Cement Asset-Level Emission Methodology

Date: September 14th, 2020

Version: 1.2

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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, 2018). 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, 2017). 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, 2018).

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, 2018).

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 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 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 sources of data that can be used to apply the methodology to calculate asset-level CO_2 emissions in the cement sector. The data sources are publicly available to the extent possible. The asset-level capacity and/or production values are 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.

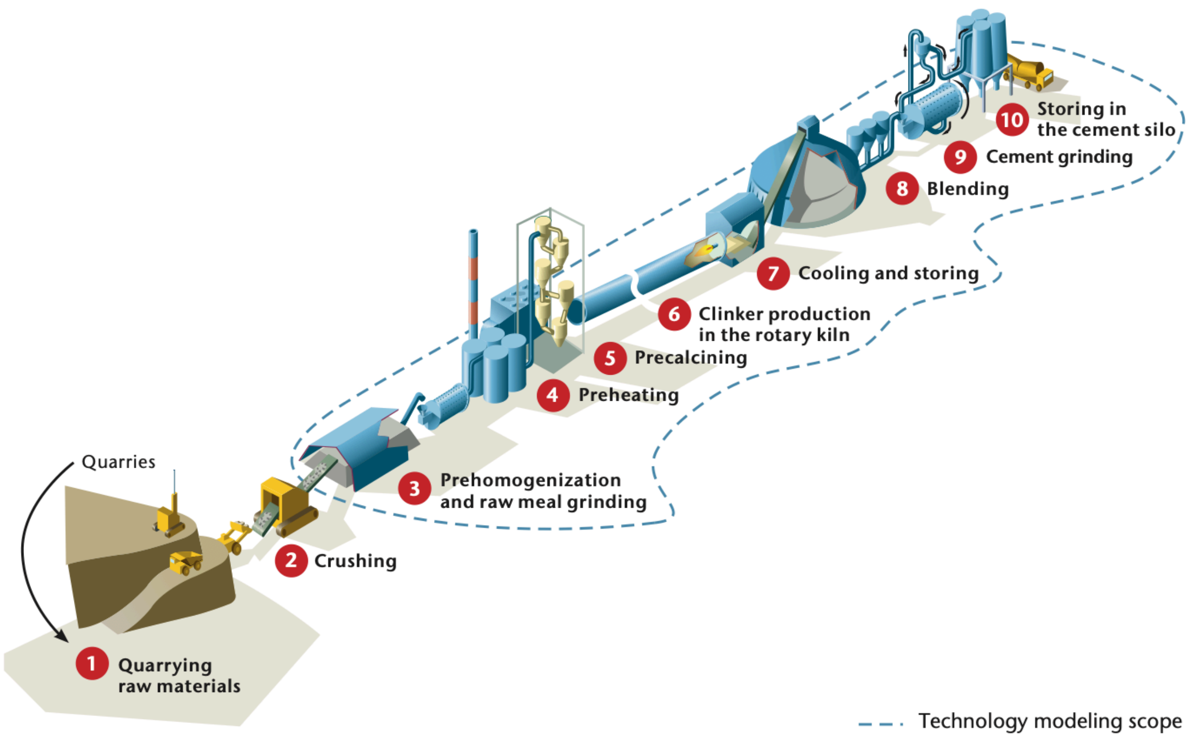
Asset Definition

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 1.1). Other than the extraction and crushing of limestone (step 1 to 2 in Figure 1.1), integrated plants process the cement from raw material to final product (see blue dotted line in Figure 1.1).

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 (step 4 and 5 in Figure 1.1), electricity generation for the kiln (step 6 Figure 1.1), and the grinding and blending of materials (step 3, 8, and 9 in Figure 1.1).

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 1.1: Cement production



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 1.1: Asset Definition

Indicator	Definition
Parameter	Asset definition
Unit	Cement plant
Denotation	Asset *i* (Technology)
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 Directory 2020*, 2020)

Asset *i* denotes the plant's technology type, e.g., dry kiln, etc. The asset-level data source (see Table 1.1) 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, 2018).

Asset-Level Emissions Model

Asset Annual Emissions

The emissions for asset *i* for year *y* are calculated as:

$$\text{Asset emissions}_i \left[\frac{\text{t CO}_2}{\text{year}_y}\right] = \text{Asset EF}_i \left[\frac{\text{t CO}_2}{\text{t Cement}}\right] * \text{Production}_i \left[\frac{\text{t Cement}}{\text{year}_y}\right]$$

Where:

- Production_i = tonnes of cement production per year (see Asset Production).
- Asset EF_i = emission factor per tonne of cement (see Asset Emission Factor).

Asset Emission Factor

The emission factor per tonne of cement for asset *i* is calculated as:

$$\text{Asset EF}_i \left[\frac{\text{t CO}_2}{\text{t Cement}}\right] = \text{Calcination EF}_i \left[\frac{\text{t CO}_2}{\text{t Cement}}\right] + \text{Fuel EF}_i \left[\frac{\text{t CO}_2}{\text{t Cement}}\right] + \text{Electricity EF}_i \left[\frac{\text{t CO}_2}{\text{t Cement}}\right]$$

Where:

- Calcination EF_i = calcination emission factor (see Calcination Emission Factor).
- Fuel EF_i = fuel emission factor (see Fuel Emission Factor).
- Electricity EF_i = electricity emission factor (see Electricity Emission Factor).

Asset Production

The production for asset *i* for year y is calculated as follows:

$$\text{Production}_i \left[\frac{\text{t Cement}}{\text{year}_y}\right] = \text{Capacity}_i \left[\frac{\text{t Cement}}{\text{year}_y}\right] * \text{Utilization factor}_i\ [\%]$$

Where:

- Capacity_i = annual capacity of asset *i*.
- $\text{Utilization factor}_i$ = annual utilization factor of asset *i*.

To calculate a cement asset's annual emissions, it is necessary to either to estimate or use the actual cement production of the asset. Due to the sensitivity and challenges of collecting a global database of asset-wise production figures, the methodology estimates production using average utilization factors. The granularity of the utilization factors will vary depending on the quality and breadth of the data source(s). For each asset, the most precise utilization factor should be applied.

Table 2.1: Capacity

Indicator	Definition
Parameter	Capacity
Unit	Tonnes cement per year
Description	Annual capacity of asset *i*
Identifier	Unique plant location, operator, and name identifier
Value applied	e.g., 12000
Granularity	Asset-level
Source	Asset Resolution, based on various sources including Global Cement (*Global Cement Directory 2020*, 2020)

Table 2.2: Utilization Factor

Indicator	Definition
Parameter	Utilization factor
Unit	Percent per year
Description	Annual utilization factor of asset *i*
Identifier	*NA*
Value applied	e.g., 65%
Granularity	Country, regional, and global averages.
Source	Various sources (see Annex)

Calcination Emission Factor

The calcination emission factor for asset i is calculated as:

$$\text{Calcination EF}_i\left[\frac{\text{t CO}_2}{\text{t Cement}}\right] = \text{Clinker to cement ratio}_i\left[\frac{\text{t Clinker}}{\text{t Cement}}\right] * \text{Calcination EF}_i\left[\frac{\text{t CO}_2}{\text{t Clinker}}\right]$$

Where:

- $\text{Clinker to cement ratio}_i$ = tonnes clinker per tonne cement. This 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.
- Calcination EF_i = emission factor of calcination per tonne of clinker. In absence of plant-specific data, CSI recommends using a default calcination factor of 0.525 $\left[\frac{\text{t CO}_2}{\text{t Clinker}}\right]$, 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 2.3: Calcination Emission Factor

Indicator	Definition
Parameter	Calcination emission factor
Unit	Tonnes CO2 per tonne clinker
Scope	Scope 1
Description	The emission factor of calcination per tonne of clinker for asset *i*
Identifier	*NA*
Value applied	0.53
Granularity	Global average
Source	Cement Sustainability Initiative, CO2 Accounting and Reporting Standard for the Cement Industry (*The Cement CO2 and Energy Protocol*, 2011, p. 46)

Table 2.4: Clinker to Cement Ratio

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

Electricity Emission Factor

The electricity emission factor for asset i is calculated as:

$$\text{Electricity EF}_i \left[\frac{\text{t CO}_2}{\text{t Cement}}\right] = \text{Electricity consumption factor}_i \left[\frac{\text{kWh}}{\text{t Cement}}\right] * \text{Electricity EF}_i \left[\frac{\text{t CO}_2}{\text{kWh}}\right]$$

Where:

- $\text{Electricity consumption factor}_i$ = power consumption in KWh per tonne of cement.
- Electricity EF_i = CO_2 intensity of the grid electricity in tonne CO_2 per kWh.[2]

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

Table 2.5: Electricity Consumption Factor

Indicator	Definition
Parameter	Electricity consumption factor
Unit	kWh per tonne cement
Scope	Scope 2
Description	Electricity consumption per tonne cement for asset *i*
Identifier	*NA*
Value applied	e.g., 0.56
Granularity	Country and regional averages by technology type
Source	GNR Database, Cement Sustainability Initiative, Table 33AGW ("GNR Project," 2020)

Table 2.6: Electricity Emission Factor

Indicator	Definition
Parameter	Electricity emission factor
Unit	Tonnes CO2 per kWh
Scope	Scope 2
Description	CO2 intensity of the grid electricity in tonne CO2 per kWh for asset *i*
Identifier	*NA*
Value applied	e.g., 100
Granularity	Country and regional averages
Source	CO2 electricity emissions from fuel Combustion 2012, International Energy Agency (*CO2 Emissions from Fuel Combustion 2012*, 2012)

Fuel Emission Factor

The fuel emission factor for asset *i* is calculated as:

$$\text{Fuel EF}_i \left[\frac{\text{t CO}_2}{\text{t Cement}}\right] = \text{Clinker to cement ratio}_i \left[\frac{\text{t Clinker}}{\text{t Cement}}\right] * \text{Fuel CF}_i \left[\frac{\text{MJ}}{\text{t Clinker}}\right] * \text{Fuel EF}_i \left[\frac{\text{t CO}_2}{\text{MJ}}\right]$$

Where:

- $\text{Clinker to cement ratio}_i$ = tonnes clinker per tonne cement (for additional details see Calcination Emission Factor). This ratio is important for the emissions intensity of cement, where a lower ratio results in a lower emission factor for the calcination process.
- Fuel CF_i = fuel consumption per tonne clinker. Generally, wet/shaft kilns consume the most energy per tonne clinker, while dry kilns with a preheater and precalciner are the most energy efficient (GCCA, 2020).
- Fuel EF_i = tonnes CO_2 per MJ of fuel.

Table 2.7: Fuel Emission Factor

Indicator	Definition
Parameter	Fuel emission factor
Unit	Tonnes CO2 per MJ
Scope	Scope 1
Description	CO2 intensity per MJ of combusted fuel for asset *i*
Identifier	*NA*
Value applied	e.g., 0.56
Granularity	Country and regional averages
Source	GNR Database, Cement Sustainability Initiative, Table 593AG ("GNR Project," 2020)

Table 2.8: Fuel Consumption Factor

Indicator	Definition
Parameter	Fuel consumption factor
Unit	MJ per tonne clinker
Scope	Scope 1
Description	Thermal fuel energy consumption per tonne clinker for asset *i*
Identifier	*NA*
Value applied	e.g., 13000
Granularity	Country and regional averages by technology type
Source	GNR Database, Cement Sustainability Initiative, Table 593AG ("GNR Project," 2020)

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Annex

Table 4.1: Utilization Sources

Company	Geography	Utilization
Anhui Conch Cement	World	0.86
China United Cement Corporation	World	0.63
Asia Cement	World	0.85
Taiwan Cement	World	0.85
UltraTech Cement	World	0.7
India Cements	World	0.7
	Egypt	0.6
	India	0.7
	Argentina	0.64
	United States of America	0.759
	Philippines	0.85
	China	0.65
	Cuba	0.58
	Pakistan	0.91
	Bangladesh	0.78
	Brazil	0.57
	EU 28	0.834
	World	0.67