specific Emission Calculation

The Option 1 above describes the QA/QC and data verification procedures for CEMS.

For non-CEMS methods involving facility-specific calculations using kiln input-based mass-balance approach, the following procedures, which were adopted from the existing available reporting programs (such as Acid Rain, EU ETS and Climate Leaders programs), could be used.

- Check the accuracy of the emissions calculations by step to ensure that computational errors are avoided. Some emission calculation checks that can avoid errors include: (a) checking the units of measurement for different variables and parameters used in the calculations for correctness and for consistency with the emissions calculated; (b) checking the conversion factors used in the calculations; and (c) checking the aggregation of data by emission sources (e.g., kilns), product type, and/or production batch number.

- Assess the representativeness of carbon and carbonate contents of raw materials determined through laboratory analysis, by comparing those values with IPCC or other available default values
- Check for consistency in production data, carbon content data, and emission estimate across time periods. Outliers must be capable of being explained by changes in the facility's operational conditions. If the differences across the annual data cannot be attributed to changes in (a) production levels, (b) type and amounts of fuels and raw materials used, and/or (c) emission generation process (for example, due to energy efficiency improvements), the plausibility of measurement error must be assumed, investigated and corrected for.
- Compare the emission estimate with prior years' emissions estimates and the national emissions estimate(s) for the industry and evaluate if the differences in the underlying input data factors (such as carbonate and carbon contents, quantity and types of raw materials used and quantity of CKD generated and recycled) are consistent with the differences in the emissions estimates. If the differences in emissions estimates could not be explained reasonably, plausibility of monitoring error should be assumed and further efforts must be undertaken to verify the calculations and rectify any error in the source data.
- Maintain comprehensive documentation of the data used and the methodology adopted, including data received through personal communication. The chemical analysis used for developing carbonate contents and non-carbonate TOC content of raw materials must be well documented and the data accurately recorded. The methodology used to derive the average quarterly emission factors and other parameters must be well documented and be made available for audit when needed.

## **8. Types of Emissions Information to be Reported**

To ensure completeness, cement production facility owners or operators would report annual GHG emissions from cement production including both combustion-related CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions and process-related CO<sub>2</sub> emissions.

Additional data for verification could include process raw material and product feed rates and carbon contents. Such data listed below would illustrate the process operating conditions at which the emissions monitoring data were obtained. EPA could use such data, for example to check the reported emissions against activity-data-based emission factors for the process.

- quantity of clinker produced
- quantity of raw material consumed, by type of raw material
- carbonate contents of raw materials by type of raw materials obtained through laboratory analysis of sample data
- carbon content of non-fuel raw materials, by type of raw material used
- quantity of CKD produced
- quantity of CKD recycled and disposed of

- carbonate content of the uncalcined CKD obtained through laboratory analysis of sampled data
- CO<sub>2</sub> estimation methodology adopted

*Initial data reporting* could include submission of facility-specific information (including the name and location of the facility, type of facility, number of emissions sources, production and other unit characteristics, primary fuels and raw materials typically used, name of and contact information for the designated person authorized to represent the facility and to certify and submit its emissions reports and respond to questions), a monitoring plan, results of the monitoring system certification tests, stack testing plan, and facility-specific emission calculation methodology, depending on the type of the monitoring system adopted.

### **8.1 Additional Data to be Retained Onsite**

Facilities could be required to retain data concerning monitoring of GHG emissions onsite for a period of at least three years from the reporting year. For CEMS, these data could include CEMS monitoring system data, including continuous-monitored GHG concentrations and stack gas flow rates, calibration and quality assurance records. For stack testing these data could include stack test reports and associated sampling and chemical analytical data for the stack test. Process data including process raw material and product feed rates and carbon contents could also be required to be retained on site for a period of at least three years from the reporting year. EPA could use such data to conduct trend analyses and potentially to develop process or activity-specific emission factors for the process.



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