A Canadian Industry-Average Cradle-to-Gate Life Cycle Assessment of Two Concrete Masonry Unit Products

EPD Project Report

**Commissioner:**



**EPD Program Operator:**



**Prepared by:**

Matt Bowick, Athena Sustainable Materials Institute

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# General Summary

This life cycle assessment (LCA) report or environmental product declaration (EPD) project background report presents industry-average results for normal-weight and light-weight concrete masonry units (CMU) in the Canadian market as produced by Canadian Concrete Masonry Producers Association (CCMPA) member companies.

The LCA has been completed to support a Type III Environmental Product Declaration (EPD) for CMUs conforming to CSA standard **A165.1-04 - Concrete block masonry units**. Specifically, this industry-average LCA has been completed in conformance with ISO 14040/44 standards [4], [5] and in accordance with ASTM International (ASTM) product category rules (PCR) for preparing an environmental product declaration for Manufactured Concrete and Concrete Masonry Products, December 2014 [1]. This EPD project report (underlying LCA report for EPD development purposes) was commissioned by the CCMPA and its members and is certified by ASTM International to conform to the requirements of ISO 14040 [5], 14044 [4],14025 [3] and 21930 [2] and the ASTM general program instructions.

# Glossary of Terms

*Based on ISO 14040/44:2006 [4], [5] – Terms and Definition Section.*

**Allocation:** Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems.

**Life Cycle:** Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

**Life Cycle Assessment (LCA):** Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

**Life Cycle Impact Assessment (LCIA):** Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.

**Life Cycle Interpretation:** Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.

**Life Cycle Inventory (LCI):** Phase of Life Cycle Assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

**Product system:** Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product.

**System boundary:** Set of criteria specifying which unit processes are part of a product system.

Note: the term system boundary is not used in this International Standard in relation to LCIA.

**System expansion:** Expanding the product system to include the additional functions related to the co-products, taking into account the requirements of 4.2.3.3.

*Based on ISO 14021:1999 [6] - Clause 7.8 Recycled content*

**Recovered material:** Material that would have otherwise been disposed of as waste or used for energy recovery but has instead been collected and recovered as a material input, in lieu of new primary material, for a recycling or a manufacturing process. (ISO 14021)

*Based on ISO 14025:2006 [3] - Clause 3 Terms and definitions*

**Type III Environmental Product Declaration (EPD):** providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information

*Note 1 the predetermined parameters are based on the ISO 14040 series of standards.*

*Note 2 the additional environmental information may be quantitative or qualitative.*

**Product Category Rules (PCR):** set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories.

*Based on ISO 21930:2007 [2] - Clause 3 Terms and definitions*

**Building product:** goods or services used during the life cycle of a building or other construction works.

**Declared unit:** quantity of a building product for use as a reference unit in an EPD, based on LCA, for the expression of environmental information needed in information modules.

**Information module:** compilation of data to be used as a basis for a type III environmental declaration, covering a unit process or a combination of unit processes that are part of the life cycle of a product.

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# Acronyms and Abbreviations

ASTM American Society for Testing and Materials

B2B Business-to-Business

C2G Cradle-to-Gate

CCMPA Canadian Concrete Masonry Producers Association

CFCs Chlorofluorocarbons

CFC-11 Trichlorofluoromethane

CO2 Carbon Dioxide

CMU Concrete Masonry Unit

CSA Canadian Standards Association

EPDs Environmental Product Declarations

GGBFS Ground Granulated Blast Furnace Slag

GWP Global Warming Potential

IPCC International Panel on Climate Change

ISO International Organization for Standardization

kg Kilogram

km Kilometer

kWh kilowatt hours

LCA Life Cycle Assessment

LCI Life Cycle Inventory

LCIA Life Cycle Impact Assessment

MJ Mega joule

N Nitrogen

O3 Ozone

PCR Product Category Rules

PM2.5 Particulate Matter less than or equal to 2.5 micrometers in diameter

PM10 Particulate Matter less than or equal to 10 micrometers in diameter

RoW Rest of World (global with the exception of Europe)

SO2 Sulfur dioxide

TRACI Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts

UN CPC United Nations Central Product Classification

# Introduction

Life cycle assessment (LCA) is an analytical tool used to comprehensively quantify and interpret the energy and material flows to and from the environment over the entire life cycle of a product, process, or service [4], [5]. Environmental flows include emissions to air, water, and land, as well as the consumption of energy and material resources. By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product. It is acknowledged that this particular LCA is conducted for the industry-average production of normal-weight and light-weight CMU products ready for shipment within Canada and as such has a business-to-business (B2B) focus. The study demonstrates CCMPA member companies' commitment to transparently sharing the environmental footprint of their CMU products in support of generating an EPD for users of CMU products in Canada.

# Study Goals

## Goals of the Study

This is a sector-driven initiative by CCMPA and its members to develop an industry-wide EPD according to ISO 14025:2006 and specifically, the ASTM PCR for Manufactured Concrete Products and Concrete Masonry Products [1]. The goal of this study is to provide information to support the development of an EPD for normal-weight and light-weight CMU, as manufactured and distributed in Canada by CCMPA member companies.

## Intended Applications and Audience

This LCA study is the background report for CCMPA's CMU EPD, which is intended for use in business-to-business (B-to-B) communication. The intended audience for this LCA report and associated EPD include manufacturer suppliers, architectural, engineering, and specifying professionals, LCA practitioners and tool developers, academia, governmental organizations, policy makers and other interested value-chain parties who require reliable information on CMUs.

## Comparative Assertions

This LCA project report does not include comparative assertions; however, the subsequent EPD may lead to future comparative studies intended to be disclosed to the public. LCAs and EPDs not covering all life cycle stages or based on a different PCR are examples of studies and EPDs offering limited comparability.

This LCA project report was independently verified by XXX, as per ISO 14025 (see Clause 8.1.3) [3] and the reference PCR requirements [1].

# Product Identification

This report serves as the basis for an EPD of CMU produced by CCMPA members at their facilities located across Canada. See Figure 1 for a visual representation of a typical CMU.



Figure 1: Concrete Masonry Unit

## Product Definitions and Standards

The following two product definitions apply, as modified from [1].

**concrete masonry unit:** a manufactured masonry unit made of concrete in which the binder is a combination of water and cementitious materials.

**concrete masonry unit, load-bearing:** a concrete masonry unit suitable for non-load-bearing and load-bearing applications, complying with CSA A165.1.

Applicable Canadian product standards for concrete masonry units (UN CPC 3755) include:

**CSA A165.1-04 - Concrete block masonry units**: this Standard applies to concrete block masonry units made from cementitious materials, water, and aggregates, with or without the inclusion of other materials. This Standard may be applied to other units of similar manufacture and size within the limitations of the Standard **[8].**

## Products Applicable to this LCA

This report is applicable to products broadly called either "normal-weight" or "light-weight" CMU, which generally have a length of 390 mm, a height of 190 mm, and a gross thickness of either 90 mm, 140 mm, 190 mm, 240 mm, or 290 mm[[1]](#footnote-1).

below summarizes the specifications for CMU products that are applicable to this LCA, according to the **"**Four Facet" system defined in **CSA A165.1-04**. Each facet is referred to by either a letter or number and separated by a slash. For example, S/20/A/M refers to a normal-weight “solid” block, with 20 MPa minimum compressive strength and known moisture content. Please note that this specification format does not address other block properties such as fire resistance ratings, thermal resistance, and sound transmission classifications.

## Material Contents

Table 2 and below present the material content by input material for the two products. The concrete mixes are average designs, weighted based on CCMPA-member CMU production (see Section 7.1). Appendix B shows the same information in Imperial units.

Table : Product Specifications Applicable to the LCA

|  |  |  |  |
| --- | --- | --- | --- |
| **Facet** | **Specification Identification** | | **Comments** |
| **Normal-weight CMU** | **Light-weight CMU** |
| **First:** Identifies the percentage content of the unit. | H, S, or Sc | | The symbols H, S and Sc indicate less than 75%, greater than 75% but less than 100%, and 100% solid content respectively. |
| **Second:** Identifies the minimum concrete material strength, in MPa. | 15 | 15 | The specified strength of the unit is based on test results of three units with a minimum strength as noted. |
| **Third:** identifies oven dry concrete density and the allowable absorption maximum as a percentage of concrete density. | A | B | A and B refer to CMUs with oven dry densities of >2,000 and 1,800-2,000 kg/m3, and absorption maximums of 175 and 200 kg/m3, respectively. |
| **Fourth:** identifies the maximum moisture content at time of delivery, expressed as a percentage of actual absorption as it relates to relative humidity and linear shrinkage of the concrete unit. | M, O | | M refers to a known moisture content maximum (See CSA A165.1-04 for further information). O refers to no limits on moisture content maximum. |

Table 2: Weighted-average Material Content for CMU Products – kg per m3

| **Material** | **Mass, kg/m3 CMU** | |
| --- | --- | --- |
| **Normal-weight** | **Light-weight** |
| Portland Cement | 137.2 | 140.1 |
| Blended Cement | 33.9 | 51.9 |
| Slag Cement (GGBFS) | 5.3 | 0.0 |
| Fly Ash | 0.9 | 0.0 |
| Crushed Coarse Aggregate | 758.2 | 185.0 |
| Natural Coarse Aggregate | 103.9 | 8.4 |
| Crushed Fine Aggregate | 156.6 | 0.0 |
| Natural Fine Aggregate | 978.7 | 139.9 |
| Expanded Slag | 0.0 | 1,207.0 |
| Pumice | 0.0 | 4.9 |
| Silica Flour | 17.6 | 20.4 |
| Water Reducing Admixture (plasticizer) | 0.1 | 0.1 |
| Water Repellant/Efflorescence Control Admixture | 0.1 | 0.0 |
| Air Entraining Admixture | 0.0 | 0.0 |
| Batch Water | 57.5 | 67.2 |
| **Total** | **2,250** | **1,825** |

Table 3: Weighted-average Material Content for CMU Products – % basis

| **Material** | **Mass, % CMU** | |
| --- | --- | --- |
| **Normal-weight** | **Light-weight** |
| Portland Cement | 6.10% | 7.68% |
| Blended Cement | 1.51% | 2.85% |
| Slag Cement (GGBFS) | 0.234% | 0% |
| Fly Ash | 0.038% | 0% |
| Crushed Coarse Aggregate | 33.7% | 10.1% |
| Natural Coarse Aggregate | 4.62% | 0.46% |
| Crushed Fine Aggregate | 6.96% | 0.00% |
| Natural Fine Aggregate | 43.50% | 7.66% |
| Expanded Slag | 0% | 66.1% |
| Pumice | 0% | 0.270% |
| Silica Flour | 0.781% | 1.118% |
| Water Reducing Admixture (plasticizer) | 0.005% | 0.003% |
| Water Repellant/Efflorescence Control Admixture | 0.004% | 0.001% |
| Air Entraining Admixture | 0.0003% | 0.0003% |
| Batch Water | 2.56% | 3.68% |
| **Total** | **100%** | **100%** |

# Declared Unit

The declared unit is the basic reference flow set by the PCR for the assessed products [1]. The declared unit for this study is defined as one cubic metre (1 m3), or optionally one cubic yard (1 yd3) of CMU.

# Reference Service Life

The reference service life of CMU is dependent on its end-use and therefore not declared herein.

# System Boundary

The assessment system boundary defines which life cycle activities are included in the analysis. As illustrated in Figure 2, the system boundary of construction products is typically characterized by the temporal flow of its life cycle – i.e. Product, Construction Process, Use, and End of Life stages. The various processes that occur at each stage are classified and grouped in information modules(or simply "modules"), labeled with alpha-numeric designations "A1" through "C4". A declared unit is defined for EPDs covering “cradle-to-gate”, or the production stage (shown infilled green in Figure 2), which consists of three modules: A1 Raw Material Supply; A2 Transport (to the manufacturer); and A3 Manufacturing.

Figure 3 shows the product stage system boundary for the declared product system. Please note that module A2 includes only the transportation effects of the raw material inputs to CMU production; transportation of plant energy sources, ancillary materials, and packaging materials is included in module A3.

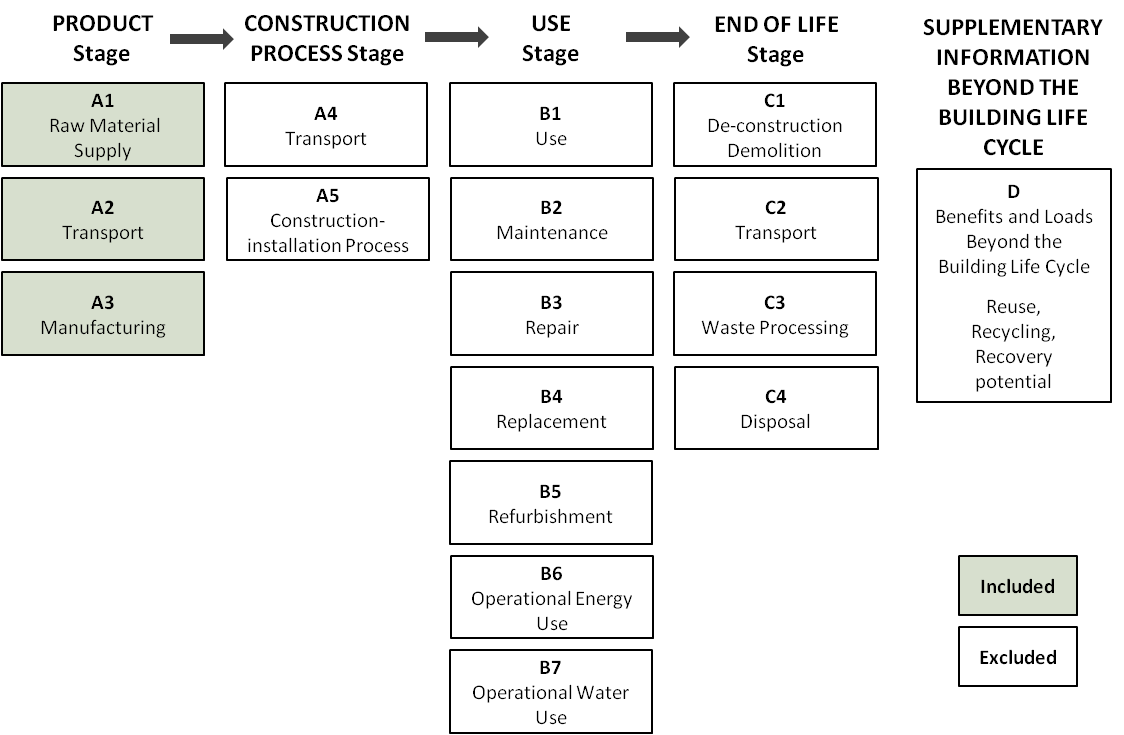


Figure : Cradle-to-Gate System Boundary for Building Products

The Product Stage includes the following processes [1]:

* Extraction and processing of raw materials, including fuels used in extraction and transport within the process;
* Average or specific transportation of raw materials (including recycled materials) from extraction site or source to manufacturing site (including any recovered materials from source to be recycled in the process) and including empty backhauls;;
* Manufacturing of the product, including batching and mixing of the concrete, forming units, curing of units, and applicable post-production finishing of units. This includes, but is not limited to;
  + Packaging, including transportation and waste disposal, to make product ready for shipment;
  + Average or specific transportation from manufacturing site to recycling/reuse/landfill for pre-consumer wastes and unutilized by-products from manufacturing, including empty backhauls;
  + Recycling/recovery/reuse/energy recovery of pre-consumer wastes and by-products from production.

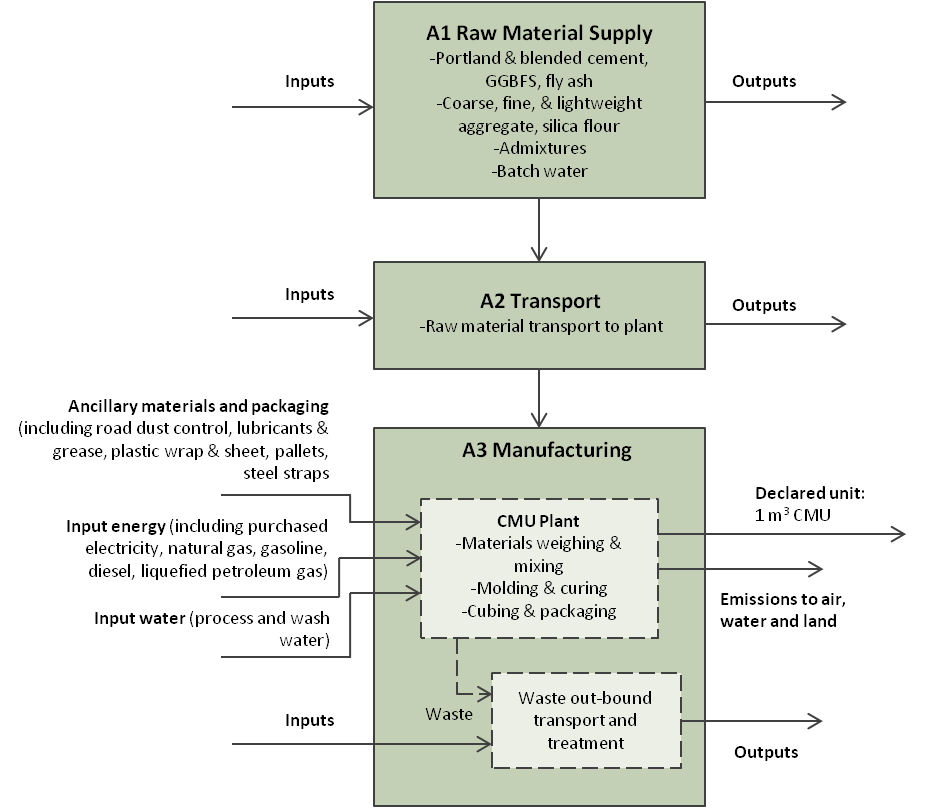


Figure : CMU Product Stage (modules A1 to A3)

The Product Stage excludes the following processes [1]:

* Production, manufacture, and construction of manufacturing capital goods and infrastructure;
* Production and manufacture of production equipment, delivery vehicles, and laboratory equipment;
* Personnel-related activities (travel, furniture, and office supplies); and
* Energy and water use related to company management and sales activities that may be located either within the factory site or at another location.

# Life Cycle Inventory

## Primary LCI Data

CCMPA engaged the Athena Institute to develop a cradle-to-gate life cycle inventory questionnaire for the manufacture of CMU and to survey a sub-population of its members to support the development of a “representative” LCA and EPD for CMU as produced by its members.

CCMPA membership applicable to this study consists of 22 companies operating 32 facilities across Canada – see Appendix A for a directory of CCMPA members and their facility locations. A total of 20 data collection surveys were distributed to CCMPA members taking into consideration regional production, plant size and type; 18 surveys were returned which were deemed complete after conducting a completeness and mass balance check.

The following primary data was obtained from CCMPA member companies, for either 2015 calendar year or 2015 fiscal year:

* CMU and other product production amounts and average concrete batch wastage;
* Normal- and light-weight concrete mix designs (as applicable);
* Inbound transportation distances and modes for raw materials, and ancillary and packaging materials;
* Facility electricity and fuel consumption, and process and wash water use;
* Ancillary and packaging material use;
* Process air emissions;
* Waste outputs and outbound transportation distances and modes.

In instances where plant data were missing for a particular parameter of interest, that plant’s data was removed from the horizontal averaging for that parameter.

Overall, the primary data is representative according to the following temporal, geographical and technological criteria:

* **Temporal**: Manufacturing process inputs and outputs were obtained for the latest available year (2015);
* **Geographical**: the facilities which completed the survey were representative of the greater membership across Canada; and
* **Technological**: Data represents contemporary technologies (e.g. autoclave and low pressure) in use in Canada.

## Secondary LCI Data

Table 4 is a summary of all secondary LCI data sources used to complete the LCA study, along with a description temporal and geographic representativeness, and a description of adjustments made. All datasets used are representative of average technology. Table 5 summarizes the generation source breakdowns for the Provincial electricity LCI processes used.

The following adjustments were made to all US LCI electricity, fuel, and transportation processes (cradle-to-use), where applicable:

* Pipeline transport dummy[[2]](#footnote-2) processes were substituted with data from the Athena LCI database;
* Solid waste treatment dummy processes were substituted with the Ecoinvent 3.1 process *Inert waste {RoW}| treatment of, sanitary landfill | Alloc Def, U.*

## Data Quality

Data quality requirements, as specified in ASTM PCR: 2014, Section 7.3, were observed [1].

This section describes the achieved data quality relative to the ISO 14044:2006 requirements. Data quality is judged on the basis of its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied within a study serving as a data source) and representativeness (geographical, temporal, and technological).

**Precision:** CCMPA members, through measurement and calculation, collected primary data on their production of CMU. For accuracy the LCA team individually validated these plant gate-to-gate input and output data.

Table : Summary of Secondary LCI Data Sources

| **Item** | **LCI Process Name** | **Source** | **Time Period1** | **Geo** | **Comments** |
| --- | --- | --- | --- | --- | --- |
| **A1 - Raw Material Supply** | | | | | |
| Portland Cement | Type GU Cement, at plant/CAN | Athena LCI database (Cement Association of Canada EPD) | 2014-2015 | Canada |  |
| Blended Cement | Type GU Cement, at plant/CAN; Slag Cement (GGBFS), at plant/NA | Athena LCI database | 2013-2015 | Canada; North America | weighted-average blend is 86.9% portland cement and 13.1% slag cement |
| Slag Cement (GGBFS) | Slag Cement (GGBFS), at plant/NA | Athena LCI database (Slag Cement Association EPD) | 2013-2015 | North America | See the report: An Industry Average Cradle-to-Gate Life Cycle Assessment of Slag Cement for the USA and Canadian Markets (Athena) for included processes. |
| Fly Ash (no processing) | n/a | n/a | n/a | n/a | No pre-processing of fly ash assumed. |
| Crushed Coarse Aggregate | Gravel, crushed {CA-QC}| production | Alloc Rec, U | Ecoinvent 3.1 database | 1997-2014 | Quebec, Canada | Canadian electricity substituted3 |
| Natural Coarse Aggregate | Sand {RoW}| gravel and quarry operation | Alloc Rec, U | Ecoinvent 3.1 database | 1997-2014 | Global (excluding Europe), Canada | Canadian electricity substituted3 |
| Crushed Fine Aggregate | Gravel, crushed {CA-QC}| production | Alloc Rec, U | Ecoinvent 3.1 database | 1997-2014 | Quebec, Canada | Canadian electricity substituted3 |
| Natural Fine Aggregate | Sand {RoW}| gravel and quarry operation | Alloc Rec, U | Ecoinvent 3.1 database | 1997-2014 | Global (excluding Europe), Canada | Canadian electricity substituted3 |
| Expanded Slag | Slag granules, at plant/CAN | Athena LCI database (Slag Cement Association EPD) | 2013-2015 | Canada | No expanded slag LCI data available. Estimated as slag granules (i.e. no grinding included) |
| Pumice | Pumice {RoW}| quarry operation | Alloc Rec, S | Ecoinvent 3.1 database | 2000-2014 | Global (excluding Europe), Canada | Canadian electricity substituted3 |
| Silica | Slag A3, at plant/CAN | Athena LCI database (Slag Cement Association EPD) | 2013-2015 | Canada | Silica flour is a by-product from material produced for the glass industry. Slag cement grinding electricity consumption used as proxy. |
| Water Reducing Admixture (plasticizer) | Concrete admixtures – Plasticisers and Superplasticisers | European Federation of Concrete Admixtures Associations (EFCA) EPD | 2015 | Europe |  |
| Water Repellant/Effloresence Control Admixture | Concrete admixtures – Water Resisting Admixtures | EFCA EPD | 2015 | Europe |  |
| Air Entraining Admixture | Concrete admixtures – Air entrainers | EFCA EPD | 2015 | Europe |  |
| Batch Water, from untreated source | n/a | n/a | n/a | n/a | no energy use for pumping assumed |
| Batch Water, from water treatment plant | Tap water {CA-QC}| tap water production, conventional treatment | Alloc Rec, U | Ecoinvent 3.1 database | 2012-2014 | Quebec, Canada | Canadian electricity substituted3 |
| **A2 - Transport** | | | | | |
| Truck, short haul | Transport, combination truck, short-haul, diesel powered/tkm/RNA | US LCI database | 2010-2011 | North America |  |
| Truck, long haul | Transport, combination truck, long-haul, diesel powered/tkm/RNA | US LCI database | 2010-2011 | North America |  |
| Rail | Transport, train, diesel powered/tkm/US | US LCI database | 2003-2008 | North America |  |
| Barge | Transport, barge, average fuel mix/US | US LCI database | 2007-2008 | North America |  |
| Ocean | Transport, ocean freighter, average fuel mix/US | US LCI database | 2007-2008 | North America |  |
| **A3 - Manufacturing** | | | | | |
| **Energy Use** | | | | | |
| Grid Electricity, Alberta | Electricity, at grid, AB CAN/NA Grid, Athena | Athena LCI database | 2012-2015 | Alberta |  |
| Grid Electricity, British Columbia | Electricity, at grid, BC CAN/NA Grid, Athena | Athena LCI database | 2012-2015 | British Columbia |  |
| Grid Electricity, Manitoba | Electricity, at grid, MB CAN/NA Grid, Athena | Athena LCI database | 2012-2015 | Manitoba |  |
| Grid Electricity, New Brunswick | Electricity, at grid, NB CAN/NA Grid, Athena | Athena LCI database | 2012-2015 | New Brunswick |  |
| Grid Electricity, Newfoundland | Electricity, at grid, NL CAN/NA Grid, Athena | Athena LCI database | 2012-2015 | Newfoundland |  |
| Grid Electricity, Ontario | Electricity, at grid, ON CAN/NA Grid, Athena | Athena LCI database | 2012-2015 | Ontario |  |
| Grid Electricity, Quebec | Electricity, at grid, AB CAN/NA Grid, Athena | Athena LCI database | 2012-2015 | Quebec |  |
| Natural Gas | Natural gas, combusted in industrial boiler, US | US LCI database | 2003-2008 | North America |  |
| Diesel | Diesel, combusted in industrial equipment/US | US LCI database | 2003-2008 | North America |  |
| Gasoline | Gasoline, combusted in equipment/US | US LCI database | 2003-2008 | North America |  |
| LPG (Liquefied Propane Gas) | Liquefied petroleum gas, combusted in industrial boiler/US | US LCI database | 2003-2008 | North America |  |
| **Process & Wash Water** | | | | | |
| From Untreated Source | n/a | n/a | n/a | n/a | no energy use for pumping assumed |
| From Water Treatment Plant | Tap water {CA-QC}| tap water production, conventional treatment | Alloc Rec, U | Ecoinvent 3.1 database | 2012-2014 | Quebec, Canada | Canadian electricity substituted3 |
| **Ancillary and Packaging Materials** | | | | | |
| Road Dust Control Chemicals (e.g., chlorides) | Calcium chloride {ROW}| soda production, solvay process | Alloc Rec, U adj; Tap water {CA-QC}| tap water production, conventional treatment | Alloc Rec, U | Ecoinvent 3.1 database | 1999-2014 | Global (excluding Europe), Canada; Quebec, Canada | Assumed to be a solution of 38% calcium chloride and 62% water (by mass); Canadian electricity substituted |
| Oil and Lubricants | Lubricating oil {RoW}| production | Alloc Def, U | Ecoinvent 3.1 database | 2000-2013 | Global (excluding Europe) |  |
| Grease | Lubricating oil {RoW}| production | Alloc Def, U | Ecoinvent 3.1 database | 2000-2013 | Global (excluding Europe) |  |
| Wood Pallets | Cradle-to gate Canadian Rough Dry Lumber | Athena LCI database | 2005-2009 | Canada |  |
| Steel Straps | Galvanized steel sheet, at plant/RNA | US LCI database | 1993-2013 | North America |  |
| Plastic Wrap | Packaging film, low density polyethylene {RoW}| production | Alloc Rec, S | Ecoinvent 3.1 database | 1993-2014 | Global (excluding Europe) |  |
| Plastic Bags and Top Sheets | Packaging film, low density polyethylene {RoW}| production | Alloc Rec, S | Ecoinvent 3.1 database | 1993-2014 | Global (excluding Europe) |  |
| **Air and Water Emissions** | | | | | |
| Process & Wash Water emissions | n/a | Quantis Water Database | 2011-2012 | Canada | 10% of process & wash water evaporation loss assumed, remaining water discharged to ground, as per [8] |
| **Outbound Waste Transport** | | | | | |
| Truck, short haul | Transport, combination truck, short-haul, diesel powered/tkm/RNA | US LCI database | 2010-2011 | North America |  |
| **Waste Treatment2** | | | | | |
| Non-Hazardous Solid Waste, to landfill | Inert waste {RoW}| treatment of, sanitary landfill | Alloc Def, U | Ecoinvent 3.1 database | 2007-2013 | Global (excluding Europe) |  |
| Hazardous Liquid Waste, to incinerator | Hazardous waste, for incineration {RoW}| treatment of hazardous waste, hazardous waste incineration | Alloc Rec, U | Ecoinvent 3.1 database | 1997--2014 | Global (excluding Europe) |  |

**Table Notes:** 1 "Time Period" is the period between the known initiation of data and its final update and/or validation

2Recycling of wastes (e.g. concrete, steel) is not part of life cycle and therefore no secondary data was required for these processes

3Where noted, the electricity process used by the data set was substituted with the Athena LCI process *Electricity, at grid, ON CAN/NA Grid. See for generation mix breakdown*

Table : Grid Electricity Generation Source Breakdowns

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Source (kWh generated per kWh consumed on-site)** | **Alberta** | **British Columbia** | **Manitoba** | **New Brunswick** | **Newfound-land** | **Ontario** | **Quebec** | **Canadian Average** |
| Bituminous & sub-bituminous coal | 0.516 | 0 | 0.00172 | 0.252 | 0 | 0.0262 | 0.00199 | 0.0796 |
| Lignite coal | 2.64E-05 | 0 | 0 | 0.00368 | 0 | 0.000187 | 4.05E-05 | 0.0205 |
| Residual fuel oil & other refined petroleum products | 0.276 | 0.0598 | 0.00124 | 0.256 | 0.0366 | 0.16 | 0.00489 | 0.0986 |
| Natural gas | 0.194 | 0.0154 | 0.000914 | 0.193 | 0 | 0.128 | 0.00172 | 0.0727 |
| Nuclear | 0.00689 | 0 | 0 | 0.0911 | 0 | 0.546 | 0.0226 | 0.155 |
| Hydro & other renewables | 0.112 | 0.987 | 1.1 | 0.295 | 1.09 | 0.249 | 1.01 | 0.652 |
| **Total** | **1.10** | **1.06** | **1.10** | **1.09** | **1.13** | **1.11** | **1.04** | **1.08** |

Note: grid electricity modeled with US LCI fuel combustion processes; values include transmission losses.

**Completeness:** All relevant, specific processes, including inputs (raw materials, energy and ancillary materials) and outputs (emissions and production volume) were considered. The relevant background materials and processes were generally taken from the Athena LCI database, the US LCI Database (adjusted for known data placeholders known as “dummy”), and Ecoinvent v 3.1 LCI database, and modeled in SimaPro software v.8.1.1.16, August 2016.

**Consistency:** System boundaries, and allocation and cut-off rules have been uniformly applied across the product life cycles and the two CMU products. The study predominantly relies on three sources of secondary data (Athena LCI, US LCI and Ecoinvent databases); adjustments were uniformly applied to all US LCI electricity, fuel, and transport processes, as per Section 7.2. Crosschecks concerning the plausibility of mass and energy flows were continuously conducted.

**Reproducibility:** Internal reproducibility is possible since the data and the models are stored and available in Athena LCI database developed in SimaPro, 2016. A high level of transparency is provided throughout the report as the LCI profile is presented for the declared product. Key secondary (generic) LCI data sources are summarized in Table 4.

**Representativeness:** The representativeness of the data is summarized as follows.

* Time related coverage: *primary* collected data for the CMU manufacturing process: 2015; all *secondary* data has been validated within the past 8 years.
* Geographical coverage: the geographical coverage is Canada.
* Technological coverage: typical or average.

Generic data is publically available and may be average or specific. Table 4 provides details of the source and quality of the LCI datasets used for purposes of completing this LCA study.

## Cut-off and Allocation Rules

The cut-off requirements as per the ASTM PCR for cement, clause 7.2, were followed. All input/output flow data reported by the facilities were included in the LCI modeling.

Allocation procedures observed the requirements and guidance of ISO 14044:2006, clause 4.3. and those specified in ASTM PCR, Section 7.5.

The allocation of material inputs (e.g. cement, aggregate, batch water, etc.) to the two CMU products is based on the assumed concrete mix designs (see Section 3.3); therefore, no allocation is required.

CMU plant LCI environmental flows (inputs and outputs) were allocated to the two products on a per-m3 CMU production basis.

In addition, the following allocation rules are applied (Section 7.5, ASTM PCR):

* Recovered materials (e.g. synthetic gypsum, fly ash, slag cement) are considered raw materials. 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; any allocations before reprocessing is allocated to the original product;
* Emissions from downstream recycling, or combustion, after the end-of-waste state is allocated to the new downstream products;

## Product Manufacturing Life Cycle Inventory

A cradle-to-gate LCA model was created in SimaPro 8.1.1.16, 2016 software. The model considers the three modules: A1 Raw material supply, A2 Transport and A3 Manufacturing.

The weighted-average concrete batch wastage was calculated to be 2.48%.

Purchased electricity and natural gas were reported to be the primary manufacturing energy inputs. The reported diesel and gasoline use are for operation of on-site mobile equipment within the facilities.

Water use within the facilities are generally used for three applications (1) equipment washing, (2) concrete curing, and (3) dust suppression of e.g. roads, material stores.

There were no emissions to water or land reported by the facilities, however a water discharge from process and wash water was assumed (see Table 4).

Table 6 summarizes the weighted-average inputs and outputs for the two products, per m3 finished CMU, and Table 7 reports the weighted-average inbound and outbound transportation distances and modes for CMU facilities. The corresponding tables in Imperial units can be found in Appendix B.

Table 6: CMU Weighted-average Manufacturing Inputs/Outputs – 1 m3 CMU

| **Item** | **Unit** | **Normal-weight CMU** | **Light-weight CMU** |
| --- | --- | --- | --- |
| **Material Inputs** | | | |
| Portland Cement | kg | 141 | 144 |
| Blended Cement | kg | 34.8 | 53.2 |
| Slag Cement (GGBFS) | kg | 5.40 | 0.00 |
| Fly Ash (no processing) | kg | 0.872 | 0.000 |
| Crushed Coarse Aggregate | kg | 777 | 190 |
| Natural Coarse Aggregate | kg | 107 | 8.64 |
| Crushed Fine Aggregate | kg | 161 | 0 |
| Natural Fine Aggregate | kg | 1,003 | 143 |
| Expanded Slag | kg | 0 | 1,237 |
| Pumice | kg | 0.00 | 5.06 |
| Silica Flour | kg | 18.0 | 20.9 |
| Water Reducing Admixture (plasticizer) | kg | 0.108 | 0.055 |
| Water Repellant/Effloresence Control Admixture | kg | 0.0942 | 0.0111 |
| Air Entraining Admixture | kg | 0.00701 | 0.00543 |
| Batch Water, from untreated source | kg | 0.727 | 0.850 |
| Batch Water, from water treatment plant | kg | 58.2 | 68.0 |
| **Water Inputs (process and wash water)** | | | |
| From Untreated Source | L | 28.6 | 28.6 |
| From Water Treatment Plant | L | 75.8 | 75.8 |
| **Ancillary & Packaging Material Inputs** | | | |
| Road Dust Control Chemicals | L | 0.114 | 0.114 |
| Oil and Lubricants | L | 0.0859 | 0.0859 |
| Grease | L | 0.0171 | 0.0171 |
| Wood Pallets | # | 0.944 | 0.944 |
| Steel Straps | kg | 0.00803 | 0.00803 |
| Plastic Wrap | kg | 0.875 | 0.875 |
| Plastic Bags and Top Sheets | kg | 0.232 | 0.232 |
| **Electricity and Fuel Inputs** | | | |
| Grid Electricity, Alberta | kWh | 6.25 | 6.25 |
| Grid Electricity, British Columbia | kWh | 2.96 | 2.96 |
| Grid Electricity, Manitoba | kWh | 2.83 | 2.83 |
| Grid Electricity, New Brunswick | kWh | 0.963 | 0.963 |
| Grid Electricity, Newfoundland | kWh | 0.125 | 0.125 |
| Grid Electricity, Ontario | kWh | 22.6 | 22.6 |
| Grid Electricity, Quebec | kWh | 2.00 | 2.00 |
| Natural Gas | m3 | 16.6 | 16.6 |
| Diesel | L | 1.67 | 1.67 |
| Gasoline | L | 0.00586 | 0.00586 |
| LPG (Liquified Propane Gas) | L | 0.0518 | 0.0518 |
| **Product Outputs** | | | |
| Finished CMU | m3 | 1 | 1 |
| **Process Emissions to Air** | | | |
| Particulates, PM-2.5 | g | 1.66 | 1.66 |
| Particulates, PM-10 | g | 10.8 | 10.8 |
| Particulates, total | g | 42.5 | 42.5 |
| Water | kg | 10.4 | 10.4 |
| **Process Emissions to Water** | | | |
| Water | L | 94.0 | 94.0 |
| **Waste Outputs** | | | |
| Non-Hazardous Solid Waste, to landfill | kg | 6.13 | 6.13 |
| Non-Hazardous Solid Waste, to recycling/reuse - concrete | kg | 52.1 | 52.1 |
| Non-Hazardous Solid Waste, to recycling/reuse - wood | kg | 1.99 | 1.99 |
| Non-Hazardous Solid Waste, to recycling/reuse - steel | kg | 0.339 | 0.339 |
| Hazardous Liquid Waste, to incinerator | L | 0.111 | 0.111 |

Table : CMU Weighted-average Manufacturing Inbound/Outbound Transport Modes and Distances

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **one-way distance (kilometers)** | | | |
| **Truck** | **Rail** | **Ocean** | **Barge** |
| **Inbound Materials** | | | | |
| Portland Cement | 342 | 0 | 41 | 0 |
| Blended Cement | 112 | 67 | 0 | 151 |
| Slag Cement (GGBFS) | 193 | 0 | 0 | 0 |
| Fly Ash (no processing) | 221 | 0 | 0 | 0 |
| Crushed Coarse Aggregate | 73 | 0 | 0 | 0 |
| Natural Coarse Aggregate | 52 | 0 | 0 | 0 |
| Crushed Fine Aggregate | 60 | 0 | 0 | 0 |
| Natural Fine Aggregate | 112 | 0 | 0 | 0 |
| Expanded Slag | 86 | 0 | 0 | 0 |
| Pumice | 862 | 0 | 0 | 0 |
| Silica Flour | 650 | 0 | 0 | 0 |
| Water Reducing Admixture (plasticizer) | 633 | 0 | 0 | 0 |
| Water Repellant/Effloresence Control Admixture | 1,432 | 0 | 0 | 0 |
| Air Entraining Admixture | 64 | 0 | 0 | 0 |
| **Outbound Waste** | | | | |
| Non-Hazardous Solid Waste, to landfill | 28 | 0 | 0 | 0 |
| Non-Hazardous Solid Waste, to recycling/reuse - concrete | 12 | 0 | 0 | 0 |
| Non-Hazardous Solid Waste, to recycling/reuse - wood | 15 | 0 | 0 | 0 |
| Non-Hazardous Solid Waste, to recycling/reuse - steel | 100 | 0 | 0 | 0 |
| Hazardous Liquid Waste, to incinerator | 58 | 0 | 0 | 0 |

# Life Cycle Impact Assessment

## Environmental Category Indicators

The ASTM PCR, Section 8.0, sets out the environmental indicators, characterization methods, resource use and waste generated measures to be supported by the LCA. This section lists the LCIA category indicators (Table 8) and resource use and waste generated parameters supported in this LCA study.

As per the ASTM PCR, Section 8, US EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI, version 2.1) impact categories are used as they provide a North American context for the mandatory category indicators to be included in this EPD. These are relative expressions only and do not predict category impact end-points, the exceeding of thresholds, safety margins or risks.

See Appendix C for a description of TRACI LCIA impact categories.

Table 8: LCIA Category Indicators

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **LCIA category indicator** | **Unit equivalence basis (indicator result)** | **Source of the characterization method** | **Level of site specificity selected** | **Environmental media** |
| Global warming potential | kg CO2 equiv. | TRACI 2.1, 2012/ IPCC 2007 | Global | Air |
| Acidification potential | kg SO2 equiv. | TRACI 2.1, 2012 | North America | Air, Water |
| Eutrophication potential | kg N equiv. | TRACI 2.1, 2012 | North America | Air, Water |
| Photochemical smog | kg O3 equiv. | TRACI 2.1, 2012 | North America | Air |
| Ozone depletion potential | kg CFC-11 equiv. | TRACI 2.1, 2012 /WMO:2003 | Global | Air |

As specified in the ASTM PCR, the following mandatory resource use and waste indicators are reported:

Total primary energy consumption, in MJ, High Heating Values (HHVs) is applied

* Non-renewable fossil, in MJ
* Non-renewable nuclear, in MJ
* Renewable (solar, wind, hydroelectric, biomass and geothermal)[[3]](#footnote-3), in MJ
* Renewable (biomass), in MJ

Material resources consumption

* Non-renewable materials, in kg
* Renewable materials, in kg
* Net fresh water (inputs minus outputs) , in liters

Waste generated

* Non-hazardous waste, in kg
* Hazardous waste, in kg.

Primary energy consumption was compiled using a cumulative energy demand model. Material resource consumption and generated waste reflect cumulative life cycle inventory flow information. The LCIA category indicators, resource use and waste measures conform to ISO 21930:2007, Section 8.2 and ISO 14044:2006.

## LCA Results

This section summarizes the results of the life cycle impact assessment (LCIA) based on the cradle-to-gate life cycle inventory inputs and outputs analysis. The results are calculated on the basis of one m3 of CMU (Table 9), but are also provided for one yd3 of CMU (see Appendix B, Table 17).

Table : LCA Results – 1 m3 CMU

|  |  |  |  |
| --- | --- | --- | --- |
| **Environmental Indicator** | **Unit** | **Normal-weight** | **Light-weight** |
| **TRACI 2.1 impact categories** | | | |
| Global warming potential | kg CO2 eq. | 260 | 270 |
| Acidification potential | kg SO2 eq. | 1.38 | 1.64 |
| Eutrophication potential | kg N eq. | 0.101 | 0.112 |
| Smog creation potential | kg O3 eq. | 19.0 | 18.9 |
| Ozone depletion potential | kg CFC-11 eq. | 2.68E-06 | 2.33E-06 |
| **Total primary energy consumption** | | | |
| Non-renewable fossil | MJ (HHV) | 2,538 | 2,519 |
| Non-renewable nuclear | MJ (HHV) | 289 | 327 |
| Renewable (non-biomass) | MJ (HHV) | 131 | 120 |
| Renewable (biomass) | MJ (HHV) | 118 | 128 |
| **Material resources consumption** | | | |
| Non-renewable material resources | kg | 2,387 | 648 |
| Renewable material resources | kg | 18.9 | 19.3 |
| Net fresh water | l | 1,040 | 743 |
| **Waste generated** | | | |
| Non-hazardous waste generated | kg | 61.9 | 61.9 |
| Hazardous waste generated | kg | 0.115 | 0.116 |

# Interpretation

## Contribution Analysis

Contribution analysis is an analytical method used to support the interpretation of LCA results and to facilitate the reader's understanding of the environmental profile of the declared products.

and Table 11 present the contributions the three production stage information modules (A1 Raw Material Supply, Transport, and A3 Manufacturing) make to total impact, for normal-weight and light-weight CMU, respectively.

Across the three production modules, A1 Raw Material Supply contributes the largest share of TRACI 2.1 impact category results, between 61% and 94% across both product types. This finding can be attributed primarily to the production of portland cement, which contributes 53% and 74% of A1 module TRACI impacts. The two primary sources of CMU facility energy use are natural gas and grid electricity. Natural gas use is a significant contributor to module A3 global warming (64%), acidification (72%), smog (40%) TRACI impacts. Grid electricity similarly accounts for 22% of module A3 global warming, 20% of acidification, and 32% of smog.

Modules A1 and A3 account for the majority of primary energy use; together contributing 87% and 89% of total energy use for normal-weight and light-weight CMU, respectively. Again, the majority of module A1 energy use can be attributed to portland cement production (46-82% across the four indicators and two products), whereas the majority of module A3 fossil fuel use can be attributed to natural gas use (64%), and over 90% of nuclear and renewable energy use (solar, wind, hydroelectric, and geothermal) is attributed to grid electricity.

Module A1 is responsible for the majority of non-renewable material resource consumption (>99%) and net fresh water use (>73%), whereas module A3 accounts for the majority of renewable material resources (>77%), and waste generation (>96%).

Module A2 is generally responsible for the least Product stage impact, <26% across all environmental indicators and the two products. The leading contributor to normal-weight CMU module A2 impact is transport of natural fine aggregate (44-46% across all indicators). Transport of expanded slag is similarly the leading contributor to light-weight CMU module A2 impact (48-52% across all indicators).

Table : Contribution Analysis, by information module – Normal-weight CMU

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Environmental Indicator** | **Unit** | **A1 Raw Material Supply** | **A2 Transport** | **A3 Manu-facturing** | **Total** |
| **TRACI 2.1 impact categories** |  |  |  |  |  |
| Global warming potential | kg CO2 eq. | 65.4% | 10.3% | 24.3% | 100.0% |
| Acidification potential | kg SO2 eq. | 52.2% | 13.1% | 34.7% | 100.0% |
| Eutrophication potential | kg N eq. | 77.1% | 10.1% | 12.8% | 100.0% |
| Smog creation potential | kg O3 eq. | 62.7% | 26.0% | 11.3% | 100.0% |
| Ozone depletion potential | kg CFC-11 eq. | 94.7% | 0.0% | 5.3% | 100.0% |
| **Total primary energy consumption** | | | | | |
| Non-renewable fossil | MJ (HHV) | 41.0% | 16.1% | 42.9% | 100.0% |
| Non-renewable nuclear | MJ (HHV) | 44.3% | 1.5% | 54.2% | 100.0% |
| Renewable (non-biomass) | MJ (HHV) | 58.0% | 0.7% | 41.3% | 100.0% |
| Renewable (biomass) | MJ (HHV) | 70.3% | 0.0% | 29.7% | 100.0% |
| **Material resources consumption** |  |  |  |  |  |
| Non-renewable material resources | kg | 100.0% | 0.0% | 0.0% | 100.0% |
| Renewable material resources | kg | 20.9% | 0.0% | 79.1% | 100.0% |
| Net fresh water | l | 81.0% | 0.0% | 19.0% | 100.0% |
| **Waste generated** |  |  |  |  |  |
| Non-hazardous waste generated | kg | 0.5% | 0.5% | 99.0% | 100.0% |
| Hazardous waste generated | kg | 4.0% | 0.0% | 96.0% | 100.0% |

Table : Contribution Analysis, by information module – Light-weight CMU

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Environmental Indicator** | **Unit** | **A1 Raw Material Supply** | **A2 Transport** | **A3 Manu-**  **facturing** | **Total** |
| **TRACI 2.1 impact categories** |  |  |  |  |  |
| Global warming potential | kg CO2 eq. | 68.3% | 8.3% | 23.3% | 100.0% |
| Acidification potential | kg SO2 eq. | 61.3% | 9.4% | 29.3% | 100.0% |
| Eutrophication potential | kg N eq. | 80.6% | 7.8% | 11.6% | 100.0% |
| Smog creation potential | kg O3 eq. | 66.5% | 22.2% | 11.3% | 100.0% |
| Ozone depletion potential | kg CFC-11 eq. | 93.9% | 0.0% | 6.1% | 100.0% |
| **Total primary energy consumption** | | | | | |
| Non-renewable fossil | MJ (HHV) | 43.2% | 13.6% | 43.2% | 100.0% |
| Non-renewable nuclear | MJ (HHV) | 51.1% | 1.1% | 47.8% | 100.0% |
| Renewable (non-biomass) | MJ (HHV) | 54.4% | 0.7% | 44.9% | 100.0% |
| Renewable (biomass) | MJ (HHV) | 72.6% | 0.0% | 27.4% | 100.0% |
| **Material resources consumption** |  |  |  |  |  |
| Non-renewable material resources | kg | 99.9% | 0.0% | 0.1% | 100.0% |
| Renewable material resources | kg | 22.6% | 0.0% | 77.4% | 100.0% |
| Net fresh water | l | 73.4% | 0.0% | 26.6% | 100.0% |
| **Waste generated** |  |  |  |  |  |
| Non-hazardous waste generated | kg | 0.6% | 0.4% | 99.0% | 100.0% |
| Hazardous waste generated | kg | 4.3% | 0.0% | 95.7% | 100.0% |

## Sensitivity Analysis

This section explores the sensitivity of cradle-to-gate results to changes in the life cycle aspects there were identified in Section 9.1 as significantly contributing to results. The analyses additionally serve to provide an indication of how the CMUs of individual CCMPA member companies may perform with respect to the Canadian weighted-average environmental profile presented herein.

The following four scenarios were investigated for normal-weight CMU:

1. The portland cement content of the concrete mix was increased by 10%;
2. Blended cement and SCM material contents in the concrete mix were substituted with portland cement;
3. Facility natural gas use was increased by 10%
4. Facility electricity use was increased by 10%

Table 12 presents the results of the four sensitivity scenarios.

Table : Sensitivity Analysis – Normal-weight CMU – ratio of scenario to baseline

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Environmental Indicator** | **+ 10% Cement** | **SCMs Subs. With Cement** | **+ 10% Natural Gas** | **+ 10% Electricity** |
| **TRACI 2.1 impact categories** |  |  |  |  |
| Global warming potential | 1.0528 | 1.0359 | 1.0156 | 1.0053 |
| Acidification potential | 1.0403 | 1.0091 | 1.0250 | 1.0069 |
| Eutrophication potential | 1.0587 | 1.0304 | 1.0033 | 1.0016 |
| Smog creation potential | 1.0513 | 1.0277 | 1.0045 | 1.0037 |
| Ozone depletion potential | 1.0512 | 0.9766 | 1.0000 | 1.0000 |
| **Total primary energy consumption** |  |  |  |  |
| Non-renewable fossil | 1.0323 | 1.0187 | 1.0281 | 1.0080 |
| Non-renewable nuclear | 1.0288 | 1.0068 | 1.0006 | 1.0490 |
| Renewable (non-biomass) | 1.0270 | 1.0164 | 1.0003 | 1.0377 |
| Renewable (biomass) | 1.0574 | 1.0427 | 1.0000 | 1.0000 |
| **Material resources consumption** |  |  |  |  |
| Non-renewable material resources | 1.0085 | 1.0019 | 1.0000 | 1.0000 |
| Renewable material resources | 1.0171 | 1.0131 | 1.0000 | 1.0000 |
| Net fresh water | 1.0258 | 1.0196 | 1.0000 | 1.0000 |
| **Waste generated** |  |  |  |  |
| Non-hazardous waste generated | 1.0039 | 1.0004 | 1.0006 | 1.0004 |
| Hazardous waste generated | 1.0031 | 1.0005 | 1.0000 | 1.0000 |

**Note:** table values are the cradle-to-gate sensitivity scenario results divided by the baseline results

## Conclusions and Limitations

The most pertinent conclusions drawn for the LCA results presented in Sections 8.2 and 9.1 are as follows:

* The amount of portland and blended cement in the concrete formulations has a significant influence on the environmental profile of the CMU products. Use of SCMs such as fly ash and slag cement, or blended cement with a high proportion of SCM can play a noteworthy role in impact reduction.
* As the manufacturing stage is a substantial consumer of energy and responsible for a large share of the impacts, any process or energy conservation improvement would directly and significantly lower the environmental profile for the CMU products.

This LCA study reports cradle-to-gate results for CMU products, with no assumptions made on intended end-use. The LCA results therefore do not provide information on the environmental performance or preference of end-use products without consideration of the full life cycle of those products.

# Additional Environmental Information

Table 13 reports two additional environmental indicators:

* *Recovered materials* sums the mass of recovered materials used in the CMU concrete formulations (i.e. the mass after processing has occurred);
* *Respiratory effects* is a TRACI 2.1 impact category – see Appendix B for further information.

Table 13: Additional Cradle-to-gate Environmental Indicator Results

|  |  |  |  |
| --- | --- | --- | --- |
| **Environmental Indicator** | **Unit** | **Normal-weight** | **Light-weight** |
| Recovered materials | kg | 28.8 | 1,264.8 |
| Respiratory effects | kg PM2.5 eq. | 0.107 | 0.252 |

# References

1. ASTM International, Product Category Rules For Preparing an Environmental Product Declaration For Manufactured Concrete and Concrete Masonry Products, December 2014.
2. ISO 21930: 2007 Building construction – Sustainability in building construction – Environmental declaration of building products.
3. ISO 14025: 2006 Environmental labeling and declarations - Type III environmental declarations - Principles and procedures.
4. ISO 14044: 2006 Environmental management - Life cycle assessment - Requirements and guidelines.
5. ISO 14040: 2006 Environmental management - Life cycle assessment - Principles and framework.
6. ISO 14021:1999 Environmental labels and declarations -- Self-declared environmental claims (Type II environmental labelling)
7. **CSA A165.1-04 - Concrete block masonry units**
8. **Quantis Water Database Technical Report version 1, 2012**

# Appendix A: CCMPA Membership Directory

| **CCMPA Member-company Corporate Address & Facility Locations Applicable to this EPD** | | | |
| --- | --- | --- | --- |
| **Basalite.jpg** | **Basalite Concrete Products**  8650 130th Street Surrey, British Columbia  V3W 1G1  [www.basalite.com](http://www.basalite.com) | boehmerblocklogo1.gif | **Boehmers**  1038 Rife Road Cambridge, Ontario  N1R 5S3  [www.boehmerblock.com](http://www.boehmerblock.com) |
| **locations:** Surrey, British Columbia | | **locations:** Kitchener, Ontario | |
| **bramptonbricklogo1-240x120.jpg** | **Brampton Brick Limited**  225 Wanless Drive Brampton, Ontario  L7A 1E9  [www.bramptonbrick.com](http://www.bramptonbrick.com) | **brownsconcreteproductslogo1.gif** | **Brown’s Concrete Products Ltd.**  3075 Herold Drive Sudbury, Ontario  P3E 6K9  [www.brownsconcrete.com](http://www.brownsconcrete.com) |
| **locations:** Brampton, Ontario; Brockville, Ontario | | **locations:** Sudbury, Ontario | |
| **canalblock1-160x63.jpg** | **Canal Block**  3562 Nugent Road Port Colborne, Ontario  L3K 5V5  [www.canalblock.com](http://www.canalblock.com) | Casey_Concrete_Logo-240x54.jpg | **Casey Concrete Ltd**  96 Park Street Amherst, Nova Scotia  B4H 2M8  [www.caseyltd.ca](http://http:/www.caseyltd.ca/) |
| **locations:** Port Colborne, Ontario | | **locations:** Amherst, Nova Scotia | |
| **centuryconcreteproducts-240x57.jpg** | **Century Concrete Products Ltd 2016**  4170 Midland Ave Scarborough, Ontario  M1V 4S6  [www.centuryconcrete.ca](http://www.centuryconcrete.ca) | cindercrete_producers_ltd-200x71.jpg | **Cindercrete Products Ltd.**  P.O. Box 306 Hwy #1 East Regina, Saskatchewan  S4P 3A1  [www.cindercrete.com](http://www.cindercrete.com) |
| **locations:** Scarborough, Ontario | | **locations:** Saskatoon, Saskatchewan | |
| **NewcreteLogoJPG-240x44.jpg** | **Concrete Products**  260 East White Hills Road P.O. Box 8056 STN ‘A’ St. John’s, Newfoundland  A1B 3M7  [www.newcrete.ca](http://www.newcrete.ca) | Day_Campbell-240x87.jpg | **Day & Campbell Limited**  1074 Upper Wellington Street Hamilton, Ontario  L9A 3S6  [www.daycampbell.com](http://www.daycampbell.com) |
| **locations:** St. John’s, Newfoundland | | **locations:** Hamilton, Ontario | |

| **CCMPA Member-company Corporate Address & Facility Locations Applicable to this EPD** | | | |
| --- | --- | --- | --- |
|  | **Eastway Concrete and Block Inc.**  192 Biesenthal Rd Pembroke, Ontario  K8A 6W7  [www.alliedconcretecanada.com](http://http:/www.alliedconcretecanada.com/) | logo_expocrete_standard2-240x59.jpg | **Expocrete, an Oldcastle company**  #38, 53016 HWY 60 Acheson, Alberta T7X 5A7  [www.expocrete.com](http://www.expocrete.com) |
| **locations:** Pembroke, Ontario | | **locations:** Acheson, Alberta; Edmonton, Alberta; Winnipeg, Manitoba | |
| [Lafarge Canada Inc.](http://http/ccmpa.ca/wp-content/uploads/2012/02/Lafargelogo.jpg) | **Lafarge Canada Inc.**  #300 115 Quarry Park Road SE  Calgary, Alberta  T2C 5G9  [www.lafarge-na.com](http://www.lafarge-na.com) | newtonbrooklogo1-240x101.jpg | **Newtonbrook Block**  2665 Aurora Road P.O. Box 69 Gormley, Ontario L0H 1G0  [www.newtonbrook.com](http://www.newtonbrook.com) |
| **locations:** Lethbridge, Alberta | | **locations:** Whitchurch-Stouffville, Ontario | |
| Niagara-Block-Logo-Caveman-No-Phone-240x164.jpg | **Niagara Block Inc.**  5000 Montrose Road Niagara Falls, Ontario L2H 1K5  [www.niagarablock.com](http://www.niagarablock.com) | permaconlogo13-e1330458866898-240x42.jpg | **Permacon**  8145, Bombardier St.  Ville D'Anjou, Quebec  H1J 1A5  [www.permacon.ca](http://www.permacon.ca) |
| **locations:** Niagara Falls, Ontario | | **locations:** Anjou, Quebec; Milton, Ontario; Quebec City, Quebec; Sherbrooke, Quebec, Stittsville, Ontario, Trois Rivieres, Quebec | |
| **richvaleyorkblockinclogo1-e1330458380650-184x185.jpg** | **Richvale-York Block Inc.**  1298 Clarke Road London, Ontario  N5V 3B5  [www.richvaleyork.com](http://www.richvaleyork.com) | santerralogo2-240x125.jpg | **Santerra Stonecraft**  5115 Rhodes Drive Windsor, Ontario  N8N 2M1  [www.santerrastonecraft.com](http://www.santerrastonecraft.com) |
| **locations:** Gormley, Ontario**;** London, Ontario | | **locations:** Windsor, Ontario | |
| **shawbricklogo1-240x99.jpg** | **Shaw Brick**  1 Shaw Dr P.O. Box 2130 Lantz, Nova Scotia  B2S 3G4  [www.shawbrick.com](http://www.shawbrick.com) | SMC-Logo-171x66.jpg | **Simcoe Block (1979) Ltd.**  207 Tiffin Street Barrie, Ontario  L4M 4T2  [www.simcoeblock.com](http://www.simcoeblock.com) |
| **locations:** Fredericton, New Brunswick; Lantz, Nova Scotia | | **locations:** Barrie, Ontario | |
| **TRI-LOGO-240x108.jpg** | **Tristar Brick & Block Ltd.**  Unit 3A -33790 Industrial Avenue Abbotsford, British Columbia V2S 7T9  [www.tristarblock.com](http://www.tristarblock.com) | VJ Rice.png | **VJ Rice Concrete Limited**  1 Rice Road  Bridgetown, Nova Scotia B0S 1C0  [http://www.riceconcrete.ca/](http://http:/www.riceconcrete.ca/) |
| **locations:** Abbotsford, British Columbia | | **locations:** Bridgetown, Nova Scotia | |

# Appendix B: Imperial Data Tables

Table : Weighted-average Material Content for CMU Products – lbs per yd3

|  |  |  |
| --- | --- | --- |
| **Material** | **Mass, lbs/yd3 CMU** | |
| **Normal-weight** | **Light-weight** |
| Portland Cement | 231.29 | 236.21 |
| Blended Cement | 57.16 | 87.55 |
| Slag Cement (GGBFS) | 8.88 | 0.00 |
| Fly Ash | 1.43 | 0.00 |
| Crushed Coarse Aggregate | 1,278.02 | 311.78 |
| Natural Coarse Aggregate | 175.19 | 14.21 |
| Crushed Fine Aggregate | 264.01 | 0.00 |
| Natural Fine Aggregate | 1,649.59 | 235.73 |
| Expanded Slag | 0.00 | 2,034.50 |
| Pumice | 0.00 | 8.32 |
| Silica Flour | 29.63 | 34.40 |
| Water Reducing Admixture (plasticizer) | 0.18 | 0.09 |
| Water Repellant/Effloresence Control Admixture | 0.15 | 0.02 |
| Air Entraining Admixture | 0.01 | 0.01 |
| Batch Water | 96.96 | 113.32 |
| **Total** | **3,792.50** | **3,076.14** |

Table : CMU Manufacturing Inputs/Outputs – 1 yd3 CMU

| **Item** | **Unit** | **Normal-weight CMU** | **Light-weight CMU** |
| --- | --- | --- | --- |
| **Material Inputs** | | | |
| Portland Cement | lbs | 237 | 242 |
| Blended Cement | lbs | 58.6 | 89.7 |
| Slag Cement (GGBFS) | lbs | 9.10 | 0.00 |
| Fly Ash (no processing) | lbs | 1.47 | 0.00 |
| Crushed Coarse Aggregate | lbs | 1,310 | 319 |
| Natural Coarse Aggregate | lbs | 179.5 | 14.6 |
| Crushed Fine Aggregate | lbs | 271 | 0 |
| Natural Fine Aggregate | lbs | 1,690 | 242 |
| Expanded Slag | lbs | 0 | 2,085 |
| Pumice | lbs | 0.00 | 8.53 |
| Silica Flour | lbs | 30.4 | 35.2 |
| Water Reducing Admixture (plasticizer) | lbs | 0.1826 | 0.0927 |
| Water Repellant/Effloresence Control Admixture | lbs | 0.1588 | 0.0187 |
| Air Entraining Admixture | lbs | 0.01182 | 0.00914 |
| Batch Water, from untreated source | lbs | 1.23 | 1.43 |
| Batch Water, from water treatment plant | lbs | 98.1 | 114.7 |
| **Water Inputs (process and wash water)** | | | |
| From Untreated Source | gal | 5.78 | 5.78 |
| From Water Treatment Plant | gal | 15.3 | 15.3 |
| **Ancillary & Packaging Material Inputs** | | | |
| Road Dust Control Chemicals | gal | 0.0231 | 0.0231 |
| Oil and Lubricants | gal | 0.0173 | 0.0173 |
| Grease | gal | 0.00345 | 0.00345 |
| Wood Pallets | # | 0.944 | 0.944 |
| Steel Straps | lbs | 0.0135 | 0.0135 |
| Plastic Wrap | lbs | 1.474 | 1.474 |
| Plastic Bags and Top Sheets | lbs | 0.392 | 0.392 |
| **Electricity and Fuel Inputs** | | | |
| Grid Electricity, Alberta | kWh | 6.25 | 6.25 |
| Grid Electricity, British Columbia | kWh | 2.96 | 2.96 |
| Grid Electricity, Manitoba | kWh | 2.83 | 2.83 |
| Grid Electricity, New Brunswick | kWh | 0.963 | 0.963 |
| Grid Electricity, Newfoundland | kWh | 0.125 | 0.125 |
| Grid Electricity, Ontario | kWh | 22.6 | 22.6 |
| Grid Electricity, Quebec | kWh | 2.00 | 2.00 |
| Natural Gas | ft3 | 584 | 584 |
| Diesel | gal | 0.337 | 0.337 |
| Gasoline | gal | 0.00118 | 0.00118 |
| LPG (Liquefied Propane Gas) | gal | 0.0105 | 0.0105 |
| **Product Outputs** | | | |
| Finished CMU | yd3 | 1 | 1 |
| **Process Emissions to Air** | | | |
| Particulates, PM-2.5 | lbs | 0.00280 | 0.00280 |
| Particulates, PM-10 | lbs | 0.0183 | 0.0183 |
| Particulates, total | lbs | 0.0717 | 0.0717 |
| Water | lbs | 17.6 | 17.6 |
| **Process Emissions to Water** | | | |
| Water | gal | 19.0 | 19.0 |
| **Waste Outputs** | | | |
| Non-Hazardous Solid Waste, to landfill | lbs | 10.3 | 10.3 |
| Non-Hazardous Solid Waste, to recycling/reuse - concrete | lbs | 87.9 | 87.9 |
| Non-Hazardous Solid Waste, to recycling/reuse - wood | lbs | 3.35 | 3.35 |
| Non-Hazardous Solid Waste, to recycling/reuse - steel | lbs | 0.571 | 0.571 |
| Hazardous Liquid Waste, to incinerator | gal | 0.0223 | 0.0223 |

Table : CMU Manufacturing Inbound/Outbound Transport Modes and Distances (mi)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **one-way distance (miles)** | | | |
| **Truck** | **Rail** | **Ocean** | **Barge** |
| **Inbound Materials** | | | | |
| Portland Cement | 212 | 0 | 26 | 0 |
| Blended Cement | 70 | 42 | 0 | 94 |
| Slag Cement (GGBFS) | 120 | 0 | 0 | 0 |
| Fly Ash (no processing) | 137 | 0 | 0 | 0 |
| Crushed Coarse Aggregate | 45 | 0 | 0 | 0 |
| Natural Coarse Aggregate | 32 | 0 | 0 | 0 |
| Crushed Fine Aggregate | 37 | 0 | 0 | 0 |
| Natural Fine Aggregate | 70 | 0 | 0 | 0 |
| Expanded Slag | 53 | 0 | 0 | 0 |
| Pumice | 536 | 0 | 0 | 0 |
| Silica Flour | 404 | 0 | 0 | 0 |
| Water Reducing Admixture (plasticizer) | 394 | 0 | 0 | 0 |
| Water Repellant/Effloresence Control Admixture | 890 | 0 | 0 | 0 |
| Air Entraining Admixture | 40 | 0 | 0 | 0 |
| **Outbound Waste** | | | | |
| Non-Hazardous Solid Waste, to landfill | 17 | 0 | 0 | 0 |
| Non-Hazardous Solid Waste, to recycling/reuse - concrete | 7 | 0 | 0 | 0 |
| Non-Hazardous Solid Waste, to recycling/reuse - Wood and comingled waste | 9 | 0 | 0 | 0 |
| Non-Hazardous Solid Waste, to recycling/reuse - Steel | 62 | 0 | 0 | 0 |
| Hazardous Liquid Waste, to incinerator | 36 | 0 | 0 | 0 |

Table : LCA Results – 1 yd3 CMU

|  |  |  |  |
| --- | --- | --- | --- |
| **Environmental Indicator** | **Unit** | **Normal-weight** | **Light-weight** |
| **TRACI 2.1 impact categories** | | | |
| Global warming potential | kg CO2 eq. | 198 | 206 |
| Acidification potential | kg SO2 eq. | 1.06 | 1.25 |
| Eutrophication potential | kg N eq. | 0.077 | 0.085 |
| Smog creation potential | kg O3 eq. | 14.5 | 14.5 |
| Ozone depletion potential | kg CFC-11 eq. | 2.05E-06 | 1.78E-06 |
| **Total primary energy consumption** | | | |
| Non-renewable fossil | MJ (HHV) | 1,941 | 1,926 |
| Non-renewable nuclear | MJ (HHV) | 221 | 250 |
| Renewable (non-biomass) | MJ (HHV) | 100 | 92 |
| Renewable (biomass) | MJ (HHV) | 90 | 98 |
| **Material resources consumption** | | | |
| Non-renewable material resources | kg | 1,825 | 496 |
| Renewable material resources | kg | 14.4 | 14.7 |
| Net fresh water | l | 795 | 568 |
| **Waste generated** | | | |
| Non-hazardous waste generated | kg | 47.3 | 47.3 |
| Hazardous waste generated | kg | 0.0880 | 0.0883 |

# Appendix C: Description of TRACI LCIA Impact Categories

**Global warming potential - kg CO2 eq.**

TRACI uses global warming potentials (CF), a midpoint metric proposed by the International Panel on Climate Change (IPCC), for the calculation of the potency of greenhouse gases relative to CO2. The 100-year time horizons recommended by the IPCC and used by the United States for policy making and reporting are adopted within TRACI. Global warming potential (GWP) – the methodology and science behind the GWP calculation can be considered one of the most accepted LCIA categories. GWP100 should be expressed on equivalency basis relative to CO2 – i.e., equivalent CO2 mass basis.

**Acidification potential - kg SO2 eq.**

As per TRACI, acidification comprises processes that increase the acidity of water and soil systems. Acidification is a more regional rather than global impact effecting fresh water and forests as well as human health when high concentrations of SO2 are attained. The Acidification potential (CF) of an air emission is calculated on the basis of the equivalence to kg SO2. This unit is updated from the previous H+ moles used in TRACI 2.

**Eutrophication potential - kg N eq.**

In TRACI, eutrophication is defined as the fertilization of surface waters by nutrients that were previously scarce. This measure encompasses the release of mineral salts and their nutrient enrichment effects on waters – typically made up of phosphorous and nitrogen compounds and organic matter flowing into waterways. The result is expressed on an equivalent mass of nitrogen (N) basis. The characterization factors estimate the eutrophication potential of a release of chemicals containing N or P to air or water, per kilogram of chemical released, relative to 1 kg N discharged directly to surface freshwater.

**Ozone depletion potential - kg CFC-11 eq.**

Stratospheric ozone depletion is the reduction of the protective ozone within the stratosphere caused by emissions of ozone-depleting substances. International consensus exists on the use of Ozone Depletion Potentials (CF), a metric proposed by the World Meteorological Organization for calculating the relative importance of CFCs, hydrochlorofluorocarbons (HFCs), and halons expected to contribute significantly to the breakdown of the ozone layer. TRACI uses the ozone depletion potentials published in the Handbook for the International Treaties for the Protection of the Ozone Layer (UNEP-SETAC 2000), where chemicals are characterized relative to CFC-11.

**Smog creation potential - kg O3 eq.**

Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level where, in the presence of sunlight, they produce photochemical smog, a symptom of photochemical ozone creation potential (POCP). While ozone is not emitted directly, it is a product of interactions of volatile organic compounds (VOCs) and nitrogen oxides (NOx). The “smog” indicator is expressed on a mass of equivalent ozone (O3) basis.

**Respiratory effects - kg PM2.5 eq.**

The midpoint level selected by TRACI is used, based on exposure to elevated particulate matter (PM) less than 2.5 micrometers in diameter. Particulate matter is the term for particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. Emissions of SO2 and NOx lead to formation of the secondary particulates sulphate and nitrate. Particles can be suspended in the air for long periods of time. Some particles are large or dark enough to be seen as soot or smoke. Others are so small that individually they can only be detected with an electron microscope. Many manmade and natural sources emit PM directly or emit other pollutants that react in the atmosphere to form PM. These solid and liquid particles come in a wide range of sizes. Particles less than 10 micrometers in diameter (PM10) pose a health concern because they can be inhaled into and accumulate in the respiratory system. Particles less than 2.5 micrometers in diameter (PM2.5) are referred to as "fine" particles and are believed to pose the greatest health risks. Because of their small size (approximately 1/30th the average width of a human hair), fine particles can lodge deep in the lungs.

1. The noted thicknesses correspond to size codes 10, 15, 20, 25, and 30. The size code refers to the nominal thickness of the block in centimetres. [↑](#footnote-ref-1)
2. "Dummy" is a term used by US LCI database that refers to “empty” LCI data sets (technosphere processes). [↑](#footnote-ref-2)
3. labelled "non-biomass" herein [↑](#footnote-ref-3)