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ENVIRONMENTAL
PRODUCT
DECLARATION

PORTLAND CEMENT

(per ASTM C219 and specified in ASTM C150,
ASTM C1157, AASHTO M 85, or CSA A3001)

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND CEMENT

ASTM Certification page

This document is a Type III industry-average Environmental Product Declaration (EPD) describing portland cements produced in the United States (US) by Portland Cement Association (PCA) members. The results of the underlying LCA are computed with the *North American (N.A.) version of the Global Cement and Concrete Association (GCCA) Industry EPD tool for cement and concrete* [4]. This tool and the underlying LCA model and database have been previously verified to conform to the prevailing sub-product category rule (PCR) [11], ISO 21930:2017 (the core PCR) [10] as well as ISO 14025:2006 [7] and ISO 14040/44:2006 Amd: 2020 LCA standards [8], [9].

This EPD is certified by ASTM to conform to the Sub-Product Category Rule (PCR) referenced below, as well as to the requirements of ISO 14025 and ISO 21930.

| | |
|------------------------|---|
| DECLARATION HOLDER | Portland Cement Association 5420 Old Orchard Road Skokie, IL, USA 60077-1083 www.cement.org |
| DECLARATION NUMBER | EPD 195 |
| PRODUCT GROUP AND NAME | Cement, UN CPC 3744 |
| DECLARED PRODUCT | Portland cement(s) as a category product |
| REFERENCE PCR | NSF Product Category Rule for <i>Preparing an Environmental Product Declaration for Portland, Blended Hydraulic, Masonry, Mortar, and Plastic (Stucco) Cements</i> . V3.1, September 2020. |
| PROGRAM OPERATOR | ASTM International 100 Barr Harbor Drive West Conshohocken, PA, USA 19428-2959 www.astm.org |
| DATE OF ISSUE | 03-12-2021 |
| PERIOD OF VALIDITY | 03-12-2021- 03-12-2026 |
| NOTES | The EPD results are computed using the <i>N.A. version of GCCA Industry EPD tool for Cement and Concrete</i> (https://concrete-epd-tool.org). |

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND CEMENT

EPD VERIFICATION

This EPD has been certified by an independent, external verifier in accordance with ISO 14025.



Tim Brooke
 ASTM International

Date
 verified



Thomas P. Gloria, Ph. D.
 Industrial Ecology Consultants

Date
 verified

Product description and applicable standards

The product under evaluation is portland cement as defined by ASTM C219 and specified in ASTM C150, ASTM C1157, AASHTO M 85 or CSA A3001.

A hydraulic cement produced by pulverizing clinker, consisting essentially of crystalline hydraulic calcium silicates, and usually containing one or more of the following: water, calcium sulfate, up to 5% limestone, and processing additions. (ASTM C219)

As a cement category portland cements have various properties, as follows:

- Type I – normal, no special properties required
- Type II – moderate sulfate resistant
- Type III – high early strength
- Type IV – low heat hydration
- Type V – high sulfate resistance

Some cements are designated with a combined type classification, such as Type I/II, indicating that the cement meets the requirements of the indicated types and is being offered as suitable for use when either type is desired.

All cement products are composed of specific combinations of calcium, silica, iron and alumina and small amounts of additives to achieve a desired profile of properties (e.g., strength, color). Clinker, the principle intermediate manufactured product within cement production, is typically produced from a combination of ingredients, including limestone (for calcium), coupled with smaller quantities of materials such as clay, iron ore, and sand (as sources of alumina, iron, and silica, respectively). So common are these building blocks that a wide variety of raw materials are suitable sources, and some sources, such clay and fly ash, may provide multiple chemical components. Cement plants are increasingly turning to industrial byproducts that otherwise would be discarded, once completing detailed analyses

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to determine the effects of using a byproduct on the manufacturing process, cement performance and facility emissions. Portland cement is the basic ingredient of concrete. Concrete, one of the most widely used construction materials in the world, is formed when portland cement creates a paste with water that binds with sand and rock to harden. The U.S. industry average portland cement, as found by this study, is 91.4% clinker by weight. Table 1 describes the cement’s composition by specific material resources.

The U.S. industry average portland cement, as found by this study, is 92.2% clinker by weight. Table 1 describes the cement’s composition by specific material resources.

Table 1. Material composition of the U.S. industry average portland cement

| Cement ingredients ^a | Portion of cement product (by weight) |
|---------------------------------|---------------------------------------|
| Clinker | 91.4% |
| Gypsum | 5.2% |
| Uncalcined limestone | 2.7% |
| Other materials | <1.0% each |

^aIt should be noted that while all portland cement products contain the ingredients listed above, the average cement production data computed for this EPD represents the weighted average use of all materials by all participating plants. These data should not be interpreted to mean that the constituent proportions presented in this table is the formulation for all portland cement products.

Applicable Standards:

- ASTM C150 / C150M – 20 Standard Specification for Portland Cement.
- ASTM C1157 / C1157M – 20 Standard Performance Specification for Hydraulic Cement.
- AASHTO M 85-20 Standard Specification for Portland Cement (ASTM Designation: C150 / C150M - 20).
- CSA A3001 – 13 Cementitious materials for use in concrete.

Declared unit

The declared unit for this study is the production of one metric ton (1 t) of portland cement awaiting delivery to a customer. The cement is either packaged and stored on pallets or housed unpackaged in silos and ready for bulk transport.

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System boundary

Life cycle stages

This EPD describes portland cement production from cradle-to-gate, as depicted in Figure 1. This includes all modules (A1-A3) of the Production stage, as defined by the PCR. Specifically, Production stage modules capture the following aspects of the life cycle:

- Extraction and processing of raw materials and packaging used to produce cement (A1);
- Transportation of raw materials and packaging from source to cement production site (A2);
- Consumption of energy and water required to produce cement (A3);
- Emissions and wastes generated from producing cement(A3);
- Transportation of wastes from cement production to end-of-life (A3); and
- End-of-life of wastes generated during cement production (A3).

The Construction, Use and End-of-life stages are excluded from the scope of the PCR and therefore from the impact results provided by this EPD.

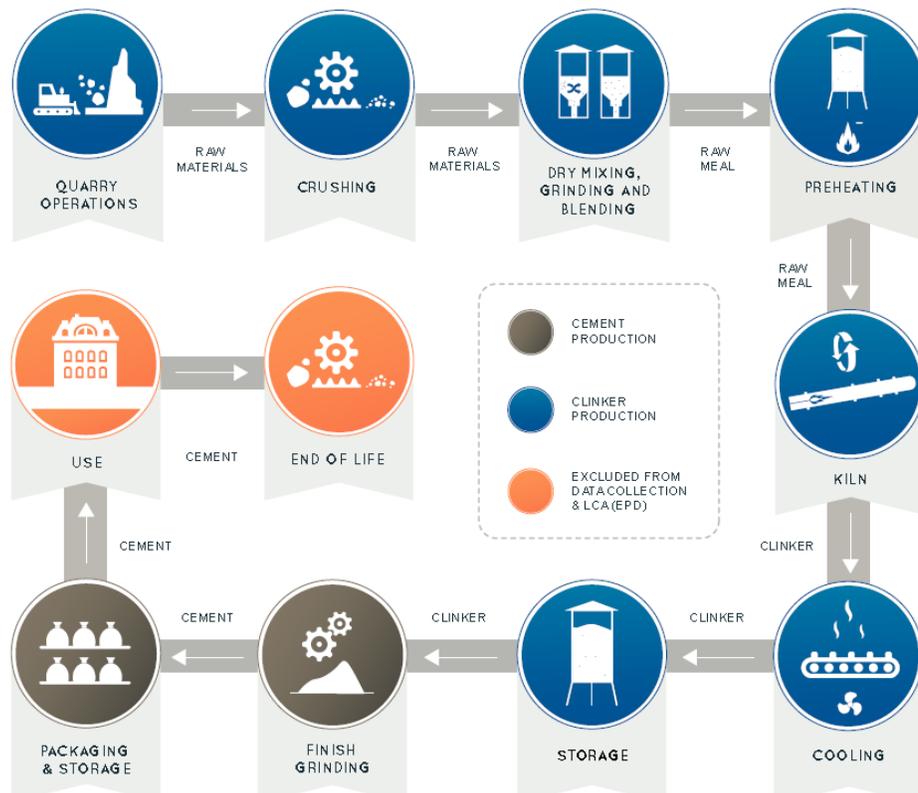


Figure 1. Boundary of the industry-average cement production processes.

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Exclusions and cut-off criteria

Several items are excluded from the foreground life cycle inventories (LCIs) used in the LCA. These relate specifically to operations at cement production plants:

Capital equipment and infrastructure. These are expected to contribute negligibly (<1%) to the total impact of cement production given the long lifetime of these items and high output of cement over this period.

Personnel-related activities, such as travel, furniture and office supplies. (Energy and water use related to on-site office operations, such as company management and sales activities, are included.)

These two categories of items are included in upstream processes (e.g., electricity generation) where they are captured in the background data used in the LCA underlying GCCA Industry EPD tool.

Allocation approach

Allocation of inventory flows and subsequently environmental impact is relevant when assets are shared between product systems. The allocation method prescribed by the PCR is applied in the underlying LCA. The sub-category PCR recognizes fly ash, furnace bottom ash, bypass dust, mill scale, polluted soils, spent catalyst, aluminum oxide waste, silica fume, granulated blast furnace slag, iron rich waste, cement kiln dust (CKD), flue gas desulfurization (FGD) gypsum, calcium fluoride rich waste and postconsumer gypsum as recovered materials and thus, the environmental impacts allocated to these materials are limited to the treatment and transportation required to use as a cement material input. Further, used tires, plastics, solvents, used oil and oily waste, coal/carbon waste, roofing asphalt, household refuse-derived waste, non-hazardous liquid waste, industrial sludge, and agricultural waste are considered non-renewable and/or renewable secondary fuels. Only the materials, water, energy, emissions, and other elemental flows associated with reprocessing, handling, sorting and transportation from the point of the generating industrial process to their use in the production process are considered. All emissions from combustion at the point of use are considered. For co-products, no credit is considered, and no allocation is applied. See the *LCA model and LCA database reports of the N.A. version of GCCA's Industry Tool for EPDs of cement and concrete* for more information [4], [5].

Data Quality Requirements and Assessment

Technology Coverage

The life cycle impact assessment (LCIA) results presented in this EPD are calculated using an industry-average LCI of US PCA members producing portland cement. The LCI is assembled with data shared by PCA members through a survey process carried out in 2020 and represents 2019 operations. Primary (gate-to-gate activity) data were collected for limestone quarrying, clinker production and portland cement manufacture. Data collection and aggregation methods are described in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

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In 2019, the US cement industry generated 86,000,000 metric tons of portland cements [13]. The LCI dataset captures 55,685,182 metric tons of PCA member production (as reported by 56 plants) or about 64% of total industry production in 2019¹.

Clinker, the main ingredient in cement production, can be produced using one of a number of technologies, or a combination of these technologies. The portland cement described by this EPD is produced under the profile of clinker production technologies shown in Table 2. A total of 53,141,130 metric tons of clinker are represented by the overall average industry dataset. It is estimated that in 2019 78,000,000 metric tons of clinker was produced in the US and hence, the plant sample represents about 68% of all US clinker production [13]. The plant average raw meal to clinker ratio is 1.59. The average total renewable and non-renewable primary energy required to produce a metric ton of clinker was calculated to be 3.88 GJ on a lower heating value basis.

Table 2. Clinker production technologies applied in the making of the portland cement described by this EPD.

| Clinker production technology | Percent of cement produced by clinker technology |
|--|--|
| Dry with preheater and precalciner | 88.5% |
| Dry with preheater | 3.1% |
| Long dry | 5.3% |
| Wet | 0.6% |
| Other (other technology or a combination of technologies) ¹ | 2.4% |

¹Reported as long semi-wet/semi-dry technology.

Geographic and Temporal Coverage

The portland cement production impacts estimated by the LCA represent cement produced in the US in 2019. Foreground data and assumptions reflect equipment, processes, and market conditions for this year. Background processes, such as some raw material operations and electricity generation (see below), are characterized by data that represent US processes where information is available. In cases where US-specific information is not available, the best available alternative information is used. Additional details describing the background data are provided in the *LCA model and LCA database report of the N.A. version of GCCA Industry EPD Tool for cement and concrete* [5]. Foreground data were collected for limestone quarrying, clinker production and Portland cement manufacture. These data are summarized in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

¹ PCA membership does not represent all cement companies operating in the USA.

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Electricity grid mix

For electricity use modeling, the PCR requires the use of subnational electricity consumption LCIs that consider power trading between regions. To do this, the US EPA's *eGrid* 2018 data are used, which identify grid mixes for ten US regions (NERC regions) and considers regional trading [14]. A weighted average of the NERC regional mixes is applied in the LCA, where the weighting reflects the portion of portland cement produced in each region. The resulting grid mix used in the LCA is shown in Table 3.

Table 3. Grid mix for portland cement production described by this EPD.

| Energy source | Portion of representative grid mix |
|---------------|------------------------------------|
| Gas | 36.40% |
| Coal and peat | 26.58% |
| Nuclear | 18.04% |
| Hydro | 7.81% |
| Wind | 6.33% |
| Solar | 1.92% |
| Biomass | 1.55% |
| Oil | 0.71% |
| Geothermal | 0.53% |
| Waste | 0.13% |
| TOTAL | 100% |

Data Completeness, Consistency, Reproducibility and Transparency

All inputs (raw materials, ancillary and packaging materials, energy, and water) and outputs (emissions to air, water and soil, solid and liquid waste, products, co-products, and by-products) were collected, reviewed, benchmarked and modeled to complete LCI production profile for portland cements. The completeness of the cradle-to-gate process chain in terms of process steps is rigorously assessed for all cement facilities.

A review of the source of individual input and output data (direct, indirect, estimate, other) shared by participating producers was conducted and summarized in Appendix A, *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

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To ensure consistency, cross checks of the energy demand and the calculated raw meal to clinker ratio against ranges reported in the *WBCSD Cement Sustainability Initiative, Cement CO₂ and Energy Protocol*, v3.1 December, 2013 were conducted per each cement facility [15]. A full description of the foreground data quality assessment is provided in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3]. Activity LCI data are transparently disclosed in the LCI report, including all data sources, and this way external reproducibility of the EPD results with the GCCA Industry EPD Tool for cement and concrete is possible [3], [4].

The majority of data describing cement manufacture (including limestone quarrying and clinker production) is based on direct measurements and engineering calculations, as opposed to approximations. This is particularly true for flows that are the major contributors to impact for cement production, namely clinker production.

It should be noted that the data quality assessment here in covers only limestone, clinker and cement production inventories (i.e., activity data). An evaluation of the quality of data used to model background processes (e.g., electricity generation) has also been carried out, and the results are presented in the LCA model and LCA database reports for the *N.A. version of GCCA's Industry EPD Tool for Cement and Concrete* [4], [5].

Limitations

This EPD represents average industry performance for PCA members producing portland cements. It considers only cement plants located in the US. Results may not adequately represent cement production systems that differ greatly from those captured by the data used in the underlying LCA.

This EPD is a declaration of potential environmental impact and does not support or provide definitive comparisons of the environmental performance of specific products. Only EPDs prepared from cradle-to-grave life cycle results and based on the same function and reference service life and quantified by the same functional unit can be used to assist purchasers and users in making informed comparisons between products.

The EPD provided here in and the underlying LCA conform to the *NSF Product Category Rule for Preparing an Environmental Product Declaration for Portland, Blended Hydraulic, Masonry, Mortar, and Plastic (Stucco) Cements*. EPDs of portland cement that follow a different PCR may not be comparable.

LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks. Further, LCA offers a wide array of environmental impact indicators, and this EPD reports a collection of those, as specified by the PCR.

In addition to the impact results, this EPD provides several metrics related to resource consumption and waste generation. These data are informational as they do not provide a measure of impact on the environment. Further, a number of LCA impact categories and inventory items are still emerging or under development and can have high levels

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of uncertainty that preclude international acceptance pending further development. Use caution when interpreting results for these categories – identified with an “*” in Table 4.

Supplementary information regarding LCA methodology

Additional information regarding databases and impact methodologies used for conducting the LCA for this EPD can be found in the *LCA core model and LCA database reports of the N.A. version of GCCA's Industry EPD Tool for Cement and Concrete* [4], [5].

Life cycle assessment results

The cradle-to-gate (A1 to A3) EPD results for producing one metric ton of portland cement are presented in Table 4.

Table 4. Production stage EPD results for portland cements.

| Impact category and inventory indicators | Unit | Portland Cements 1 metric ton |
|---|-----------------------|----------------------------------|
| Global warming potential, GWP 100, IPCC 2013 | kg CO ₂ eq | 922 |
| Ozone depletion potential, ODP | kg CFC-11 eq | 2.10E-05 |
| Acidification potential, AP | kg SO ₂ eq | 1.75 |
| Eutrophication potential, EP | kg N eq | 1.02 |
| Smog formation potential, SFP | kg O ₃ eq | 32.9 |
| Abiotic depletion potential for non-fossil mineral resources, ADP elements* | kg Sb eq | 1.97E-04 |
| Abiotic depletion potential for fossil resources, ADP fossil* | MJ Surplus | 363 |
| Renewable primary resources used as an energy carrier (fuel), RPR _E * | MJ LHV | 138.4 |
| Renewable primary resources with energy content used as material, RPR _M * | MJ LHV | 3.55 |
| Non-renewable primary resources used as an energy carrier (fuel), NRPR _E * | MJ LHV | 4080 |
| Non-renewable primary resources with energy content used as material, NRPR _M * | MJ LHV | 4.75 |
| Secondary materials, SM* | kg | 95.8 |
| Renewable secondary fuels, RSF* | MJ LHV | 54.3 |
| Non-renewable secondary fuels, NRSF* | MJ LHV | 523 |
| Net use of freshwater, NFW* | m ³ | 1.04 |
| Hazardous waste disposed, HWD* | kg | 0.013 |
| Non-hazardous waste disposed, NHWD* | kg | 309 |
| High-level radioactive waste, conditioned, to final repository, HLRW* | kg | x¹⁾ |
| Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW* | kg | x¹⁾ |
| Components for re-use, CRU* | kg | 0 |
| Materials for recycling, MFR* | kg | 0.52 |
| Materials for energy recovery, MER* | kg | 0 |
| Recovered energy exported from the product system, EE* | MJ LHV | 1.94 |
| Additional Inventory Parameters for Transparency | | |
| Global warming potential - biogenic, GWP _{bio} * | kg CO ₂ eq | 0.72 |

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| Impact category and inventory indicators | Unit | Portland Cements 1 metric ton |
|--|-----------------------|----------------------------------|
| Emissions from calcination* | kg CO ₂ eq | 480 |
| Emissions from combustion of waste from renewable sources* | kg CO ₂ eq | 0.203 |
| Emissions from combustion of waste from non-renewable sources* | kg CO ₂ eq | 48.8 |

¹⁾ x – Not all LCA datasets for upstream materials include these impact categories and thus results may be incomplete.

^{*}) Use caution when interpreting results for these categories

Interpretation

Based on the portland cement EPD results calculated with the GCCA Industry EPD Tool for cement and concrete, the following conclusions could be reached [4]. The Manufacturing module (A3) drives most of the potential environmental impacts. Manufacturing impacts are primarily driven by energy use (electricity and thermal fuels) used during the pyroprocessing of limestone in the production of clinker. Clinker content in cement similarly defines the relative environmental profile of the final cement product. Raw material extraction (A1) is the second largest contributor to the Production stage EPD results, followed by raw material transportation (A2).

Additional environmental information

Of the responding plants, around 15% of the facilities are ISO 9001 certified and another 29% are ISO 14001 certified or both. The rest of the plants adhere to different types of corporate or company specific internal environmental management systems, e.g., Spectra QEST (www.spectraqest.com/) which is designed to assist responsible plant personnel by tracking and notifying them of major reporting, monitoring and recordkeeping requirements, EnviroLIS, a database management system to track permits and permit conditions and all environmental related tasks or maintain similar ISO 14001 environmental management system without certification.

Air pollution abatement equipment used at PCA members cement facilities may consist of any mix of the following technologies: high and low temperature baghouses, bin vents, drum filters, dry filters, cartridge filters, precipitators, water sprinklers for dust control, Selective non-catalytic reduction (SNCR), Selective catalytic reduction (SCR), wet scrubbers, dry scrubbers (dry sorbent injection, DSI), Activated Carbon Injection (ASI), and Regenerative Thermal Oxidizer (RTO).

It is also noted that about a third of the plants package some of their cements, the majority bulk load their cements for sale.

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References

1. ASTM C150 / C150M – 20 Standard Specification for Portland Cement.
2. ASTM International, Program Operator Rules, version:8.0, 04/29/20.
3. Athena Sustainable Materials Institute 2021, Portland Cement Association (PCA) – Life Cycle Inventory Summary Report. Prepared by: Mr. Jamie Meil, Mr. Grant Finlayson and Lindita Bushi, PhD, Prepared for: PCA, February 2021.
4. Global Cement and Concrete Association (GCCA) 2020. *N.A. version of Industry EPD tool for Cement and Concrete*. <https://concrete-epd-tool.org/>.
5. GCCA and PCA, *GCCA Industry EPD Tool for Cement and Concrete (V3.0), LCA Model, North American version*, Prepared by Quantis, November 2020.
6. ISO 14021:2016 Environmental labels and declarations - Self-declared environmental claims (Type II environmental labelling).
7. ISO 14025:2006 Environmental labeling and declarations - Type III environmental declarations - Principles and procedures.
8. ISO 14040:2006/Amd1:2020 Environmental management - Life cycle assessment - Principles and framework.
9. ISO 14044:2006/Amd1:2017/Amd2:2020 Environmental management - Life cycle assessment - Requirements and guidelines.
10. ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services.
11. NSF International, Product Category Rule Environmental Product Declarations, PCR for Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements, v3.1, Sept. 2020.
12. NSF International, Product Category Rule Environmental Product Declarations, PCR for Concrete, February 2020.
13. US EPA (2020) eGRID 2018. The Emissions and Generation Resource Integrated Database. <http://www.epa.gov/energy/egrid>.
14. US Geological Survey (USGS), National Minerals Information Center, Cement Statistics and Information, RY 2019. <https://www.usgs.gov/centers/nmic/cement-statistics-and-information>.
15. WBCSD CSI 2013: CO₂ and Energy Protocol Version 3.1 of 9 December 2013. <https://www.cement-co2-protocol.org/en/>.

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND CEMENT

Participating PCA members

| Member | Corporate headquarters | Website |
|---------------------------------|-------------------------------|------------------------|
| Argos USA Corp. | Alpharetta, GA | argos.co/usa |
| Ash Grove Cement | Overland Park, KS | ashgrove.com |
| Buzzi Unicem USA, Inc. | Bethlehem, PA | buzziunicemusa.com |
| CalPortland Company | Glendora, CA | calportland.com |
| CEMEX USA | Houston, TX | cemexusa.com |
| Continental Cement | Chesterfield, MO | continentalcement.com |
| Drake Cement | Scottsdale, AZ | drakecement.com |
| Federal White Cement | Woodstock, ON | federalwhitecement.com |
| GCC of America | Glendale, CO | gccusa.com |
| LafargeHolcim | Rosemont, IL | lafarge-na.com |
| Lehigh Hanson | Irving, TX | lehighhanson.com |
| Martin Marietta Materials, Inc. | Dallas, TX | martinmarietta.com |
| Mitsubishi Cement Corporation | Henderson, NV | mitsubishicement.com |
| Monarch Cement Company | Humboldt, KS | monarchcement.com |
| National Cement Group | Encino, CA | nationalcement.com |
| Salt River Materials Group | Scottsdale, AZ | srmaterials.com |
| St. Marys Cement | Toronto, ON | stmaryscement.com |
| Suwannee American Cement | Branford, FL | suwanneecement.com |
| Titan America LLC | Norfolk, VA | titanamerica.com |



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America's Cement Manufacturers™



ENVIRONMENTAL
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PORTLAND- LIMESTONE CEMENT

(per ASTM C219 and specified in ASTM C595,
AASHTO M 240, or CSA A3001)

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ASTM Certification page

This document is a Type III industry-average Environmental Product Declaration (EPD) describing Portland-limestone cement produced in the United States (US) by Portland Cement Association (PCA) members. The results of the underlying LCA are computed with the *North American (N.A.) version of the Global Cement and Concrete Association (GCCA) Industry EPD tool for cement and concrete* [4]. This tool and the underlying LCA model and database have been previously verified to conform to the prevailing sub-product category rule (PCR) [11], ISO 21930:2017 (the core PCR) [10] as well as ISO 14025:2006 [7] and ISO 14040/44:2006 Amd: 2020 LCA standards [8], [9].

This EPD is certified by ASTM to conform to the Sub-Product Category Rule (PCR) referenced below, as well as to the requirements of ISO 14025 and ISO 21930.

| | |
|------------------------|---|
| DECLARATION HOLDER | Portland Cement Association 5420 Old Orchard Road Skokie, IL, USA 60077-1083 www.cement.org |
| DECLARATION NUMBER | EPD 196 |
| PRODUCT GROUP AND NAME | Cement, UN CPC 3744 |
| DECLARED PRODUCT | Portland-limestone cement |
| REFERENCE PCR | NSF Product Category Rule for <i>Preparing an Environmental Product Declaration for Portland, Blended Hydraulic, Masonry, Mortar, and Plastic (Stucco) Cements</i> . V3.1, September 2020 |
| PROGRAM OPERATOR | ASTM International 100 Barr Harbor Drive West Conshohocken, PA, USA 19428-2959 www.astm.org |
| DATE OF ISSUE | 03-12-2021 |
| PERIOD OF VALIDITY | 03-12-2021- 03-12-2026 |
| NOTES | The EPD results are computed using the <i>N.A. version of GCCA Industry EPD tool for Cement and Concrete</i> (https://concrete-epd-tool.org). |

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND-LIMESTONE CEMENT

EPD VERIFICATION

This EPD has been certified by an independent, external verifier in accordance with ISO 14025.



Tim Brooke
ASTM International

Date
verified



Thomas P. Gloria, Ph. D.
Industrial Ecology Consultants

Date
verified

Description of the product

The product under evaluation is portland-limestone cement as defined by ASTM C219 and specified in ASTM C595, ASTM C1157, AASHTO M 240, or CSA A3001.

A hydraulic cement consisting of two or more inorganic constituents (at least one of which is not portland cement or portland cement clinker) which separately or in combination contribute to the strength gaining properties of the cement, (made with or without other constituents, processing additions and functional additions, by intergrinding or other blending) (ASTM C219).

As per ASTM C595, portland-limestone cement (Type IL) shall be a hydraulic cement in which the limestone content is more than 5% but less than or equal to 15% by mass of the blended cement.

All cement products are composed of specific combinations of calcium, silica, iron and alumina and small amounts of additives to achieve a desired profile of properties (e.g., strength, color). Clinker, the principle intermediate manufactured product within cement production, is typically produced from a combination of ingredients, including limestone (for calcium), coupled with smaller quantities of materials such as clay, iron ore, and sand (as sources of alumina, iron, and silica, respectively). So common are these building blocks that a wide variety of raw materials are suitable sources, and some sources, such clay and fly ash, may provide multiple chemical components. Cement plants are increasingly turning to industrial byproducts that otherwise would be discarded, once completing detailed analyses to determine the effects of using a byproduct on the manufacturing process, cement performance and facility emissions. The U.S. industry average portland-limestone cement, as found by this study, is 82.7% clinker by weight. Table 1 describes the cement's composition by specific material resources.

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Table 1. Material composition of the U.S. industry average portland-limestone cement.

| Cement ingredients ^a | Portion of cement product (by weight) |
|---------------------------------|---------------------------------------|
| Clinker | 82.7% |
| Gypsum | 5.8% |
| Uncalcined limestone | 10.8% |
| Other materials | <1.0% |

¹It should be noted that while all portland-limestone cement contains (in-part) clinker and gypsum, the remaining composition may include one or more other materials; however, the main other constituent is uncalcined limestone. The average cement production data computed for this EPD represents the weighted average use of all materials by all participating plants producing portland-limestone cement. These data should not be interpreted to mean that all portland-limestone cement contain all of the ingredients listed in this table nor in the proportions presented.

Applicable Standards:

ASTM C595 / C595M – 20 Standard Specification for Blended Hydraulic Cements.

ASTM C1157 / C1157M – 20 Standard Performance Specification for Hydraulic Cement.

AASHTO M 240M/M 240-20 Standard Specification for Blended Hydraulic Cement (ASTM C595/C595M-20).

CSA A3001 – 13 Cementitious materials for use in concrete.

Declared unit

The declared unit for this study is the production of one metric ton (1 t) of portland-limestone cement awaiting delivery to a customer. The cement is either packaged and stored on pallets or housed unpackaged in silos and ready for bulk transport.

System boundary

Life cycle stages

This EPD describes portland-limestone cement production from cradle-to-gate, as depicted in Figure 1. This includes all modules (A1-A3) of the Production stage, as defined by the PCR. Specifically, Production stage modules capture the following aspects of the life cycle:

- Extraction and processing of raw materials and packaging used to produce cement (A1);
- Transportation of raw materials and packaging from source to cement production site (A2);
- Consumption of energy and water required to produce cement (A3);
- Emissions and wastes generated from producing cement(A3);
- Transportation of wastes from cement production to end-of-life (A3); and

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- End-of-life of wastes generated during cement production (A3).

The Construction, Use and End-of-life stages are excluded from the scope of the PCR and therefore from the impact data provided by this EPD.

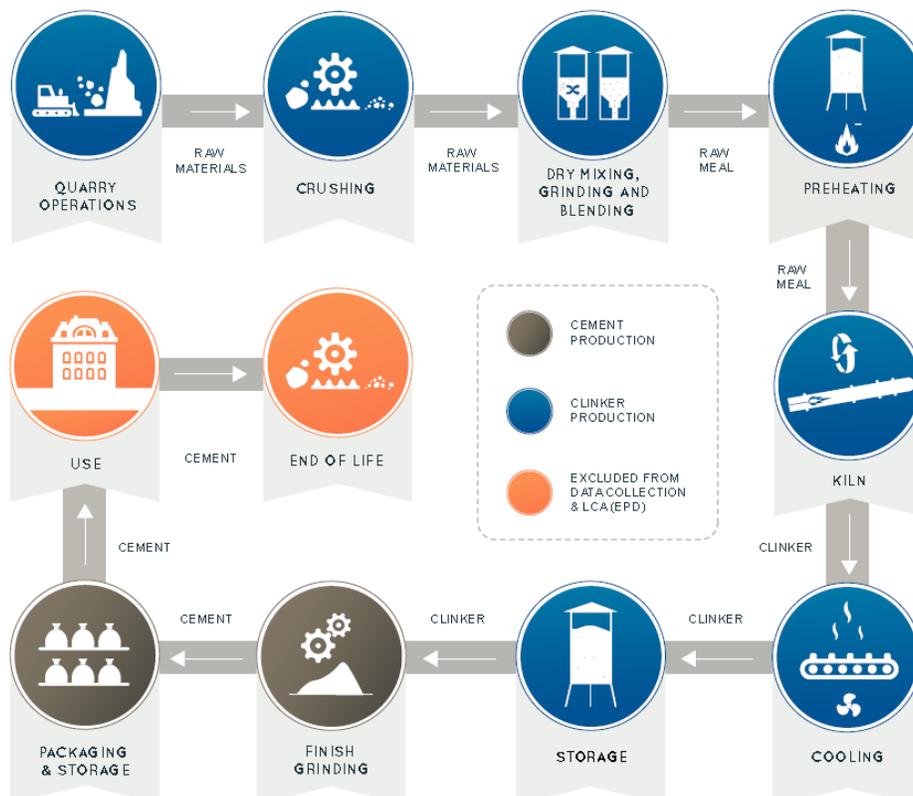


Figure 1. Boundary of the industry-average cement production processes.

Exclusions and cut-off criteria

Several items are excluded from the foreground life cycle inventories (LCIs) used in the LCA. These relate specifically to operations at cement production plants:

Capital equipment and infrastructure. These are expected to contribute negligibly (<1%) to the total impact of cement production given the long lifetime of these items and high output of cement over this period.

Personnel-related activities, such as travel, furniture and office supplies. (Energy and water use related to on-site office operations, such as company management and sales activities, are included.)

These two categories of items are included in upstream processes (e.g., electricity generation) where they are captured in the background data used in the LCA underlying GCCA Industry EPD tool.

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND-LIMESTONE CEMENT

Allocation approach

Allocation of inventory flows and subsequently environmental impact is relevant when assets are shared between product systems. The allocation method prescribed by the PCR is applied in the underlying LCA. The sub-category PCR recognizes fly ash, furnace bottom ash, bypass dust, mill scale, polluted soils, spent catalyst, aluminum oxide waste, silica fume, granulated blast furnace slag, iron rich waste, cement kiln dust (CKD), flue gas desulfurization (FGD) gypsum, calcium fluoride rich waste and postconsumer gypsum as recovered materials and thus, the environmental impacts allocated to these materials are limited to the treatment and transportation required to use as a cement material input. Further, used tires, plastics, solvents, used oil and oily waste, coal/carbon waste, roofing asphalt, household refuse-derived waste, non-hazardous liquid waste, industrial sludge, and agricultural waste are considered non-renewable and/or renewable secondary fuels. Only the materials, water, energy, emissions, and other elemental flows associated with reprocessing, handling, sorting and transportation from the point of the generating industrial process to their use in the production process are considered. All emissions from combustion at the point of use are considered. For co-products, no credit is considered, and no allocation is applied. See the *LCA model and LCA database reports of the N.A. version of GCCA's Industry Tool for EPDs of cement and concrete* for more information [4], [5].

Data Quality Requirements and Assessment

Technology Coverage

The life cycle impact assessment (LCIA) results presented in this EPD are calculated using an industry-average LCI of US PCA members producing portland-limestone cement. The LCI is assembled with data shared by PCA members through a survey process carried out in 2020, representing 2019 operations. Primary (gate-to-gate activity) data were collected for limestone quarrying, clinker production and portland-limestone cement manufacture. Data collection and aggregation methods are described in the Portland Cement Association Life Cycle Inventory Summary Report, February 2021 [3].

Portland limestone cement is a relatively new type of blended cement in the US market. Currently, there are no separate national statistics kept on portland-limestone cement production. The LCI dataset captures 820,451 metric tons of PCA member production (as reported by 15 plants), which equated to about half of all the blended cement reported by PCA member study participants.

Clinker, the main ingredient in cement production, can be produced using one of a number of technologies, or a combination of these technologies. The portland-limestone cement described by this EPD is produced under the profile of clinker production technologies shown in Table 2. A total of 53,141,130 metric tons of clinker are represented by the overall average industry dataset. It is estimated that in 2019 78,000,000 metric tons of clinker was produced in the US and hence, the plant sample represents about 68% of all US clinker production [13]. The plant average raw meal to clinker ratio is 1.59. The average total renewable and non-renewable primary energy required to produce a metric ton of clinker was calculated to be 3.88 GJ on a lower heating value basis.

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND-LIMESTONE CEMENT

Table 2. Clinker production technologies applied in the making of the portland-limestone cement described by this EPD.

| Clinker production technology | Percent of cement produced by clinker technology |
|--|--|
| Dry with preheater and precalciner | 88.5% |
| Dry with preheater | 3.1% |
| Long dry | 5.3% |
| Wet | 0.6% |
| Other (other technology or a combination of technologies) ¹ | 2.4% |

¹Reported as long semi-wet/semi-dry technology.

Geographic and Temporal Coverage

The EPD results are representative for the portland-limestone cement produced in the US in 2019. Foreground data and assumptions reflect equipment, processes, and market conditions for this year. Background processes, such as some raw material operations and electricity generation (see below), are characterized by data that represent US processes where information is available. In cases where US-specific information is not available, the best available alternative information is used. Additional details describing the background data are provided in the *LCA model and LCA database* report of the *N.A. version of GCCA Industry EPD Tool for cement and concrete* [5]. Foreground data were collected for limestone quarrying, clinker production and portland-limestone cement manufacture. These data are summarized in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

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Electricity grid mix

For electricity use modeling, the PCR requires the use of subnational electricity consumption LCIs that consider power trading between regions. To do this, the US EPA's *eGrid* 2018 data are used, which identify grid mixes for ten US regions (NERC regions) and considers regional trading [14]. A weighted average of the NERC regional mixes is applied in the LCA, where the weighting reflects the portion of portland-limestone cement produced in each region. The resulting grid mix used in the LCA is shown in Table 3.

Table 3. Grid mix for portland-limestone cement production described by this EPD.

| Energy source | Portion of representative grid mix |
|---------------|------------------------------------|
| Gas | 49.11% |
| Coal and peat | 19.76% |
| Nuclear | 15.22% |
| Hydro | 7.05% |
| Wind | 3.21% |
| Waste | 2.11% |
| Biomass | 1.98% |
| Geothermal | 0.70% |
| Oil | 0.54% |
| Solar | 0.31% |
| TOTAL | 100% |

Data Completeness, Consistency, Reproducibility and Transparency

All inputs (raw materials, ancillary and packaging materials, energy, and water) and outputs (emissions to air, water and soil, solid and liquid waste, products, co-products, and by-products) were collected, reviewed, benchmarked and modeled to complete LCI production profile for portland-limestone cement. The completeness of the cradle-to-gate process chain in terms of process steps is rigorously assessed for all cement facilities.

A review of the source of individual input and output data (direct, indirect, estimate, other) shared by participating producers was conducted and summarized in Appendix A, *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND-LIMESTONE CEMENT

To ensure consistency, cross checks of the energy demand and the calculated raw meal to clinker ratio against ranges reported in the *WBCSD Cement Sustainability Initiative, Cement CO₂ and Energy Protocol*, v3.1 December, 2013 were conducted per each cement facility [15]. A full description of the foreground data quality assessment is provided in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3]. Activity LCI data are transparently disclosed in the LCI report, including all data sources, and this way external reproducibility of the EPD results with the GCCA Industry EPD Tool for cement and concrete is possible [3], [4].

The majority of data describing cement (limestone quarrying and clinker) production is based on direct measurements and engineering calculations, as opposed to approximations. This is particularly true for flows that are the major contributors to impact for cement production, namely clinker production.

It should be noted that the data quality assessment here in covers only limestone, clinker and cement production inventories (i.e., activity data). An evaluation of the quality of data used to model background processes (e.g., electricity generation) has also been carried out, and the results are presented in the LCA model and LCA database reports for the *N.A. version of GCCA's Industry EPD Tool for Cement and Concrete* [4], [5].

Limitations

This EPD represents average industry performance for PCA Member producing portland-limestone cement. It considers only cement plants located in the US. Results may not adequately represent cement production systems that differ greatly from those captured by the data used in the underlying LCA.

This EPD is a declaration of potential environmental impact and does not support or provide definitive comparisons of the environmental performance of specific products. Only EPDs prepared from cradle-to-grave life cycle results and based on the same function and reference service life and quantified by the same functional unit can be used to assist purchasers and users in making informed comparisons between products.

The EPD provided here in and the underlying LCA conform to the *NSF Product Category Rule for Preparing an Environmental Product Declaration for Portland, Blended Hydraulic, Masonry, Mortar, and Plastic (Stucco) Cements*. EPDs of portland-limestone cement that follow a different PCR may not be comparable.

LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks. Further, LCA offers a wide array of environmental impact indicators, and this EPD reports a collection of those, as specified by the PCR.

In addition to the impact results, this EPD provides several metrics related to resource consumption and waste generation. These data are informational as they do not provide a measure of impact on the environment. Further, a number of LCA impact categories and inventory items are still emerging or under development and can have high levels

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND-LIMESTONE CEMENT

of uncertainty that preclude international acceptance pending further development. Use caution when interpreting results for these categories – identified with an “*” in Table 4.

Supplementary information regarding LCA methodology

Additional information regarding databases and impact methodologies used for conducting the LCA for this EPD can be found in the *LCA core model and LCA database reports of the N.A. version of GCCA's Industry EPD Tool for Cement and Concrete* [4], [5].

Life cycle assessment results

The cradle-to-gate (A1 toA3) EPD results for producing portland-limestone cement are presented in Table 4.

Table 4. Production stage EPD results for portland-limestone cement

| Impact category and inventory indicators | Unit | PLC Cement 1 metric ton |
|---|-----------------------|----------------------------|
| Global warming potential, GWP 100, IPCC 2013 | kg CO ₂ eq | 846 |
| Ozone depletion potential, ODP | kg CFC-11 eq | 2.17E-05 |
| Acidification potential, AP | kg SO ₂ eq | 1.64 |
| Eutrophication potential, EP | kg N eq | 0.94 |
| Smog formation potential, SFP | kg O ₃ eq | 30.2 |
| Abiotic depletion potential for non-fossil mineral resources, ADP elements* | kg Sb eq | 1.93E-04 |
| Abiotic depletion potential for fossil resources, ADP fossil* | MJ Surplus | 359 |
| Renewable primary resources used as an energy carrier (fuel), RPR _E * | MJ LHV | 128 |
| Renewable primary resources with energy content used as material, RPR _M * | MJ LHV | 0.26 |
| Non-renewable primary resources used as an energy carrier (fuel), NRPR _E * | MJ LHV | 3907 |
| Non-renewable primary resources with energy content used as material, NRPR _M * | MJ LHV | 0 |
| Secondary materials, SM* | kg | 107 |
| Renewable secondary fuels, RSF* | MJ LHV | 49 |
| Non-renewable secondary fuels, NRSF* | MJ LHV | 473 |
| Net use of freshwater, NFW* | m ³ | 1.0 |
| Hazardous waste disposed, HWD* | kg | 1.13E-02 |
| Non-hazardous waste disposed, NHWD* | kg | 279 |
| High-level radioactive waste, conditioned, to final repository, HLRW* | kg | x¹⁾ |
| Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW* | kg | x¹⁾ |
| Components for re-use, CRU* | kg | 0 |
| Materials for recycling, MFR* | kg | 0.47 |
| Materials for energy recovery, MER* | kg | 0 |
| Recovered energy exported from the product system, EE* | MJ LHV | 1.76 |
| Additional Inventory Parameters for Transparency | | |
| Global warming potential - biogenic, GWP _{bio} * | kg CO ₂ eq | 0.87 |

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND-LIMESTONE CEMENT

| Impact category and inventory indicators | Unit | PLC Cement 1 metric ton |
|--|-----------------------|----------------------------|
| Emissions from calcination* | kg CO ₂ eq | 434 |
| Emissions from combustion of waste from renewable sources* | kg CO ₂ eq | 0.18 |
| Emissions from combustion of waste from non-renewable sources* | kg CO ₂ eq | 44.2 |

¹⁾ x – Not all LCA datasets for upstream materials include these impact categories and thus results may be incomplete.

* Use caution when interpreting results for these categories

Interpretation

Based on the portland-limestone cement EPD results calculated with the GCCA Industry EPD Tool for cement and concrete, the following conclusions could be reached [4]. The Manufacturing module (A3) drives most of the potential environmental impacts. Manufacturing impacts are primarily driven by energy use (electricity and thermal fuels) used during the pyroprocessing of limestone in the production of clinker. Clinker content in cement similarly defines the relative environmental profile of the final cement product. Raw material extraction (A1) is the second largest contributor to the Production stage EPD results, followed by the transportation (A2).

Additional environmental information

Of the responding plants, around 15% of the facilities are ISO 9001 certified and another 29% are ISO 14001 certified or both. The rest of the plants adhere to different types of corporate or company specific internal environmental management systems, e.g., Spectra QEST (www.spectraqest.com/) which is designed to assist responsible plant personnel by tracking and notifying them of major reporting, monitoring and recordkeeping requirements, EnviroLIS, a database management system to track permits and permit conditions and all environmental related tasks or maintain similar ISO 14001 environmental management system without certification.

Air pollution abatement equipment used at PCA members cement facilities may consist of any mix of the following technologies: high and low temperature baghouses, bin vents, drum filters, dry filters, cartridge filters, precipitators, water sprinklers for dust control, Selective non-catalytic reduction (SNCR), Selective catalytic reduction (SCR), wet scrubbers, dry scrubbers (dry sorbent injection, DSI), Activated Carbon Injection (ASI), and Regenerative Thermal Oxidizer (RTO).

It is also noted that about a third of the plants package some of their cements, the majority bulk load their cements for sale.

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND-LIMESTONE CEMENT

References

1. ASTM C595 / C595M – 20 Standard Specification for Blended Hydraulic Cements.
2. ASTM International, Program Operator Rules, version:8.0, 04/29/20.
3. Athena Sustainable Materials Institute 2021, Portland Cement Association (PCA) – Life Cycle Inventory Summary Report. Prepared by: Mr. Jamie Meil, Mr. Grant Finlayson and Lindita Bushi, PhD, Prepared for: PCA, February 2021.
4. Global Cement and Concrete Association (GCCA) 2020. *N.A. version of Industry EPD tool for Cement and Concrete*. <https://concrete-epd-tool.org/>.
5. GCCA and PCA, *GCCA Industry EPD Tool for Cement and Concrete (V3.0), LCA Model, North American version*, Prepared by Quantis, November 2020.
6. ISO 14021:2016 Environmental labels and declarations - Self-declared environmental claims (Type II environmental labelling).
7. ISO 14025:2006 Environmental labeling and declarations - Type III environmental declarations - Principles and procedures.
8. ISO 14040:2006/Amd1:2020 Environmental management - Life cycle assessment - Principles and framework.
9. ISO 14044:2006/Amd1:2017/Amd2:2020 Environmental management - Life cycle assessment - Requirements and guidelines.
10. ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services.
11. NSF International, Product Category Rule Environmental Product Declarations, PCR for Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements, v3.1, Sept. 2020.
12. NSF International, Product Category Rule Environmental Product Declarations, PCR for Concrete, February 2020.
13. US EPA (2020) eGRID 2018. The Emissions and Generation Resource Integrated Database. <http://www.epa.gov/energy/egrid>.
14. US Geological Survey (USGS), National Minerals Information Center, Cement Statistics and Information, RY 2019. <https://www.usgs.gov/centers/nmic/cement-statistics-and-information>.
15. WBCSD CSI 2013: CO₂ and Energy Protocol Version 3.1 of 9 December 2013. <https://www.cement-co2-protocol.org/en/>

ENVIRONMENTAL PRODUCT DECLARATION PORTLAND-LIMESTONE CEMENT

Participating PCA members

| Member | Corporate headquarters | Website |
|---------------------------------|-------------------------------|------------------------|
| Argos USA Corp. | Alpharetta, GA | argos.co/usa |
| Ash Grove Cement | Overland Park, KS | ashgrove.com |
| Buzzi Unicem USA, Inc. | Bethlehem, PA | buzziunicemusa.com |
| CalPortland Company | Glendora, CA | calportland.com |
| CEMEX USA | Houston, TX | cemexusa.com |
| Continental Cement | Chesterfield, MO | continentalcement.com |
| Drake Cement | Scottsdale, AZ | drakecement.com |
| Federal White Cement | Woodstock, ON | federalwhitecement.com |
| GCC of America | Glendale, CO | gccusa.com |
| LafargeHolcim | Rosemont, IL | lafarge-na.com |
| Lehigh Hanson | Irving, TX | lehighhanson.com |
| Martin Marietta Materials, Inc. | Dallas, TX | martinmarietta.com |
| Mitsubishi Cement Corporation | Henderson, NV | mitsubishicement.com |
| Monarch Cement Company | Humboldt, KS | monarchcement.com |
| National Cement Group | Encino, CA | nationalcement.com |
| Salt River Materials Group | Scottsdale, AZ | srmaterials.com |
| St. Marys Cement | Toronto, ON | stmaryscement.com |
| Suwannee American Cement | Branford, FL | suwanneecement.com |
| Titan America LLC | Norfolk, VA | titanamerica.com |



PCA® *Since 1916*
America's Cement Manufacturers™



ENVIRONMENTAL
PRODUCT
DECLARATION

BLENDED HYDRAULIC CEMENT

(per ASTM C219 and specified in ASTM C595,
ASTM C1157, AASHTO M 240, or CSA A3001)

ENVIRONMENTAL PRODUCT DECLARATION BLENDED HYDRAULIC CEMENT

ASTM Certification page

This document is a Type III industry-average Environmental Product Declaration (EPD) covering Blended hydraulic cements produced in the United States (US) by Portland Cement Association (PCA) members. The results of the underlying LCA are computed with the *North American (N.A.) version of the Global Cement and Concrete Association's (GCCA) Industry EPD tool for cement and concrete* [4]. This tool and the underlying LCA model and database have been previously verified to conform to the prevailing sub-product category rule (PCR) [11], ISO 21930:2017 (the core PCR) [10] as well as ISO 14025:2006 [7] and ISO 14040/44:2006 Amd: 2020 LCA standards [8], [9].

This EPD is certified by ASTM to conform to the Sub-Product Category Rule (PCR) referenced below, as well as to the requirements of ISO 14025 and ISO 21930.

| | |
|------------------------|---|
| DECLARATION HOLDER | Portland Cement Association 5420 Old Orchard Road Skokie, IL, USA 60077-1083 www.cement.org |
| DECLARATION NUMBER | EPD 193 |
| PRODUCT GROUP AND NAME | Cement, UN CPC 3744 |
| DECLARED PRODUCT | Blended Hydraulic cement(s) as a category product |
| REFERENCE PCR | NSF Product Category Rule for <i>Preparing an Environmental Product Declaration for Portland, Blended Hydraulic, Masonry, Mortar, and Plastic (Stucco) Cements</i> . V3.1, September 2020. |
| PROGRAM OPERATOR | ASTM International 100 Barr Harbor Drive West Conshohocken, PA, USA 19428-2959 www.astm.org |
| DATE OF ISSUE | 03-12-2021 |
| PERIOD OF VALIDITY | 03-12-2021- 03-12-2026 |
| NOTES | The EPD results are computed using the <i>N.A. version of GCCA Industry EPD tool for Cement and Concrete</i> (https://concrete-epd-tool.org). |

ENVIRONMENTAL PRODUCT DECLARATION BLENDED HYDRAULIC CEMENT

EPD VERIFICATION

This EPD has been certified by an independent, external verifier in accordance with ISO 14025.



Tim Brooke
ASTM International

Date
verified



Thomas P. Gloria, Ph. D.
Industrial Ecology Consultants

Date
verified

Product description and applicable standards

The product under evaluation is blended hydraulic cement as defined by ASTM C219 and specified in ASTM C595, ASTM C1157, AASHTO M 240 or CSA A3001.

A hydraulic cement consisting of two or more inorganic constituents (at least one of which is not portland cement or portland cement clinker) which separately or in combination contribute to the strength gaining properties of the cement, (made with or without other constituents, processing additions and functional additions, by intergrinding or other blending). (ASTM C219)

As a category, blended cement types are identified by their proportional constituents, such as:

Type IP (ASTM C595) — Portland-pozzolan cement is a hydraulic cement in which the pozzolan constituent is up to 40 % by mass of the blended cement.

Type IS (ASTM C595) — is a hydraulic cement in which the slag constituent is up to 95 % by mass of the blended cement. Portland blast-furnace slag cement with a slag content equal to or exceeding 70 % by mass, is permitted to contain hydrated lime.

Type IL (ASTM C595) —Portland-limestone cement shall be a hydraulic cement in which the limestone content is more than 5 % but less than or equal to 15 % by mass of the blended cement.

Type IT (ASTM C595) —Ternary blended cement shall be a hydraulic cement consisting of an intimate and uniform blend produced either by intergrinding, by blending, or a combination of intergrinding, and blending Portland cement clinker or Portland cement with (1) two different pozzolans, (2) slag and a pozzolan, (3) a pozzolan and a limestone, or (4) a slag and a limestone. Ternary blended cement Type IT(S≥70) shall have a maximum limestone content of 15 % by mass and is permitted to contain hydrated lime. All other ternary blended cements shall have a maximum pozzolan content of 40 % by mass of the blended cement, a maximum limestone content of 15 % by mass of the blended cement, and the total content of pozzolan, limestone, and

ENVIRONMENTAL PRODUCT DECLARATION

BLENDED HYDRAULIC CEMENT

slag shall be less than 70 % by mass of the blended cement. Any slag, pozzolan, or limestone used as ingredient in Portland cement used to manufacture a blended cement shall be included in the total amount of those materials.

All cement products are composed of specific combinations of calcium, silica, iron and alumina and small amounts of additives to achieve a desired profile of properties (e.g., strength, color). Clinker, the principle intermediate manufactured product within cement production, is typically produced from a combination of ingredients, including limestone (for calcium), coupled with smaller quantities of materials such as clay, iron ore, and sand (as sources of alumina, iron, and silica, respectively). So common are these building blocks that a wide variety of raw materials are suitable sources, and some sources, such as clay and fly ash, may provide multiple chemical components. Cement plants are increasingly turning to industrial byproducts that otherwise would be discarded, once completing detailed analyses to determine the effects of using a byproduct on the manufacturing process, cement performance and facility emissions.

The U.S. industry average blended hydraulic cement, as found by this study, is 70.7% clinker by weight. Table 1 describes the cement’s composition by specific material resources.

Table 1. Material composition of the U.S. industry average blended hydraulic cement

| Cement Ingredients ^a | Portion of cement product (by weight) |
|-------------------------------------|---------------------------------------|
| Clinker | 70.7% |
| Slag | 10.7% |
| Gypsum | 5.4% |
| Uncalcined limestone | 6.1% |
| Fly ash | 6.0% |
| Other (e.g., anhydrites, pozzolans) | <1.0% each |

^aIt should be noted that while all blended hydraulic cement products contain (in-part) clinker and gypsum, the remaining composition may include one or more other materials. The average cement production data computed for this EPD represents the weighted average use of all materials by all participating plants. The data should not be interpreted to mean that all blended cement products contain all of the ingredients listed in this table nor in the ratios presented.

Applicable Standards:

ASTM C595 / C595M – 20 Standard Specification for Blended Hydraulic Cements.

ASTM C1157 / C1157M – 20 Standard Performance Specification for Hydraulic Cement.

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AASHTO M 240M/M 240-20 Standard Specification for Blended Hydraulic Cement (ASTM C595/C595M-20).
CSA A3001 – 13 Cementitious materials for use in concrete.

Declared unit

The declared unit for this study is the production of one metric ton (1 t) of blended hydraulic cement awaiting delivery to a customer. The cement is either packaged and stored on pallets or housed unpackaged in silos and ready for bulk transport.

System boundary

Life cycle stages

This EPD describes blended hydraulic cement production from cradle-to-gate, as depicted in Figure 1. This includes all modules (A1-A3) of the Production stage, as defined by the PCR. Specifically, Production stage modules capture the following aspects of the life cycle:

- Extraction and processing of raw materials and packaging used to produce cement (A1);
- Transportation of raw materials and packaging from source to cement production site (A2);
- Consumption of energy and water required to produce cement (A3);
- Emissions and wastes generated from producing cement (A3);
- Transportation of wastes from cement production to end-of-life (A3); and
- End-of-life of wastes generated during cement production (A3).

The Construction, Use and End-of-life stages are excluded from the scope of the PCR and therefore from the impact data provided by this EPD.

Exclusions and cut-off criteria

Several items are excluded from the foreground life cycle inventories (LCIs) used in the LCA. These relate specifically to operations at cement production plants:

Capital equipment and infrastructure. These are expected to contribute negligibly (<1%) to the total impact of cement production given the long lifetime of these items and high output of cement over this period.

Personnel-related activities, such as travel, furniture and office supplies. (Energy and water use related to on-site office operations, such as company management and sales activities, are included.)

These two categories of items are included in upstream processes (e.g., electricity generation) where they are captured in the background data used in the LCA underlying GCCA Industry EPD tool.

ENVIRONMENTAL PRODUCT DECLARATION BLENDED HYDRAULIC CEMENT

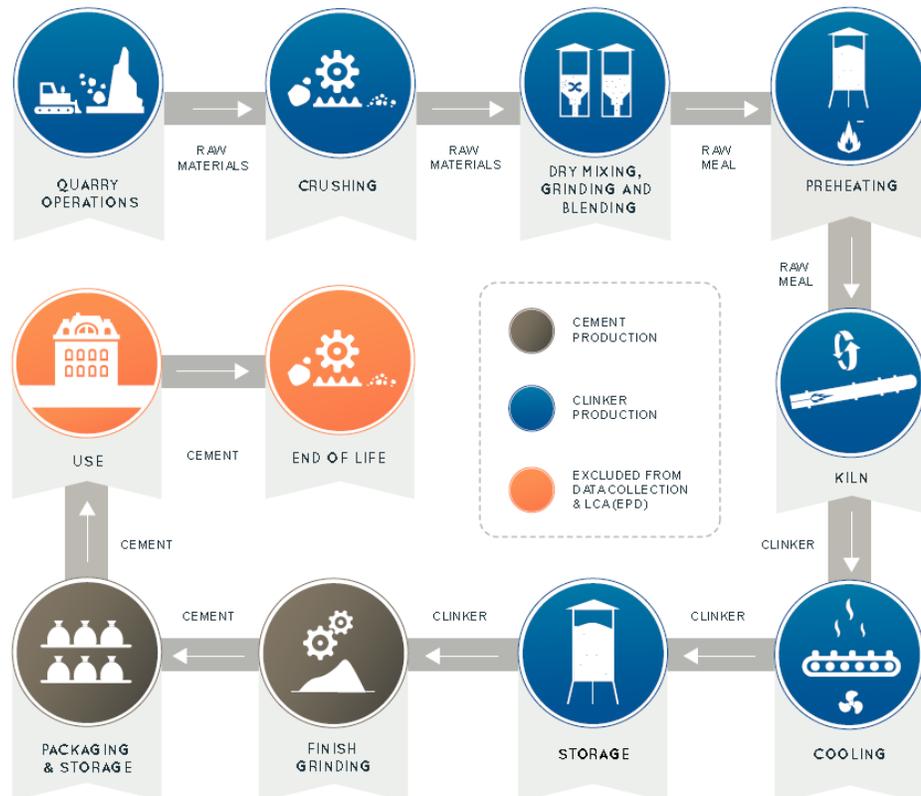


Figure 1. Boundary of the industry-average cement production processes.

Allocation approach

Allocation of inventory flows and subsequently environmental impact is relevant when assets are shared between product systems. The allocation method prescribed by the PCR is applied in the underlying LCA. The sub-category PCR recognizes fly ash, furnace bottom ash, bypass dust, mill scale, polluted soils, spent catalyst, aluminum oxide waste, silica fume, granulated blast furnace slag, iron rich waste, cement kiln dust (CKD), flue gas desulfurization (FGD) gypsum, calcium fluoride rich waste and postconsumer gypsum as recovered materials and thus, the environmental impacts allocated to these materials are limited to the treatment and transportation required to use as a cement material input. Further, used tires, plastics, solvents, used oil and oily waste, coal/carbon waste, roofing asphalt, household refuse-derived waste, non-hazardous liquid waste, industrial sludge, and agricultural waste are considered non-renewable and/or renewable secondary fuels. Only the materials, water, energy, emissions, and other elemental flows associated with reprocessing, handling, sorting and transportation from the point of the generating industrial process to their use in the production process are considered. All emissions from combustion at the point of use are considered. For co-products, no credit is considered, and no allocation is applied. See the *LCA model and LCA database* reports of the of the *N.A. version of GCCA's Industry Tool for EPDs of cement and concrete* for more information [4], [5].

ENVIRONMENTAL PRODUCT DECLARATION
BLENDED HYDRAULIC CEMENT

Data Quality Requirements and Assessment

Technology Coverage

The life cycle impact assessment (LCIA) results presented in this EPD are calculated using an industry-average LCI of US PCA members producing blended hydraulic cement. The LCI is assembled with data shared by PCA members through a survey process carried out in 2020, representing 2019 operations. Primary (gate-to-gate activity) data were collected for limestone quarrying, clinker production and blended hydraulic cement manufacture. Data collection and aggregation methods are described in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

It is estimated that the US cement industry produced 2,000,000 metric tons of blended hydraulic cements [13]. The LCI captures 1,637,140 metric tons of blended cements (as reported by 22 plants) or 80% of total US production¹.

Clinker, the main ingredient in cement production, can be produced using one of a number of technologies, or a combination of these technologies. The blended cement described by this EPD is produced under the profile of clinker production technologies shown in Table 2. A total of 53,141,130 metric tons of clinker are represented by the overall average industry dataset. It is estimated that in 2019 78,000,000 metric tons of clinker was produced in the US and hence, the plant sample represents about 68% of all US clinker production [13]. The plant average raw meal to clinker ratio is 1.59. The average total renewable and non-renewable primary energy required to produce a metric ton of clinker was calculated to be 3.88 GJ on a lower heating value basis.

Table 2. Clinker production technologies applied in the making of the portland cement described by this EPD.

| Clinker production technology | Percent of cement produced by clinker technology |
|--|--|
| Dry with preheater and precalciner | 88.5% |
| Dry with preheater | 3.1% |
| Long dry | 5.3% |
| Wet | 0.6% |
| Other (other technology or a combination of technologies) ¹ | 2.4% |

¹ PCA membership does not represent all cement companies operating in the USA.

ENVIRONMENTAL PRODUCT DECLARATION

BLENDED HYDRAULIC CEMENT

¹Reported as long semi-wet/semi-dry technology.

Geographic and Temporal Coverage

The blended cement production impacts estimated by the LCA represent cement produced in the US in 2019. Foreground data and assumptions reflect equipment, processes, and market conditions for this year. Background processes, such as some raw material operations and electricity generation (see below), are characterized by data that represent US processes where information is available. In cases where US-specific information is not available, the best available alternative information is used. Additional details describing the background data are provided in the *LCA model and LCA database report of the N.A. version of GCCA Industry EPD Tool for cement and concrete* [5]. Foreground data were collected for limestone quarrying, clinker production and Portland cement manufacture. These data are summarized in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

Electricity grid mix

For electricity use modeling, the PCR requires the use of subnational electricity consumption LCIs that consider power trading between regions. To do this, the US EPA's *eGrid* 2018 data are used, which identify grid mixes for ten US regions (NERC regions) and considers regional trading [14]. A weighted average of the NERC regional mixes is applied in the LCA, where the weighting reflects the portion of blended cement produced in each region. The resulting grid mix used in the LCA is shown in Table 3.

Table 3. Grid mix for blended hydraulic cement production described by this EPD.

| Energy source | Portion of representative grid mix |
|---------------|------------------------------------|
| Gas | 35.37% |
| Coal and peat | 29.81% |
| Nuclear | 16.91% |
| Wind | 6.98% |
| Hydro | 6.46% |
| Biomass | 1.61% |
| Waste | 1.56% |
| Geothermal | 0.69% |
| Oil | 0.41% |
| Solar | 0.21% |
| TOTAL | 100% |

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Data Completeness, Consistency, Reproducibility and Transparency

All inputs (raw materials, ancillary and packaging materials, energy, and water) and outputs (emissions to air, water and soil, solid and liquid waste, products, co-products, and by-products) were collected, reviewed, benchmarked and modeled to complete LCI production profile for blended cements. The completeness of the cradle-to-gate process chain in terms of process steps is rigorously assessed for all cement facilities.

A review of the source of individual input and output data (direct, indirect, estimate, other) shared by participating producers was conducted and summarized in Appendix A, *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

To ensure consistency, cross checks of the energy demand and the calculated raw meal to clinker ratio against ranges reported in the *WBCSD Cement Sustainability Initiative, Cement CO₂ and Energy Protocol*, v3.1 December, 2013 were conducted per each cement facility [15]. A full description of the foreground data quality assessment is provided in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3]. Activity LCI data are transparently disclosed in the LCI report, including all data sources, and this way external reproducibility of the EPD results with the GCCA Industry EPD Tool for cement and concrete is possible [3], [4].

The majority of data describing cement manufacture (including limestone quarrying and clinker production) is based on direct measurements and engineering calculations, as opposed to approximations. This is particularly true for flows that are the major contributors to impact for cement production, namely clinker production.

It should be noted that the data quality assessment here in covers only limestone, clinker and cement production inventories (i.e., activity data). An evaluation of the quality of data used to model background processes (e.g., electricity generation) has also been carried out, and the results are presented in the LCA model and LCA database reports for the *N.A. version of GCCA's Industry EPD Tool for Cement and Concrete* [4], [5].

Limitations

This EPD represents average industry performance for PCA Member producing blended cements. It considers only cement plants located in the US. Results may not adequately represent cement production systems that differ greatly from those captured by the data used in the underlying LCA.

This EPD is a declaration of potential environmental impact and does not support or provide definitive comparisons of the environmental performance of specific products. Only EPDs prepared from cradle-to-grave life cycle results and

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based on the same function and reference service life and quantified by the same functional unit can be used to assist purchasers and users in making informed comparisons between products.

The EPD provided here in and the underlying LCA conform to the *NSF Product Category Rule for Preparing an Environmental Product Declaration for Portland, Blended Hydraulic, Masonry, Mortar, and Plastic (Stucco) Cements*. EPDs of blended cement that follow a different PCR may not be comparable.

LCA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks. Further, LCA offers a wide array of environmental impact indicators, and this EPD reports a collection of those, as specified by the PCR.

In addition to the impact results, this EPD provides several metrics related to resource consumption and waste generation. These data are informational as they do not provide a measure of impact on the environment. Further, a number of LCA impact categories and inventory items are still emerging or under development and can have high levels of uncertainty that preclude international acceptance pending further development. Use caution when interpreting results for these categories – identified with an “*” in Table 4.

Supplementary information regarding LCA methodology

Additional information regarding databases and impact methodologies used for conducting the LCA for this EPD can be found in the *LCA core model and LCA database reports of the N.A. version of GCCA's Industry EPD Tool for Cement and Concrete* [4], [5].

Life cycle assessment results

The cradle-to-gate (A1 to A3) EPD results of producing one metric ton of blended hydraulic cement are presented in Table 4.

Table 4. Production stage EPD results for blended hydraulic cements.

| Impact category and inventory indicators | Unit | Blended Cements 1 metric ton |
|---|-----------------------|---------------------------------|
| Global warming potential, GWP 100, IPCC 2013 | kg CO ₂ eq | 742 |
| Ozone depletion potential, ODP | kg CFC-11 eq | 1.99E-05 |
| Acidification potential, AP | kg SO ₂ eq | 1.46 |
| Eutrophication potential, EP | kg N eq | 0.95 |
| Smog formation potential, SFP | kg O ₃ eq | 26.6 |
| Abiotic depletion potential for non-fossil mineral resources, ADP elements* | kg Sb eq | 1.83E-04 |
| Abiotic depletion potential for fossil resources, ADP fossil* | MJ Surplus | 318 |

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| Impact category and inventory indicators | Unit | Blended Cements 1 metric ton |
|---|-----------------------|---------------------------------|
| Renewable primary resources used as an energy carrier (fuel), RPR _E * | MJ LHV | 135 |
| Renewable primary resources with energy content used as material, RPR _M * | MJ LHV | 5.96 |
| Non-renewable primary resources used as an energy carrier (fuel), NRPR _E * | MJ LHV | 3610 |
| Non-renewable primary resources with energy content used as material, NRPR _M * | MJ LHV | 0 |
| Secondary materials, SM* | kg | 264 |
| Renewable secondary fuels, RSF* | MJ LHV | 42 |
| Non-renewable secondary fuels, NRSF* | MJ LHV | 405 |
| Net use of freshwater, NFW* | m ³ | 0.92 |
| Hazardous waste disposed, HWD* | kg | 9.70E-03 |
| Non-hazardous waste disposed, NHWD* | kg | 239 |
| High-level radioactive waste, conditioned, to final repository, HLRW* | kg | x¹⁾ |
| Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW* | kg | x¹⁾ |
| Components for re-use, CRU* | kg | 0 |
| Materials for recycling, MFR* | kg | 0.4 |
| Materials for energy recovery, MER* | kg | 0 |
| Recovered energy exported from the product system, EE* | MJ LHV | 1.50 |
| Additional Inventory Parameters for Transparency | | |
| Global warming potential - biogenic, GWP _{bio} * | kg CO ₂ eq | 0.73 |
| Emissions from calcination* | kg CO ₂ eq | 371 |
| Emissions from combustion of waste from renewable sources* | kg CO ₂ eq | 0.16 |
| Emissions from combustion of waste from non-renewable sources* | kg CO ₂ eq | 378 |

¹⁾ x – Not all LCA datasets for upstream materials include these impact categories and thus results may be incomplete.

*¹⁾ Use caution when interpreting results for these categories.

Interpretation

Based on the blended cement EPD results calculated with the GCCA Industry EPD Tool for cement and concrete, the following conclusions could be reached [4]. The Manufacturing module (A3) drives most of the potential environmental impacts. Manufacturing impacts are primarily driven by energy use (electricity and thermal fuels) used during the pyroprocessing of limestone in the production of clinker. Clinker content in cement similarly defines the relative environmental profile of the final cement product. Raw material extraction (A1) is the second largest contributor to the Production stage EPD results, followed by transportation (A2).

Additional environmental information

Of the responding plants, around 15% of the facilities are ISO 9001 certified and another 29% are ISO 14001 certified or both. The rest of the plants adhere to different types of corporate or company specific internal environmental management systems, e.g., Spectra QEST (www.spectraqest.com/) which is designed to assist responsible plant personnel by tracking and notifying them of major reporting, monitoring and recordkeeping requirements, EnviroLIS, a

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database management system to track permits and permit conditions and all environmental related tasks or maintain similar ISO 14001 environmental management system without certification.

Air pollution abatement equipment used at PCA members cement facilities may consist of any mix of the following technologies: high and low temperature baghouses, bin vents, drum filters, dry filters, cartridge filters, precipitators, water sprinklers for dust control, Selective non-catalytic reduction (SNCR), Selective catalytic reduction (SCR), wet scrubbers, dry scrubbers (dry sorbent injection, DSI), Activated Carbon Injection (ASI), and Regenerative Thermal Oxidizer (RTO).

It is also noted that about a third of the plants package some of their cements, the majority bulk load their cements for sale.

References

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9. ISO 14044:2006/Amd1:2017/Amd2:2020 Environmental management - Life cycle assessment - Requirements and guidelines.
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11. NSF International, Product Category Rule Environmental Product Declarations, PCR for Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements, v3.1, Sept. 2020.
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13. US EPA (2020) eGRID 2018. The Emissions and Generation Resource Integrated Database. <http://www.epa.gov/energy/eGRID>.
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15. WBCSD CSI 2013: CO₂ and Energy Protocol Version 3.1 of 9 December 2013. <https://www.cement-co2-protocol.org/en/>

ENVIRONMENTAL PRODUCT DECLARATION
BLENDED HYDRAULIC CEMENT

Participating PCA members

| Member | Corporate headquarters | Website |
|---------------------------------|-------------------------------|--|
| Argos USA Corp. | Alpharetta, GA | argos.co/usa |
| Ash Grove Cement | Overland Park, KS | ashgrove.com |
| Buzzi Unicem USA, Inc. | Bethlehem, PA | buzziunicemusa.com |
| CalPortland Company | Glendora, CA | calportland.com |
| CEMEX USA | Houston, TX | cemexusa.com |
| Continental Cement | Chesterfield, MO | continentalcement.com |
| Drake Cement | Scottsdale, AZ | drakecement.com |
| Federal White Cement | Woodstock, ON | federalwhitecement.com |
| GCC of America | Glendale, CO | gccusa.com |
| LafargeHolcim | Rosemont, IL | lafarge-na.com |
| Lehigh Hanson | Irving, TX | lehighhanson.com |
| Martin Marietta Materials, Inc. | Dallas, TX | martinmarietta.com |
| Mitsubishi Cement Corporation | Henderson, NV | mitsubishicement.com |
| Monarch Cement Company | Humboldt, KS | monarchcement.com |
| National Cement Group | Encino, CA | nationalcement.com |
| Salt River Materials Group | Scottsdale, AZ | srmaterials.com |
| St. Marys Cement | Toronto, ON | stmaryscement.com |
| Suwannee American Cement | Branford, FL | suwanneecement.com |
| Titan America LLC | Norfolk, VA | titanamerica.com |



PCA® *Since 1916*
America's Cement Manufacturers™



ENVIRONMENTAL
PRODUCT
DECLARATION

MASONRY CEMENT

(per ASTM C219 and specified in ASTM C91 or
CSA A3002)

ENVIRONMENTAL PRODUCT DECLARATION MASONRY CEMENT

ASTM Certification page

This document is a Type III industry-average Environmental Product Declaration (EPD) covering masonry cements produced in the United States (US) by Portland Cement Association (PCA) members. The results of the underlying LCA are computed with the North American (N.A.) version of the Global Cement and Concrete Association (GCCA) Industry EPD tool for cement and concrete [4]. This tool and the underlying LCA model and database have been previously verified to conform to the prevailing sub-product category rule (PCR) [11], ISO 21930:2017 (the core PCR) [10] as well as ISO 14025:2006 [7] and ISO 14040/44:2006 Amd: 2020 LCA standards [8], [9].

This EPD is certified by ASTM to conform to the Sub-Product Category Rule (PCR) referenced below, as well as to the requirements of ISO 14025 and ISO 21930.

| | |
|-------------------------------|--|
| DECLARATION HOLDER | Portland Cement Association 5420 Old Orchard Road Skokie, IL, USA 60077-1083 www.cement.org |
| DECLARATION NUMBER | EPD 194 |
| PRODUCT GROUP AND NAME | Cement, UN CPC 3744 |
| DECLARED PRODUCT | Masonry cement(s) as a category product |
| REFERENCE PCR | NSF Product Category Rule for <i>Preparing an Environmental Product Declaration for Portland, Blended Hydraulic, Masonry, Mortar, and Plastic (Stucco) Cements</i> . V3.1, September 2020. |
| PROGRAM OPERATOR | ASTM International 100 Barr Harbor Drive West Conshohocken, PA, USA 19428-2959 www.astm.org |
| DATE OF ISSUE | 03-12-2021 |
| PERIOD OF VALIDITY | 03-12-2021- 03-12-2026 |
| NOTES | The EPD results are computed using the N.A. version of GCCA Industry EPD tool for Cement and Concrete (https://concrete-epd-tool.org). |

ENVIRONMENTAL PRODUCT DECLARATION MASONRY CEMENT

EPD VERIFICATION

This EPD has been certified by an independent, external verifier in accordance with ISO 14025.



Tim Brooke
 ASTM International

Date
 verified



Thomas P. Gloria, Ph. D.
 Industrial Ecology Consultants

Date
 verified

Product description and applicable standards

The product under evaluation is masonry cement as defined by ASTM C219 and specified in ASTM C91 or CSA A3002.

A hydraulic cement manufactured for use in mortars for masonry construction or in plasters, or both, which contains a plasticizing material and, possibly, other performance-enhancing addition(s). (ASTM C219)

Type N—For use in preparation of Specification C270 Type N mortar without further addition of cements or hydrated lime, and for use in preparation of Specification C270 Type S or Type M mortar when cement is added in accordance with the requirements of C270.

Type S—For use in preparation of Specification C270 Type S mortar without further addition of cements or hydrated lime.

Type M—For use in preparation of Specification C270 Type M mortar without further addition of cements or hydrated lime.

All cement products are composed of specific combinations of calcium, silica, iron and alumina and small amounts of additives to achieve a desired profile of properties (e.g., strength, color). Clinker, the principle intermediate manufactured product within cement production, is typically produced from a combination of ingredients, including limestone (for calcium), coupled with smaller quantities of materials such as clay, iron ore, and sand (as sources of alumina, iron, and silica, respectively). So common are these building blocks that a wide variety of raw materials are suitable sources, and some sources, such clay and fly ash, may provide multiple chemical components. Cement plants are increasingly turning to industrial byproducts that otherwise would be discarded, once completing detailed analyses to determine the effects of using a byproduct on the manufacturing process, cement performance and facility emissions. The U.S. industry average masonry cement, as found by this study, is 55.2% clinker by weight. Table 1 describes the cement's composition by specific material resources.

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Table 1. Material composition of the U.S. industry average masonry cement

| Cement ingredients ^a | Portion of cement product (by weight) |
|--------------------------------------|---------------------------------------|
| Clinker | 55.2% |
| Unclined limestone or hydraulic lime | 34.9% |
| Gypsum | 6.7% |
| Slag | 1.4% |
| Other materials | <1.0% each |

^aIt should be noted that while all masonry cement products contain the ingredients listed above (except dust, which may or may not be used by a particular cement producer), the average cement production data computed for this EPD represents the weighted average use of all materials by all participating plants. The data should not be interpreted to mean that the ingredient proportions presented in this table is the formulation for all masonry cement products.

Declared unit

The declared unit for this study is the production of one metric ton (1 t) of masonry cement awaiting delivery to a customer. The cement is either packaged and stored on pallets or housed unpackaged in silos and ready for bulk transport.

System boundary

Life cycle stages

This EPD describes masonry cement production from cradle-to-gate, as depicted in Figure 1. This includes all modules (A1-A3) of the Production stage, as defined by the PCR. Specifically, Production stage modules capture the following aspects of the life cycle:

- Extraction and processing of raw materials and packaging used to produce cement (A1);
- Transportation of raw materials and packaging from source to cement production site (A2);
- Consumption of energy and water required to produce cement (A3);
- Emissions and wastes generated from producing cement(A3);
- Transportation of wastes from cement production to end-of-life (A3); and
- End-of-life of wastes generated during cement production (A3).

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The Construction, Use and End-of-life stages are excluded from the scope of the PCR and therefore from the impact data provided by this EPD.

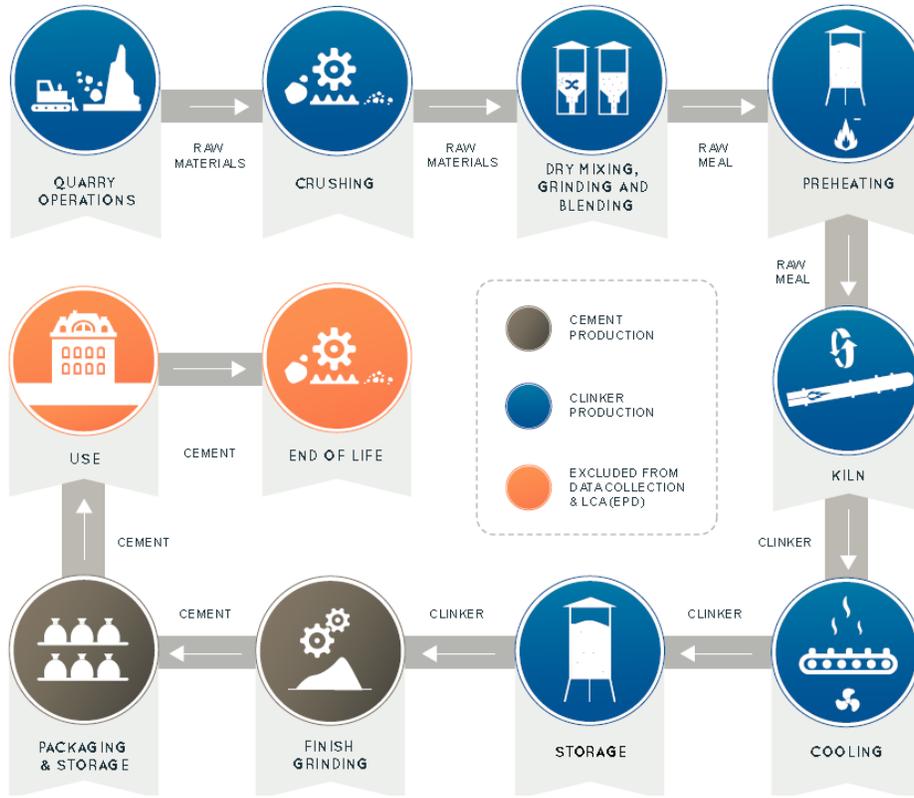


Figure 1. Boundary of the industry-average cement production processes..

Exclusions and cut-off criteria

Several items are excluded from the foreground life cycle inventories (LCIs) used in the LCA. These relate specifically to operations at cement production plants:

Capital equipment and infrastructure. These are expected to contribute negligibly (<1%) to the total impact of cement production given the long lifetime of these items and high output of cement over this period.

Personnel-related activities, such as travel, furniture and office supplies. (Energy and water use related to on-site office operations, such as company management and sales activities, are included.)

These two categories of items are included in upstream processes (e.g., electricity generation) where they are captured in the background data used in the LCA underlying GCCA Industry EPD tool.

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Allocation approach

Allocation of inventory flows and subsequently environmental impact is relevant when assets are shared between product systems. The allocation method prescribed by the PCR is applied in the underlying LCA. The sub-category PCR recognizes fly ash, furnace bottom ash, bypass dust, mill scale, polluted soils, spent catalyst, aluminum oxide waste, silica fume, granulated blast furnace slag, iron rich waste, cement kiln dust (CKD), flue gas desulfurization (FGD) gypsum, calcium fluoride rich waste and postconsumer gypsum as recovered materials and thus, the environmental impacts allocated to these materials are limited to the treatment and transportation required to use as a cement material input. Further, used tires, plastics, solvents, used oil and oily waste, coal/carbon waste, roofing asphalt, household refuse-derived waste, non-hazardous liquid waste, industrial sludge, and agricultural waste are considered non-renewable and/or renewable secondary fuels. Only the materials, water, energy, emissions, and other elemental flows associated with reprocessing, handling, sorting and transportation from the point of the generating industrial process to their use in the production process are considered. All emissions from combustion at the point of use are considered. For co-products, no credit is considered, and no allocation is applied. See the *LCA model and LCA database reports of the N.A. version of GCCA's Industry Tool for EPDs of cement and concrete* for more information [4], [5].

Data Quality Requirements and Assessment

Technology Coverage

The life cycle impact assessment (LCIA) results presented in this EPD are calculated using an industry-average LCI of US PCA members producing masonry cements. The LCI is assembled with data shared by PCA members through a survey process carried out in 2020 and represents 2019 operations. Primary (gate-to-gate activity) data were collected for limestone quarrying, clinker production and masonry cement manufacture. Data collection and aggregation methods are described in the *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

In 2019, the US cement industry generated 2,400,000 metric tons of masonry cements [13]. The LCI captures 1,109,471 metric tons of PCA member production (as reported by 32 plants) and therefore 46% of total industry production in 2019.

Clinker, the main ingredient in cement production, can be produced using one of a number of technologies, or a combination of these technologies. The masonry cement described by this EPD is produced under the profile of clinker production technologies shown in Table 2. A total of 53,141,130 metric tons of clinker are represented by the overall average industry dataset. It is estimated that in 2019 78,000,000 metric tons of clinker was produced in the US and hence, the plant sample represents about 68% of all US clinker production [13]. The plant average raw meal to clinker ratio is 1.59. The average total renewable and non-renewable primary energy required to produce a metric ton of clinker was calculated to be 3.88 GJ on a lower heating value basis.

¹ PCA membership does not represent all cement companies operating in the US.

ENVIRONMENTAL PRODUCT DECLARATION MASONRY CEMENT

Table 2. Clinker production technologies applied in the making of the masonry cement described by this EPD.

| Clinker production technology | Percent of cement produced by clinker technology |
|--|--|
| Dry with preheater and precalciner | 88.5% |
| Dry with preheater | 3.1% |
| Long dry | 5.3% |
| Wet | 0.6% |
| Other (other technology or a combination of technologies) ¹ | 2.4% |

¹Reported as long semi-wet/semi-dry technology.

Geographic and Temporal Coverage

The masonry cement production impacts estimated by the LCA represent cement produced in the US in 2019. Foreground data and assumptions reflect equipment, processes, and market conditions for this year. Background processes, such as some raw material operations and electricity generation (see below), are characterized by data that represent US processes where information is available. In cases where US-specific information is not available, the best available alternative information is used. Additional details describing the background data are provided in the LCA model and LCA database reports of the *N.A. version of GCCA Industry Tool for EPDs of cement and concrete* [5]. Foreground gate-to-gate data were collected for limestone quarrying, clinker production and masonry cement manufacture. These data are summarized in the report *Portland Cement Association Life Cycle Inventory Summary Report*, February 2021 [3].

Electricity grid mix

For electricity use modeling, the PCR requires the use of subnational electricity consumption LCIs that consider power trading between regions. To do this, the US EPA's *eGrid* 2018 data are used, which identify grid mixes for ten US regions (NERC regions) and considers regional trading [14]. A weighted average of the NERC regional mixes is applied in the LCA, where the weighting reflects the portion of masonry cement produced in each region. The resulting grid mix used in the LCA is shown in Table 3.

Table 3. Grid mix for masonry cement production described by this EPD.

| Energy source | Portion of representative grid mix |
|---------------|------------------------------------|
| Gas | 43.62% |

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| | |
|---------------|--------|
| Coal and peat | 24.97% |
| Nuclear | 20.13% |
| Hydro | 3.61% |
| Wind | 3.53% |
| Biomass | 1.82% |
| Solar | 1.13% |
| Oil | 0.81% |
| Waste | 0.21% |
| Geothermal | 0.16% |
| TOTAL | 100% |

Data Completeness, Consistency, Reproducibility and Transparency

All inputs (raw materials, ancillary and packaging materials, energy, and water) and outputs (emissions to air, water and soil, solid and liquid waste, products, co-products, and by-products) were collected, reviewed, benchmarked, and modeled to complete LCI production profile for masonry cements. The completeness of the cradle-to-gate process chain in terms of process steps is rigorously assessed for all cement facilities.

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The majority of data describing cement manufacture (including limestone quarrying and clinker production) is based on direct measurements and engineering calculations, as opposed to approximations. This is particularly true for flows that are the major contributors to impact for cement production, namely clinker production.

It should be noted that the data quality assessment here in covers only limestone, clinker and cement production inventories (i.e., activity data). An evaluation of the quality of data used to model background processes (e.g., electricity

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Limitations

This EPD represents average industry performance for PCA Member producing masonry cements. It considers only cement plants located in the US. Results may not adequately represent cement production systems that differ greatly from those captured by the data used in the underlying LCA.

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Additional information regarding databases and impact methodologies used for conducting the LCA for this EPD can be found in the *LCA core model and LCA database reports of the N.A. version of GCCA's Industry EPD Tool for Cement and Concrete* [4], [5].

Life cycle assessment results

The cradle-to-gate impacts of producing masonry cement are presented in Table 4.

ENVIRONMENTAL PRODUCT DECLARATION MASONRY CEMENT

Table 4. Production stage EPD results for masonry cements.

| Impact category and inventory indicators | Unit | Masonry Cements 1 metric ton |
|---|-----------------------|---------------------------------|
| Global warming potential, GWP 100, IPCC 2013 | kg CO ₂ eq | 589 |
| Ozone depletion potential, ODP | kg CFC-11 eq | 1.77E-05 |
| Acidification potential, AP | kg SO ₂ eq | 1.24 |
| Eutrophication potential, EP | kg N eq | 0.7 |
| Smog formation potential, SFP | kg O ₃ eq | 22.4 |
| Abiotic depletion potential for non-fossil mineral resources, ADP elements* | kg Sb eq | 1.81E-04 |
| Abiotic depletion potential for fossil resources, ADP fossil* | MJ Surplus | 285 |
| Renewable primary resources used as an energy carrier (fuel), RPR _E * | MJ LHV | 141 |
| Renewable primary resources with energy content used as material, RPR _M * | MJ LHV | 75 |
| Non-renewable primary resources used as an energy carrier (fuel), NRPR _E * | MJ LHV | 3030 |
| Non-renewable primary resources with energy content used as material, NRPR _M * | MJ LHV | 7.0 |
| Secondary materials, SM* | kg | 91.1 |
| Renewable secondary fuels, RSF* | MJ LHV | 32.8 |
| Non-renewable secondary fuels, NRSF* | MJ LHV | 316 |
| Net use of freshwater, NFW* | m ³ | 0.87 |
| Hazardous waste disposed, HWD* | kg | 7.59E-03 |
| Non-hazardous waste disposed, NHWD* | kg | 186 |
| High-level radioactive waste, conditioned, to final repository, HLRW* | kg | x¹⁾ |
| Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW* | kg | x¹⁾ |
| Components for re-use, CRU* | kg | 0 |
| Materials for recycling, MFR* | kg | 0.31 |
| Materials for energy recovery, MER* | kg | 0 |
| Recovered energy exported from the product system, EE* | MJ LHV | 1.17 |
| Additional Inventory Parameters for Transparency | | |
| Global warming potential - biogenic, GWP _{bio} * | kg CO ₂ eq | 0.70 |
| Emissions from calcination* | kg CO ₂ eq | 290 |
| Emissions from combustion of waste from renewable sources* | kg CO ₂ eq | 0.12 |
| Emissions from combustion of waste from non-renewable sources* | kg CO ₂ eq | 29.5 |

¹⁾ x – Not all LCA datasets for upstream materials include these impact categories and thus results may be incomplete.

* Use caution when interpreting results for these categories

Interpretation

Based on the masonry cements EPD results calculated with the GCCA Industry EPD Tool for cement and concrete, the following conclusions could be reached [4]. The Manufacturing module (A3) drives most of the potential environmental impacts. Manufacturing impacts are primarily driven by energy use (electricity and thermal fuels) used during the pyroprocessing of limestone in the production of clinker. Clinker content in cement similarly defines the relative

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environmental profile of the final cement product. Raw material extraction (A1) is the second largest contributor to the Production stage EPD results, followed by the transportation (A2).

Additional environmental information

Of the responding plants, around 15% of the facilities are ISO 9001 certified and another 29% are ISO 14001 certified or both. The rest of the plants adhere to different types of corporate or company specific internal environmental management systems, e.g., Spectra QEST (www.spectraquest.com/) which is designed to assist responsible plant personnel by tracking and notifying them of major reporting, monitoring and recordkeeping requirements, EnviroLIS, a database management system to track permits and permit conditions and all environmental related tasks or maintain similar ISO 14001 environmental management system without certification.

Air pollution abatement equipment used at PCA members cement facilities may consist of any mix of the following technologies: high and low temperature baghouses, bin vents, drum filters, dry filters, cartridge filters, precipitators, water sprinklers for dust control, Selective non-catalytic reduction (SNCR), Selective catalytic reduction (SCR), wet scrubbers, dry scrubbers (dry sorbent injection, DSI), Activated Carbon Injection (ASI), and Regenerative Thermal Oxidizer (RTO).

It is also noted that about a third of the plants package some of their cements, the majority bulk load their cements for sale.

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Participating PCA members

| Member | Corporate headquarters | Website |
|---------------------------------|------------------------|------------------------|
| Argos USA Corp. | Alpharetta, GA | argos.co/usa |
| Ash Grove Cement | Overland Park, KS | ashgrove.com |
| Buzzi Unicem USA, Inc. | Bethlehem, PA | buzziunicemusa.com |
| CalPortland Company | Glendora, CA | calportland.com |
| CEMEX USA | Houston, TX | cemexusa.com |
| Continental Cement | Chesterfield, MO | continentalcement.com |
| Drake Cement | Scottsdale, AZ | drakecement.com |
| Federal White Cement | Woodstock, ON | federalwhitecement.com |
| GCC of America | Glendale, CO | gccusa.com |
| LafargeHolcim | Rosemont, IL | lafarge-na.com |
| Lehigh Hanson | Irving, TX | lehighhanson.com |
| Martin Marietta Materials, Inc. | Dallas, TX | martinmarietta.com |
| Mitsubishi Cement Corporation | Henderson, NV | mitsubishicement.com |
| Monarch Cement Company | Humboldt, KS | monarchcement.com |
| National Cement Group | Encino, CA | nationalcement.com |
| Salt River Materials Group | Scottsdale, AZ | srmaterials.com |
| St. Marys Cement | Toronto, ON | stmaryscement.com |
| Suwannee American Cement | Branford, FL | suwanneecement.com |
| Titan America LLC | Norfolk, VA | titanamerica.com |