Cement Asset-Level Emission Methodology

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2° investing initiative

Contents

Introduction

Sector background

Cement is used to bind together the elements that make up concrete (sand, gravel), the world's most widely used manufactured material (IEA, 2018c). Through the decomposition and calcinating limestone in a rotating kiln heated up to 1,450°C, clinker is produced, the binding agent in cement. The clinker is then ground with sand and gravel to create cement (IEA, 2017b). Clinker accounts for 65% of the material composition of cement.

As outlined by the International Energy Agency (IEA) in its 2018 Cement Technology Roadmap developed with the Cement Sustainability Initiative (CSI), the cement sector is both extremely energy (requiring both electricity and thermal energy) and emission intensive. It is "the third-largest industrial energy consumer, comprising 7% of the global industrial energy use [...]" and it accounts for "the second-largest share of total direct industrial carbon dioxide (CO_2) emissions, at 27% (2.2 gigatonnes CO_2 per year) in 2014" (IEA, 2018c).

Process emissions, which arise when limestone is turned into calcium oxide and then clinker, account for 60%-70% of total emissions. Remaining emissions come from fossil-fuel combustion (Hatfield, 2020). The IEA identified reducing the share of clinker in cement as a key mechanism to decarbonizing the sector (IEA, 2018c).

As raw materials are available globally and transportation is costly, cement production is spread across the globe. Global cement production was estimated at 4.1 billion tonnes (t) in 2017 by the United States Geological Survey, of which 52% is produced in China, ahead of India (6.2%), the European Union (5.3%) and the USA (1.9%) (CEMBUREAU, 2017; Hatfield, 2020).

Document structure

The 2° Investing Initiative (2DII) developed open-source methodologies to calculate carbon dioxide (CO_2) emissions at the level of an individual asset for eight sectors (aviation, automotive, power, oil & gas, coal, shipping, cement, and steel).

This document describes the methodology step by step and suggests data sources that can be used to apply the methodology to calculate asset-level CO_2 emissions in the cement sector. Publicly available data sources were used whenever possible. The asset-level activity data is however still largely unavailable in the public domain.

2DII works with its data spin off Asset Resolution (AR) to source asset-level capacity and/or production values and calculate asset-level emissions in the context of its research. AR sources asset-level data from leading industry data providers and carries out complementary research in house. This document gives insights into this asset-level data. Alternative sources can be used provided they comply with the data specifications as set out in the methodology.

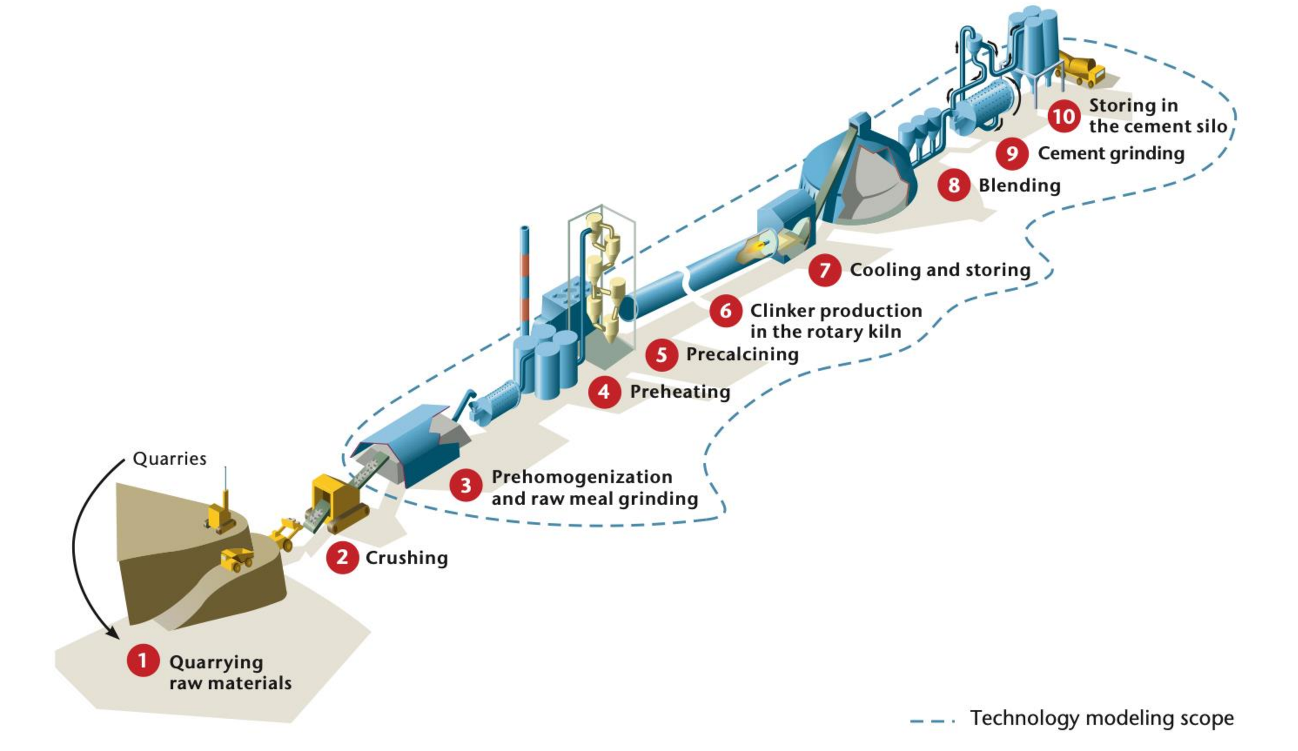
Asset Definition

Similar to complex industrial processes like steel production, cement undergoes extensive and intensive processing from raw material, primarily limestone and clay, to ultimately cement (see Figure 1). Other than the extraction and crushing of limestone (see step 1 to 2 in Figure 1), integrated plants process the cement from raw material to final product (see blue dotted line in Figure 1).

The emission methodology is developed to calculate the scope 1 and 2 emission factors and absolute emissions for an integrated cement plant, which is defined as an asset. The methodology focuses on the most energy and emission intensive cement processes — thermal combustion for the production of clinker (see step 4 and 5 in Figure 1), electricity generation for the kiln (see step 6 Figure 1), and the grinding and blending of materials (see step 3, 8, and 9 in Figure 1).

The methodology does *not* calculate scope 3 emissions from the extraction and crushing of limestone and other raw materials used in the production of cement. Likewise, the methodology does *not* estimate scope 3 emissions from the transportation of cement products.

Figure 1. Cement production process



Note: A dry-process kiln is shown with a precalciner and multistage cyclone preheater, which is considered state-of-the-art technology. The modelling results used for the analysis in this roadmap include steps 3-10 of the above figure.

Source: *Technology Roadmap - Low-Carbon Transition in the Cement Industry*, 2018

The source of the asset-level data is AR. AR derives asset production capacities from the Global Cement Directory (GCD) and in-house research. GCD distinguishes between integrated- and grinding-plants. It covers 2330 active integrated assets around the world with a total production capacity of 4.05 billion tonnes of cement per year. Additionally, it covers grinding plants, mothballed plants and plants that are under construction (Global Cement, 2020).

Table 1. Asset definition

Indicator	Definition
Parameter	Asset definition
Unit	Cement plant
Description	Asset a characterized by kiln technology type
Technology	Integrated plant
Technology Type	Mixed kiln, Semi-wet/semi-dry kiln, Dry kiln with preheater and precalciner, Dry kiln without preheater, and Wet/shaft kiln
Identifier	Unique plant location, operator, and name identifier
Source	Asset Resolution, based on various sources including Global Cement (Global Cement, 2020)

Asset *a* denotes the plant's technology type, e.g., dry kiln, etc. The asset-level data source (see Table 1) provides for active integrated facilities: the capacity, name, location, and the kiln type (e.g., wet, dry, semi-dry, etc.). The kiln type has a significant impact on the plant's emissions since the dry process is more thermally efficient than the wet process (IEA, 2018c).

Asset-Level Emission Model

Emission Factor

The emission factor (EF), expressed as tonnes of CO_2 emitted per tonnes (t) of cement, reflects the asset's relative greenhouse gas (GHG) impact per unit of activity (t of cement). It is the ratio between the annual emissions and cement production:

$$\text{Emission factor}_{\,a,f,y}\left[\frac{\text{t CO}_2}{\text{t cement}}\right] = \frac{\text{Emissions}_{\,a,f,y}\ [\text{t CO}_2]}{\text{Production}_{\,a,y}\ [\text{t cement}]}$$

Where: a = asset, f = fuel, y = year

The asset's emission factor is calculated using the calcination, electricity, and fuel emission factor (EF) (described in detail in the following sections) as follows:

$$\text{Emission factor}_{\,a,f,y}\left[\frac{\text{t CO}_2}{\text{t cement}}\right] = \text{Calcination EF}_{\,a,y}\ \text{Electricity EF}_{\,a,y} + \text{Fuel EF}_{\,a,f,y}\left[\frac{\text{t CO}_2}{\text{t cement}}\right]$$

Where: a = asset, f = fuel, y = year

Absolute Emissions

The absolute annual emissions can be used to assess the absolute GHG impact of an asset compared to other assets and external benchmarks in the cement sector. The absolute emissions indicator is calculated as follows:

$$\text{Emissions}_{\,a,f,y}\ [\text{t CO}_2] = \text{Emission factor}_{\,a,f,y}\left[\frac{\text{t CO}_2}{\text{t cement}}\right] * \text{Production}_{\,a,y}\ [\text{t cement}]$$

Where: a = asset, f = fuel, y = year

Production

The asset's absolute emissions depend on either estimated or actual cement production. Due to the sensitivity and challenges of collecting a global database of asset-wise production figures, the methodology estimates production using asset capacity (see Table 2) and average utilization factors (see Table 3). The granularity of the utilization factors will vary depending on the quality and breadth of the data source(s), and the most precise utilization factor possible for each asset is used. The annual production for asset *a* is calculated as follows:

$$\text{Production}_{\,a,y}\ [\text{t cement}] = \ \text{Capacity}_{\,a}\ [\text{t cement}] * \text{Utilization factor}_{\,a,y}\ [\%]$$

Where: a = asset, y = year

Table 2. Capacity

Indicator	Definition
Parameter	Capacity
Unit	t cement per year
Scope	Scope 1
Description	Capacity of asset *a*
Value applied	e.g., 12000
Granularity	Asset-level
Source	Asset Resolution, based on various sources including Global Cement (Global Cement, 2020)

Table 3. Utilization factor

Indicator	Definition
Parameter	Utilization factor
Unit	%
Scope	Scope 1
Description	Annual utilization factor of asset *a*
Value applied	e.g., 86%
Granularity	Country, regional, and global averages
Source	Asset Resolution, based on various sources including Global Cement (Global Cement, 2020)

Calcination Emission Factor

The calcination emission factor (EF) for an asset is calculated from the clinker to cement ratio (see Table 4) and the clinker calcination emission factor (see Table 5) as follows:

$$\text{Calcination EF}_{a,y}\left[\frac{\text{t CO}_2}{\text{t cement}}\right] = \text{Clinker to cement ratio}_{a,y}\left[\frac{\text{t clinker}}{\text{t cement}}\right] * \text{Clinker calcination EF}_{a}\left[\frac{\text{t CO}_2}{\text{t clinker}}\right]$$

Where: a = asset, y = year

The clinker to cement ratio is not only important for the properties of cement, but also for the emissions intensity, where a lower ratio results in a lower emission factor for the calcination process. In the absence of plant-specific data, CSI recommends using a default clinker calcination factor of 0.525, which corresponds to the IPCC default corrected for magnesium carbonates (IPCC, 2006). The GNR database covers annual clinker to cement ratios by country and region (GCCA, 2020).

Table 4. Clinker to cement ratio

Indicator	Definition
Parameter	Clinker to cement ratio
Unit	t clinker per t cement
Scope	Scope 1
Description	% of clinker compared to non-clinker materials for asset *a*
Value applied	e.g., 40%
Granularity	Country and regional averages
Source	GNR Database, Cement Sustainability Initiative, Table 92AGW (GCCA, 2020)

Table 5. Clinker calcination emission factor

Indicator	Definition
Parameter	Clinker calcination emission factor
Unit	t CO_2 per t clinker
Scope	Scope 1
Description	Emission factor of calcination per t of clinker for asset *a*
Value applied	0.53
Granularity	Global average
Source	The Cement CO2 and Energy Protocol, p. 46 (CSI, 2011)

Electricity Emission Factor

The electricity emission factor (EF) of an asset is calculated from the electricity consumption factor (CF) (see Table 6) and the electricity generation emission factor (GEF)[1] (see Table 7), as follows:

$$\text{Electricity EF}_{a,y}\left[\frac{\text{t CO}_2}{\text{t cement}}\right] = \text{Electricity CF}_{a,y}\left[\frac{\text{kWh}}{\text{t cement}}\right] * \text{Electricity GEF}_{a,y}\left[\frac{\text{t CO}_2}{\text{kWh}}\right]$$

Where: a = asset, y = year

Table 6. Electricity consumption factor

Indicator	Definition
Parameter	Electricity consumption factor
Unit	kWh per t cement
Scope	Scope 1
Description	Annual electricity consumption per t cement for asset *a*
Value applied	e.g., 0.56
Granularity	Country and regional averages
Source	GNR Database, Cement Sustainability Initiative, Table 33AGW (GCCA, 2020)

Table 7. Electricity generation emission factor

Indicator	Definition
Parameter	Electricity generation emission factor
Unit	t CO_2 per kWh
Scope	Scope 2
Description	CO_2 intensity of the electricity in t CO_2 per kWh for asset *a*
Value applied	e.g., 100
Granularity	Country and regional averages
Source	CO2 electricity emissions from fuel Combustion 2012, International Energy Agency (IEA, 2012a)

Fuel Emission Factor

The fuel emission factor (EF) is calculated from the clinker to cement ratio, the fuel consumption factor (CF) (see Table 8) and fuel combustion emission factor (CEF) (see Table 9).

The fuel combustion factor depends on the type of kiln used. Generally, wet/shaft kilns consume the most energy per t clinker, while dry kilns with a preheater and precalciner are the most energy efficient (GCCA, 2020). The fuel emission factor is calculated as follows:

$$\text{Fuel EF}_{a,f,y}\left[\frac{\text{t CO}_2}{\text{t cement}}\right] = \text{Clinker to cement ratio}_{a,y}\left[\frac{\text{t clinker}}{\text{t cement}}\right] * \text{Fuel CF}_{a,f}\left[\frac{\text{MJ}}{\text{t clinker}}\right] * \text{Fuel CEF}_{a,f}\left[\frac{\text{t CO}_2}{\text{MJ}}\right]$$

Where: a = asset, f = fuel, y = year

[1] All electricity emissions are assumed to be scope 2, i.e., purchased electricity (IEA, 2018c).

Table 8. Fuel consumption factor

Indicator	Definition
Parameter	Fuel consumption factor
Unit	MJ fuel per t clinker
Scope	Scope 1
Description	Thermal fuel consumption per t clinker for asset *a*
Value applied	e.g., 13000
Granularity	Country and regional averages
Source	GNR Database, Cement Sustainability Initiative, Table 593AG (GCCA, 2020)

Table 9. Fuel combustion emission factor

Indicator	Definition
Parameter	Fuel combustion emission factor
Unit	t CO_2 per MJ
Scope	Scope 1
Description	CO_2 intensity per MJ of combusted fuel for asset *a*
Value applied	e.g., 0.56
Granularity	Country and regional averages
Source	GNR Database, Cement Sustainability Initiative, Table 593AG (GCCA, 2020)

Outlook and Limitations

The asset-level emission model develops key indicators, the emission factor and the absolute emissions, to assess the CO_2 emissions in the cement sector. The methodology focuses on the most energy and emission intensive cement processes — thermal combustion for the production of clinker and electricity generation. A limitation of this model is the lack of comprehensive coverage of asset-level indicators, such as the utilization factor and the lack of asset-level electricity and fuel emission factors. Further work on improving the asset-level indicator coverage, increasing the granularity of input indicators and benchmarking against external sources is underway.

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