LIFE CYCLE ASSESSMENT

A.C. MILLER CONCRETE PRODUCTS, INC.

Products Included:

Precast Concrete

Study Completed:

May 2021

Critical Review Completed:

July 2021

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DOCUMENT SUMMARY

The following table identifies the relevant details of the life cycle assessment (LCA) for use in various certification programs.

MANUFACTURER	A.C. Miller Concrete Products, Inc. 31 E. Bridge Street, Spring City, PA 19475 9558 Route 22, Blairsville, PA 15717
PRODUCT(S)	Precast Concrete
DECLARED UNIT	1 metric tonne of precast concrete for a period of 75 years
REFERENCE SERVICE LIFE (RSL)	75 years
REFERENCE STANDARDS	☒ ISO 14040 ☒ ISO 14044 ☒ ISO 21930 ☒ EN 15804+A1
REFERENCE PCR	ASTM International Precast Concrete (UN CPC 3755)
LCA SCOPE	Cradle-to-Gate with Options (A4, A5, C1-C4)
LCA STUDY DETAILS	Completed: May 2021 LCA Practitioner: Lindsay Corner, WAP Sustainability Consulting, LLC
LCA REVIEW DETAILS	Completed: July, 2021 LCA Reviewer: Jack Geibig, Ecoform INTERNAL ☒ EXTERNAL
PROGRAM OPERATOR	NSF International
YEAR OF PRIMARY DATA	2020
LCA SOFTWARE	GaBi 10.0.0.71
LCA DATABASE	GaBi Database 2021.1
LCIA METHODOLOGY	TRACI 2.1
APPLICABLE REGION(S)	North America

Important Note: Results presented in this report are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.

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1 EXECUTIVE SUMMARY

Current trends in corporate sustainability emphasize transparency and the evaluation of environmental and social impacts throughout a product's entire value chain. Thus, life cycle assessment (LCA) is considered to be an important delivery tool of transparent market communication and product optimization opportunities. By calculating the potential environmental impacts of their products, A.C. Miller hopes to better understand areas of high environmental impacts, within and outside their direct production process, and participate in voluntary reporting of product environmental performance.

An important element to understanding the results from an LCA is the concept of a "Declared Unit". In short, the declared unit is the "what" and "how much" of a product that is being assessed. For this study, the declared unit is one metric tonne of precast concrete, with the products in the study having a Reference Service Life (RSL) of 75 years and being manufactured during calendar year 2020.

According to the international standards that dictate the LCA process (ISO 14040 and ISO 14044), the goal and scope of a study must be clearly described. In the case of this assessment, the LCA was conducted for two central reasons. First, it will be used to develop a standardized method to inform the design process using key environmental parameters, such as greenhouse gas emissions and energy demand. Second, it will be used to develop publicly available environmental product declarations (EPDs). The latter reason will require a critical review by an independent third party. The critical review ensures that the LCA has met all relevant standards and that the results are plausible. The critical review does not ensure that the results can be compared to the results of other LCA studies.

Key inputs evaluated in the study include electrical and thermal energy consumption, transportation, sourcing of raw materials, generation of waste and end-of-life disposal. The evaluation of transportation includes the transportation of raw materials to the manufacturing site, shipping to the customer and transportation of the product to its end-of-life disposal site.

The results presented in this study are a weighted-average of the impacts of the products manufactured in A.C. Miller's Blairsville, PA and Spring City, PA plants based on the mass of products sold in 2020.

The graph below shows the weighted-average Global Warming Potential (GWP) impacts per declared unit of precast concrete products studied over the course of 75 years. The dark blue bar (A1-A3) represents raw material sourcing and the manufacturing process and has the largest impact (72%). Roughly 70% of the A1-A3 impact is from the cement usage alone. The light blue bar (C4), which accounts for the second largest impact (17%) represents the end-of-life disposal. The medium blue bar (A4) and green bar (C2) account for the next largest impacts and represent transportation to the customer (5.8%) and transportation to end-of-life (5.1%), respectively. Overall, the weighted-average impacts for A.C. Miller's precast concrete products is 253 kg of CO_2e per metric tonne over a 75-year life cycle.

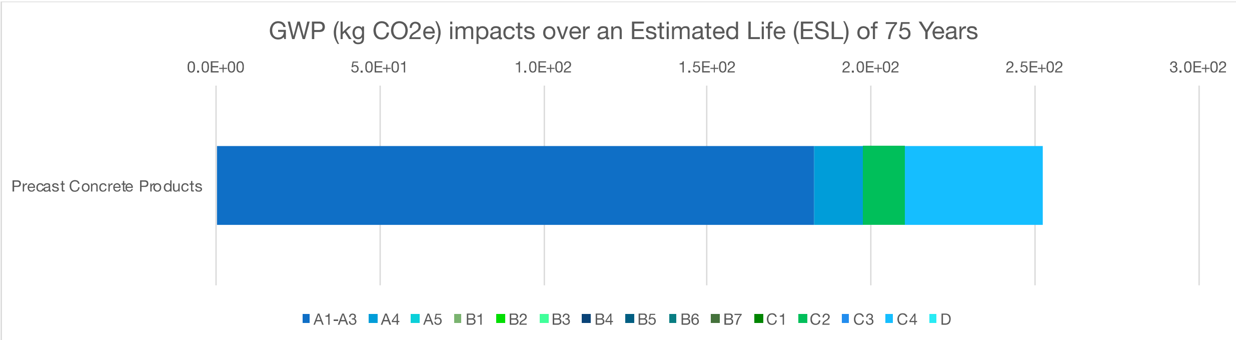

Figure 1: Overview of Product Impacts

Note: A1-A3 equals the stage of raw material extraction, transportation, and product manufacturing; A4 transportation to customers; A5 installation; B1 use; B2 maintenance; B3 repairing; B4 replacement; B5 refurbishment; B6 operational energy use; B7 operational water usage; C1 deconstruction; C2 waste transportation; C3 waste processing; and C4 waste disposal.

In order to further reduce the environmental impacts over the concrete's life cycle, A.C. Miller should consider taking the following steps:

- Reduce cement usage or replace it with a less carbon-intensive material
- Explore alternative end-of-life pathways in which concrete can be reused in order to reduce the amount of landfill waste

A sensitivity analysis was conducted to understand the impacts of each manufacturing facility. Overall, the environmental impacts of the two plants are similar with the Spring City's A1-A3 GWP impacts being about 4% greater than that of Blairsville. This is due to the fact that Spring City uses about 50% more electricity per declared unit compared to Blairsville. Also, certain energy sources such as kerosene and ultra-low sulfur diesel are used in Spring City but are not utilized in Blairsville. Despite these differences, the carbon intensity of the overall product between the two manufacturing locations is fairly consistent due to the slight differences in product formulation.

2 GENERAL INFORMATION

This LCA project report represents the systematic and comprehensive summary of project documentation and showcases any data and information of importance to the results and as required by the product category rules (PCRs) listed below.

2.1 COMPANY PROFILE

Based in Pennsylvania, A.C. Miller provides a broad range of precast concrete products including manholes, accelerated bridge systems, rail platforms, stormwater and sewerage systems, and firewalls.

2.2 LCA COMMISSIONERS AND PRACTITIONERS

A.C. Miller commissioned this LCA study. Primary data were provided by A.C. Miller associates from the facility in which the products are produced. WAP Sustainability Consulting was contracted to develop the LCA model and complete this background report. Lindsay Corner of WAP Sustainability served as the project manager and lead LCA practitioner. Primary data were collected and quality assured through efforts of both WAP Sustainability and A.C. Miller.

2.3 REPORTING DATE

This LCA study was commenced in January 2021 and a draft was submitted for critical review in May 2021.

2.4 INTENDED APPLICATION AND REASONS FOR THE STUDY

This LCA was conducted for the development and release of Environmental Product Declarations (EPDs) based on the following product category rules:

- ASTM International Precast Concrete (UN CPC 3755)

This PCR complies with ISO 21930, though the LCA report was written to additionally comply with EN 15804.

2.5 TARGET GROUP/AUDIENCE

The intended audience includes LCA critical reviewers and internal management. The EPDs created from this report may be used for business-to-business or business-to-consumer communication.

2.6 COMPARATIVE ASSERTIONS AND PUBLIC DISCLOSURE

This study was not completed with the intent that comparative assertions with external objects or general public disclosures (i.e. comparative marketing claims) would be made. However, the results from the report will be used as the basis of product optimization documentation and will be used to develop EPDs. The EPDs will be disclosed to the public.

2.7 STANDARDS AND PCR COMPLIANCE

This LCA has been critically reviewed for compliance with ISO 14040, 14044, and the PCR mentioned in section 2.4. The critical review confirmed that this LCA meets the requirements of these standards, and the verification statement and checklist are included in the appendix of this document.

2.8 PRODUCT DESCRIPTION

2.8.1 Product Classification and Description

This life cycle assessment report covers products that fall under CSI division 03 40 00. Products reviewed in this study include precast concrete products used for road, transportation, and underground utility projects.

This LCA was conducted for products derived from A.C. Miller's products manufactured at the facilities located in Spring City, Pennsylvania and Blairsville, Pennsylvania. A.C. Miller's precast products consist primarily of cement, a coarse aggregate, and a fine aggregate. Additionally, admixtures are utilized to protect against freezing and to improve durability. All products in this review are considered precast concrete products.

Results in this LCA are presented based on a representative precast product that is based on the total materials purchased during 2020 and annual production data.

2.8.2 Applicability

A.C. Miller products are used in utility, transportation, environmental, and heavy civil projects such as the construction of:

- Box Culverts;
- Manholes;
- Train stations;
- Tunnels;
- Stormwater systems;
- Wastewater systems and
- Freshwater systems

2.8.3 Technical Data

Table 1 shows the technical specifications of the products, including any testing data as appropriate.

Table 1: Technical Data

	Precast Concrete
Compressive Strength, psi after 18 hours	6,239-6,462
Compressive Strength, psi after 7 days	7,823-8,022
Compressive Strength, psi after 14 days	7,926-8,189
Compressive Strength, psi after 28 days	8,571-8,626
Additional Hardware	-

2.9 ADDITIONAL ENVIRONMENTAL INFORMATION

There is no additional environmental information that will be included in the EPD.

3 SCOPE OF THE STUDY

3.1 LCA METHODOLOGICAL FRAMEWORK

The LCA follows an attributional approach.

3.2 DECLARED UNIT

For this study, the declared unit is being defined as one metric tonne of installed precast concrete product. Table 2 shows additional details related to the declared unit.

Table 2: Declared Unit Details

	Precast Concrete
Mass per declared unit [kg]	1,000
Density [lbs/cu ft]	130-150

3.3 REFERENCE SERVICE LIFE

As this study is a Cradle-to-Gate with options study excluding the use phase, a reference service life is not provided.

3.4 SYSTEM BOUNDARY

The LCA Is considered a Cradle-to-Gate with options (EOL) study. An overview of the system boundary is shown in Figure 2 and a summary of the life cycle stages included in this LCA is presented in Table 3.

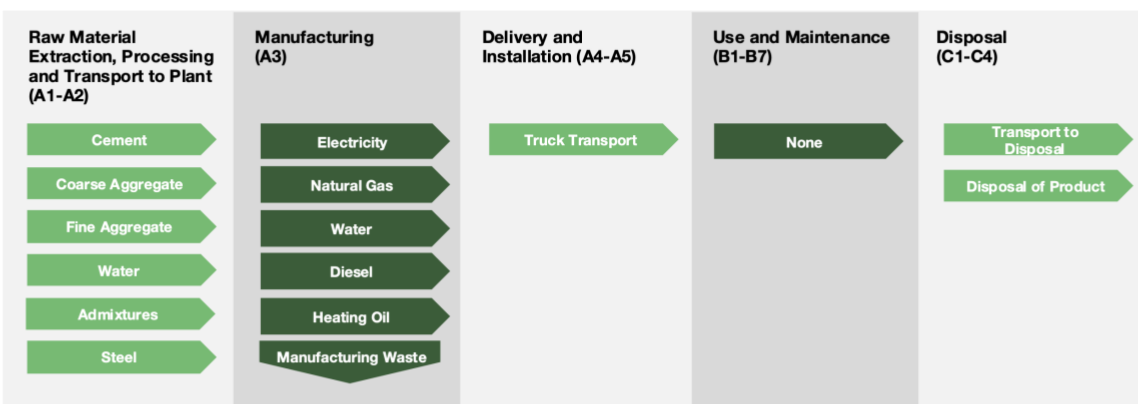

Figure 2: System Boundary Diagram

Table 3: Life Cycle Stages Included in the Study

Production			Construction		Use							End of Life				Benefits & Loads Beyond System Boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw Material Supply	Transport	Manufacturing	Transport to Site	Assembly/Install	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction	Transport	Waste Processing	Disposal	Reuse, Recovery, Recycling Potential
X	X	X	X	X	MND	MND	MND	MND	MND	MND	MND	X	X	X	X	MND

X = Module Included in LCA Report, MND = Module not Declared

3.4.1 Product Stage (A1-A3)

This stage includes an aggregation of raw material extraction and supplier processing, delivery of the materials to the manufacturing site, and impacts from manufacturing. This stage is summarized in Table 4.

Table 4: Items Included in Life Cycle Stages A1-A3

Included	Excluded
Extraction and processing of raw materials	Production, manufacture, and construction of manufacturing capital goods and infrastructure
Processing of recycled raw materials from previous product system	Formwork
Transportation of materials to the manufacturing location	Production and manufacture of production equipment, delivery vehicles, and laboratory equipment
Manufacturing of products, including energy, water, and material usage and water disposal	Personnel-related activities (travel, furniture, and office supplies)
Waste generation from manufacturing and transportation to disposal	Energy and water use related to company management and sales activities

The products were modeled in GaBi to produce the potential environmental impacts over their lifetime. For any materials unavailable in the GaBi database, appropriate proxies were used. Details on these proxies are mentioned in Appendix A. Specific descriptions of secondary unit processes can be viewed through the GaBi dataset documentation online at http://www.gabi-software.com/america/databases/gabi-data-search/.

The raw materials for the product were obtained from various suppliers across North America. The general composition is represented in Table 5.

Table 5: Material Composition per Declared Unit

	Precast Concrete
Cement	10%-20%
Fly Ash	0%-5%
Coarse Aggregate	30%-40%
Fine Aggregate	30%-40%
Water (batch water)	0%-10%
Admixtures	1%-2%
Steel	1%-5%

The materials are delivered to the manufacturing facility via truck and are accounted for in the model. The distances were modeled by material and were calculated using the supplier location and the location of manufacturing. Transportation data are shown in Table 6, though they are presented as an average to protect the identity of the suppliers.

Table 6: A2 Transportation Data

Input	Distance (miles)	Distance (km)
Cement	46	74
Fly Ash	41	66
Coarse Aggregate	36	58
Fine Aggregate	72	116
Water	0	0
Admixtures	131-600	211-966
Steel	231-342	372-550

A.C. Miller precast concrete products are manufactured utilizing molds with natural gas as the main energy source. Cement is delivered to the manufacturing site via bulk containers and is poured into the mold. Sand and stone aggregates are then added to the cement. To keep materials at the proper suspension, to protect against freezing, and to improve durability, admixtures and water are combined with the other materials. Then, rebar is placed into the mold for reinforcement. Excess concrete is shaped into blocks and reused by neighboring organizations for various purposes.

Energy resources used in the manufacturing process are accounted for in the model. The electricity is sourced from the power grid, and no onsite electricity generation is used. Electricity production datasets from GaBi and eGRID are used to assess the generation, distribution, and transmission of electricity. Secondary datasets for other fuels and waste were utilized from the GaBi database, as shown in Appendix A. Manufacturing inputs and outputs per declared unit were calculated by using annual figures and dividing them by annual production. The product does not require any packaging materials. These details are summarized in Table 7.

Table 7: Manufacturing Inputs and Outputs per Declared Unit

Manufacturing Data	Precast Concrete
Utilities	
Electricity [kWh]	25.3
Natural Gas [MJ]	167
Heating Oil [gallons]	0.110
Diesel [gallons]	0.0326
Water (batch and process) [gallons]	18.3
Waste	
Waste to Landfill [kg]	0
Waste to Incineration [kg]	0
Waste to Waste-to-Energy [kg]	0
Waste to Recycling [kg]	5.00

3.4.2 Delivery and Installation Stage (A4-A5)

In this stage, the product is transported to the building site and installed. This stage is summarized in Table 8.

Table 8: Items Included in Life Cycle Stages A4-A5

Included	Excluded
Transportation from the manufacturing gate to the construction site, including fuel usage	Production of multi-use installation tools
Energy used to install the product	Installation materials that are sold as part of the product system (accounted for in A1-A3)

The product is delivered to the customer via truck. Transportation averages are calculated based on sales records and are shown in

Table 9.

Table 9: Transport to Building Site (A4) per Declared Unit

	Precast Concrete
Vehicle Type	U.S. Flatbed truck, platform / 49,000 payload
Fuel Efficiency [L/100km]	1,308
Fuel Type	Diesel
Distance [km]	216
Capacity Utilization [%]	98
Weight of Products Transported [kg]	1,000

The trucks used for delivery houses a crane that is used to install the product. The crane is used to remove the product from the truck bed and place it into the appropriate place of installation. Since the truck that delivers the product is the same truck used to install the product, the fuel utilized by the truck could not be split between the A4 and A5 stages. As such, it was estimated that the emissions and fuel associated with installation (A5) would be 1% that of the delivery (A4). The fuel used during transportation and installation are included in the study.

Installation equipment is required though the manufacturing of this equipment is not included in the study as these are multi-use cranes and trucks and the impacts per declared unit are considered negligible. However, the energy required to operate the crane is included, as indicated in Table 10. There is not any packaging or installation waste associated with the product.

Table 10: Installation Scenario Details (A5) per Declared Unit

	Precast Concrete
Ancillary Materials [kg]	0
Net Freshwater Consumption [m^3]	0
Electricity Usage [kWh]	0
Diesel Usage [kg]	0.0392
Product wastage [%]	0
Waste materials at the construction site before waste processing, generated by product installation [kg]	0
Packaging Waste to Landfill [kg]	0
Packaging Waste to Incineration [kg]	0
Packaging Waste to Recycling [kg]	0

The product should be installed according to the manufacturer's instructions.

3.4.3 Use Stage (B1-B7)

This study does not include the impacts associated with use, maintenance, repair, operational energy and water use, replacement, and refurbishment (B1-B7).

3.4.4 End-of-Life (C1-C4)

In this stage, the product is transported to the end-of-life facility and disposed.

Table 11: Items Included in Life Cycle Stages C1-C4

Included	Excluded
Energy and materials required for deconstructing the product	Production of end-of-life capital equipment and facilities
Transportation of the product to the end-of-life facility	
Waste processing for reuse, recycling, energy recover, and/or reclamation	
Waste disposal, including all resource inputs and management activities of the disposal site	

Table 12 shows the parameters for the end-of-life scenario utilized in the model.

Table 12: End-of-Life Scenario Details (C1-C4)

	Precast Concrete
Collected as mixed construction waste [kg]	1,000
Waste to Landfill [kg]	1,000
Distance to Landfill [km]	161
Waste to Incineration [kg]	0
Distance to Incineration [km]	0
Waste to Recycling [kg]	0
Distance to Recycling [km]	0

3.5 CUT-OFF CRITERIA

Material inputs greater than 1% (based on total mass of the final product) were included within the scope of analysis. Material inputs less than 1% were included if sufficient data was available to warrant inclusion and/or the material input was thought to have significant environmental impact. Cumulative excluded material inputs and environmental impacts are less than 5% based on total weight of the declared unit.

The list of excluded materials and energy inputs include:

- As the equipment used during the installation of the product is considered multi-use equipment and can be reused after each installation, the per-declared unit impacts from production of this equipment are considered negligible and therefore are not included.

- Some material inputs may have been excluded within the GaBi datasets used for this project. All GaBi datasets have been critically reviewed and conform to the exclusion requirement of the PCR, Part A: “Calculation Rules for the Life Cycle Assessment and Requirements on the Background Report”.

3.6 ALLOCATION PROCEDURES

General principles of allocation were based on ISO 14040/44. There are no products other than the product under study that are produced as part of the manufacturing processes. Since there are no co-products, no allocation based on co-products is required.

To derive a per-unit value for manufacturing inputs such as electricity, thermal energy and water, allocation based on total production by mass was adopted. As a default, secondary GaBi datasets use a physical mass basis for allocation.

Of relevancy to the defined system boundary is the method in which recycled materials were handled. Throughout the study recycled materials were accounted for via the cut-off method. Under this method, impacts and benefits associated with the previous life of a raw material from recycled stock are excluded from the system boundary. Additionally, impacts and benefits associated with secondary functions of materials at end of life are also excluded (i.e. production into a third life or energy generation from the incineration plant). The study does include the impacts associated with reprocessing and preparation of recycled materials that are part of the bill of materials of the products under study.

3.7 DATA QUALITY REQUIREMENTS

Secondary datasets utilized in the model are disclosed in Appendix A along with data quality indicators related to the geographic, temporal, and technological coverage of the dataset. Additionally, details on proxies are provided, if applicable.

3.7.1 Geographic Coverage

The geographical scope of the manufacturing portion of the life cycle is the United States. All primary data were collected from the manufacturer. The geographic coverage of primary data is considered excellent.

The geographical scope of the raw material acquisition is the United States. Customer distribution and site installation stages of the life cycle is the United States.

In selecting secondary data (i.e. GaBi Datasets), priority was given to the accuracy and representativeness of the data. When available and deemed of significant quality, country-specific data was used. However, priority was given to technological relevance and accuracy in selecting secondary data. This often led to the substitution of regional and/or global data for country-specific data. The geographical coverage of secondary datasets can be referenced in the dataset references table in Appendix A. Overall geographic data quality is considered great.

3.7.2 Time Coverage

Primary data were provided by the manufacturer and represent all information for calendar year 2020. Using this data meets the PCR requirements. Time coverage of this primary data is considered excellent.

Data necessary to model cradle-to-gate unit processes was sourced from Sphera LCI datasets. Time coverage of the GaBi datasets varies from approximately 2010 to present. All datasets rely on at least one 1-year average data. Overall time coverage of the datasets is considered excellent and meets the requirement of the PCR that all data be updated within a 10- year period. The specific time coverage of secondary datasets can be referenced in Appendix A.

3.7.3 Technological Coverage

Primary data provided by the manufacturer is specific to the technology the company uses in manufacturing their product. It is site-specific and considered of good quality. It is worth noting that the energy and water used in manufacturing the product includes overhead energy such as lighting, heating and sanitary use of water. Sub-metering was not available to extract process-only energy and water use from the total energy use. Sub-metering would improve the technological coverage of data quality.

Data necessary to model cradle-to-gate unit processes was sourced from GaBi LCI datasets. Technological coverage of the datasets is considered good relative to the actual supply chain of the manufacturer. While improved life cycle data from suppliers would improve technological coverage, the use of lower-quality generic datasets does meet the goal of this LCA.

3.7.4 Treatment of Missing Data

Primary data was used for all manufacturing processes. Whenever available, supplier data was used for raw materials used in the production process. When primary data did not exist, secondary data for raw material production was used from the GaBi database, as shown in Appendix A. Any proxies used for raw materials have also been detailed in Appendix A.

3.7.5 Data Quality Assessment

Appendix A shows an assessment for the data quality of all secondary processes included in the model. Additionally, the following sections provide details on the data quality of the model itself.

3.7.5.1 Precision

The precision of the data is considered high. Product engineers provided detailed bills of materials, and facility managers provided utility information for the manufacturing facilities. The raw material transportation distances were calculated based on the raw material manufacturers' address provided by A.C. Miller associates. Proxy datasets were utilized in the LCA model when primary data and secondary data were not available, as shown in Appendix A. Precision can be increased via sub-metering individual manufacturing processes to better account for manufacturing processes rather than including overhead utility information.

3.7.5.2 Completeness

The data included is consider complete. The LCA model included all known material and energy flows, with the exception of what is listed in Section 3.5. As pointed out in that section, no known flows above 1% were excluded and the sum of all excluded flows totals less than 5%.

3.7.5.3 Consistency

The consistency of the model is considered high. The bills of materials provided by the product engineers were developed for multiple internal departments use and maintained regularly. Furthermore, modeling assumptions were consistent across the model, with preference given towards Sphera data, where available.

3.7.5.4 Reproducibility

This study is considered reproducible. Descriptions of the data and assumptions through this report would allow a practitioner to utilize the LCA tool to generate results for the products.

3.7.5.5 Uncertainty

Uncertainty for the secondary datasets is discussed in the documentation published by Sphera. Uncertainty of the primary data comes from the utility data allocated to each product. The yearly total energy use changes over time due to more efficient operations, warmer or cooler seasons and other factors. Because energy data comes directly from utility bills, the uncertainty is mainly based on the accuracy of the utility meters.

4 LIFE CYCLE INVENTORY ANALYSIS

Primary data was collected from A.C. Miller associates. All calculation procedures adhere to ISO14044. Collection and processing of major data points is described below.

- Electrical Energy, Thermal Energy, Diesel and Water Consumption.
    - Data was collected for January 2020 through December 2020 through yearly utility bills and consumption was divided by production during this period to derive an energy use-per-production unit for use in the LCA.
- Raw Materials and Purchasing
    - Bills of materials were obtained from A.C. Miller associates. The technical team provided formulation information and supplier locations.
- Waste Value
    - Facility waste estimates were provided by A.C. Miller associates.
- Shipping Distance to customers.
    - Transport from the manufacturing plant to the installation site is based on sales data.
- End of life Scenarios
    - Product waste is assumed to be disposed of in a construction waste landfill. No credits were taken for energy production from end-of-life processes.

Data was reviewed for accuracy as it was collected by first calculating the per-unit values and comparing them against published studies. Any inconsistencies in data were resolved through email and telephone communication with technical associates at the manufacturer.

5 LIFE CYCLE IMPACT ASSESSMENT

5.1 SELECTION OF IMPACT PARAMETERS

Environmental Impacts were calculated using the GaBi software platform. Impact results have been calculated using TRACI 2.1 characterization factors. Results presented in this report are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.

Table 13: LCIA Indicators

Abbreviation	Parameter	Unit
	TRACI 2.1	
AP	Acidification potential of soil and water	kg SO_2 eq
EP	Eutrophication potential	kg N eq
GWP	Global warming potential (100 years, includes biogenic CO_2)	kg CO_2 eq
ODP	Depletion of stratospheric ozone layer	kg CFC 11 eq
Resources	Depletion of non-renewable fossil fuels	MJ, surplus energy
POCP	Photochemical ozone creation potential (Smog formation potential, SFP)	kg O_3 eq

In addition, the following indicators on the uptake and emissions of CO_2 are reported as they are included in the global warming potential figures above.

Table 14: Biogenic Carbon Indicators

Parameter	Parameter	Unit
BCRP	Biogenic Carbon Removal from Product	[kg CO2]
BCEP	Biogenic Carbon Emission from Product	[kg CO2]
BCRK	Biogenic Carbon Removal from Packaging	[kg CO2]
BCEK	Biogenic Carbon Emission from Packaging	[kg CO2]
BCEW	Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	[kg CO2]
CCE	Calcination Carbon Emissions	[kg CO2]
CCR	Carbonation Carbon Removals	[kg CO2]
CWNR	Carbon Emissions from Combustion of Waste from Non- Renewable Sources used in Production Processes	[kg CO2]

Throughout the life cycle of the product, there are no emissions to air, water, and soil.

In addition to the environmental parameters described in the previous section, the following resource use and waste categories are also disclosed.

Abbreviation	Parameter	Unit
	Resource Use Parameters	
RPR_E	Use of renewable primary energy excluding renewable primary energy resources used as raw materials	MJ, net calorific value (LHV)
RPR_M	Use of renewable primary energy resources used as raw materials	MJ, net calorific value
RPR_T	Total use of renewable primary energy resources	MJ, net calorific value
$NRPR_E$	Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	MJ, net calorific value
$NRPR_M$	Use of non-renewable primary energy resources used as raw materials	MJ, net calorific value
$NRPR_T$	Total use of non-renewable primary energy resources	MJ, net calorific value
SM	Use of secondary materials	kg
RSF	Use of renewable secondary fuels	MJ, net calorific value
NRSF	Use of non-renewable secondary fuels	MJ, net calorific value
RE	Recovered energy	MJ, net calorific value
FW	Net use of fresh water	m^3
	Waste Parameters and Output Flows	
HWD	Disposed-of-hazardous waste	kg
NHWD	Disposed-of non-hazardous waste	kg
HLRW	High-level radioactive waste, conditioned, to final repository	kg
ILLRW	Intermediate- and low-level radioactive waste, conditioned, to final repository	kg
CRU	Components for reuse	kg
MR	Materials for recycling	kg
MER	Materials for energy recovery	kg
EEE	Exported electrical energy	MJ
EET	Exported thermal energy	MJ

5.2 LCA RESULTS

All results are given per declared unit, as shown in Section 3.2, which is one metric tonne of precast concrete. Each product under study is reported separately by life cycle stage.

The LCIA results presented below are for 1 metric tonne of precast concrete.

Impact Category	A1-A3	A4	A5	C1	C2	C3	C4
TRACI LCIA Impacts							
AP [kg SO_2 eq]	3.11E-01	2.24E-02	2.24E-04	0.00E+00	3.66E-02	0.00E+00	1.87E-01
EP [kg N eq]	1.90E-02	3.56E-03	3.56E-05	0.00E+00	4.22E-03	0.00E+00	1.04E-02
GWP [kg CO_2 eq]	1.83E+02	1.45E+01	1.45E-01	0.00E+00	1.28E+01	0.00E+00	4.24E+01
ODP [kg CFC 11 eq]	3.93E-13	2.90E-15	2.90E-17	0.00E+00	2.57E-15	0.00E+00	1.47E-13
Resources [MJ]	1.53E+02	2.73E+01	2.73E-01	0.00E+00	2.41E+01	0.00E+00	8.56E+01
POCP [kg O_3 eq]	7.13E+00	5.02E-01	5.02E-03	0.00E+00	8.34E-01	0.00E+00	3.33E+00
Carbon Emissions and Uptake							
BCRP [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCEP [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCRK [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCEk [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCEW [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CCE [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CCR [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CWNR [kg CO_2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Resource Use Indicators							
RPR_E [MJ]	1.21E+02	8.48E+00	8.48E-02	0.00E+00	7.49E+00	0.00E+00	5.59E+01
RPR_M [MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RPR_T [MJ]	1.21E+02	8.48E+00	8.48E-02	0.00E+00	7.49E+00	0.00E+00	5.59E+01
$NRPR_E$ [MJ]	1.53E+03	2.06E+02	2.06E+00	0.00E+00	1.82E+02	0.00E+00	6.73E+02
$NRPR_M$ [MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
$NRPR_T$ [MJ]	1.53E+03	2.06E+02	2.06E+00	0.00E+00	1.82E+02	0.00E+00	6.73E+02
SM [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF [MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF [MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RE [MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW [m^3]	3.44E-01	3.62E-02	3.62E-04	0.00E+00	3.20E-02	0.00E+00	9.24E-02
Output Flows and Waste Categories							
HWD [kg]	1.93E-05	1.72E-08	1.72E-10	0.00E+00	1.52E-08	0.00E+00	6.36E-08
NHWD [kg]	1.22E+00	1.89E-02	1.89E-04	0.00E+00	1.67E-02	0.00E+00	1.00E+03
HLRW [kg]	7.87E-05	6.94E-07	6.94E-09	0.00E+00	6.13E-07	0.00E+00	6.49E-06
ILLRW [kg]	7.55E-02	5.84E-04	5.84E-06	0.00E+00	5.16E-04	0.00E+00	5.60E-03
CRU [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MR [kg]	5.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MER [kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EEE [MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EET [MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Modules B1-B7 and D are not declared in this assessment.

6 INTERPRETATION

Within this section, the results of the life cycle assessment will be interpreted according to the goal and scope of the study. This interpretation will include a dominance analysis, a sensitivity check, and a data quality check, before providing conclusions based on the LCA.

6.1 DOMINANCE ANALYSIS

A dominance analysis was performed for the products in the LCA to show which of the life cycle modules contributes to the majority of the impacts. Due to the relevance of these impact categories to the product type and the manufacturer's interests, this dominance analysis will be provided for Global Warming Potential (GWP) results.

6.1.1 Global Warming Potential (GWP)

Global warming potential (GWP) is a measure of how much heat a greenhouse gas traps in the atmosphere up to a specified time horizon and measured relative to carbon dioxide.

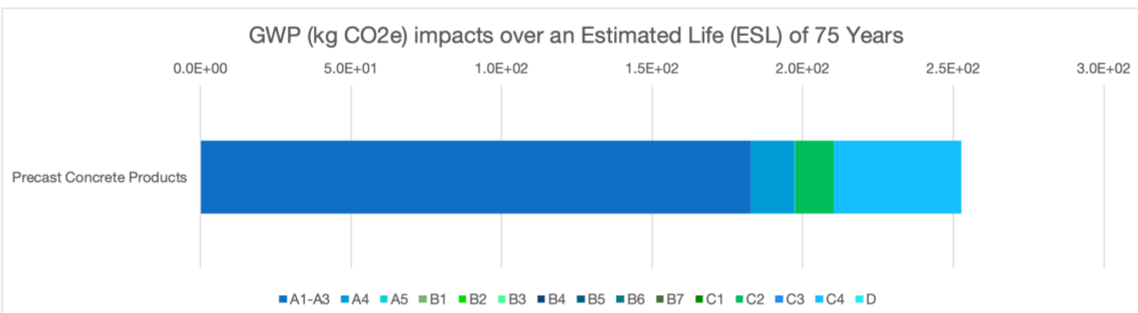

Figure 3: GWP Impacts per Declared Unit

The dominance analysis shows that the raw material sourcing and manufacturing activities are the most impactful. This is primarily a result of the choice of materials used in the product formula. The materials with the largest A1-A3 impacts are cement (65% of A1-A3 emissions) and sand (7% of A1-A3 impacts). As such, it is recommended A.C. Miller that considers reducing the amount of these materials utilized in the product or replace these substances with less carbon intensive materials.

6.1.2 Abiotic Depletion Potential of Fossil Resources (ADPF)

Abiotic Depletion Potential Fossil Fuel (ADP Fossil) refers to the measure of the depletion of fossil resources and was additionally reported on the provide additional context to the results.

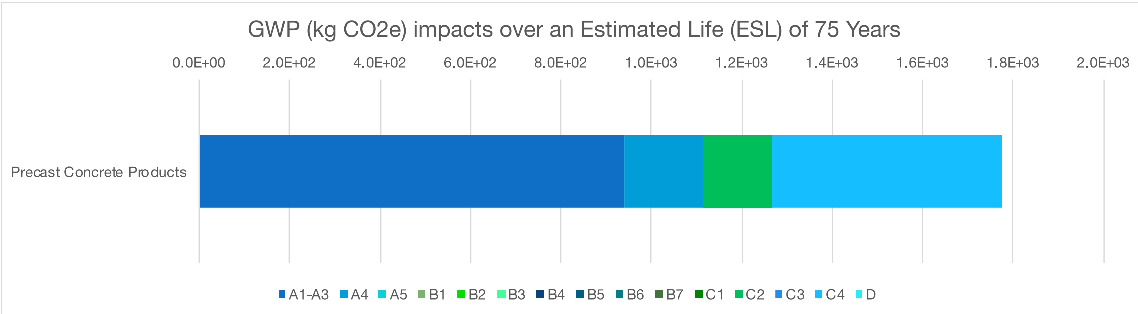

Figure 4: ADPF Impacts per Declared Unit

ADP – fossil refers to the depletion of abiotic resources such as fossil fuels. Phases A1-A3 contribute the most to ADP-fossil through the extraction and use of cement during manufacturing. The end-of-life module (C4) has the second largest ADP – Fossils impact, mainly due to the resources used to landfill the product at end-of-life. Transportation via truck (A4) to customer and transportation to end-of-life (C2) have lesser overall ADP-fossil impacts.

6.2 SENSITIVITY ANALYSIS

A sensitivity analysis is performed within life cycle assessment to determine how the results of an LCA are affected by the assumptions the LCA practitioner made during the course of the study. Of relevance to this model is the utilization of a weighted average the various manufacturing facilities instead of supplying facility-specific results.

6.2.1 Manufacturing Facility Sensitivity Analysis

A.C. Miller products are manufactured at two plants. Primary energy, water, and waste data for calendar year 2020 was provided for each facility as well as 2020 production at each plant. Using this information, the study utilized a weighted average based on the consumption and production at both sites.

A sensitivity analysis was conducted to understand the impacts of each manufacturing facility. In order to compare the facilities evenly, two scenarios were created – one for each plant. In each scenario, the energy, water, and waste specific to that facility were used however, the same formulation was used for both scenarios for consistency purposes. The table below shows the deviation of results from the Blairsville plant for each impact category.

Table 15: Sensitivity Analysis of Manufacturing Location on A1-A3 Impacts

Impact Category	Spring City
GWP [kg CO2 eq]	4.1%
ODP [kg CFC 11 eq]	0.3%
AP [kg SO2 eq]	4.8%
EP [kg Phosphate eq]	5.1%
POCP [kg Ethene eq]	7.2%
ADP-elements [kg Sb eq]	-2.1%

Impact Category	Spring City
ADP-fossil fuel [MJ]	6.9%

The table above shows the A1-A3 impacts for the Spring City manufacturing facility relative to the Blairsville manufacturing facility. Overall, the environmental impacts of the two plants are similar. The reason the Spring City location has slightly higher A1-A3 impacts is due to the energy usage. Spring City uses about 50% more electricity per declared unit compared to Blairsville. Also, certain energy sources such as kerosene and ultra-low sulfur diesel are used in Spring City but are not utilized in Blairsville. Despite these differences, overall, the carbon intensity of both plants is consistent between the two sites.

6.3 DATA QUALITY ASSESSMENT

The assessed data quality for each data point utilized within the study can be viewed in the Data Quality Section of the report, found in Section3.7. Overall data quality is considered good. Improvements can be made through the modification of datasets to incorporate more regional specificity, both in terms of energy and technology. However, the data was considered appropriate in relation to the goal, scope and budget of the project.

Primary data also includes the bill of materials used to formulate the products that are included in the study. Overall this data is considered excellent. Data quality can be increased through the use of supplier-specific secondary datasets.

6.4 TRANSPARENCY DECISIONS THAT MAY HAVE AFFECTED THE LCA

Throughout this report, value choices and judgements that may have affected the LCA have been described. Additional decisions are summarized below:

- Manufacturing inputs including energy and water were allocated by mass of production at each facility. Waste records were not provided however, A.C. Miller associates provided an estimated 0.5% waste per unit of production.
- The inclusion of overhead energy and water data was determined appropriate due to the inability to sub-meter and isolate manufacturing energy from overhead energy.
- The use and selection of secondary datasets from GaBi – The selection of which generic dataset to use to represent an aspect of a supply chain is a significant value choice. Collaboration between LCA practitioner, A.C. Miller associates and GaBi data experts was valuable in determining best-case scenarios in the selection of data. However, no generic data can be a perfect fit. Improved supply chain specific data would improve the accuracy of results, however budgetary and time constraints have to be taken into account.
- Average transportation distances between the manufacturing facilities and customers (A4) were given based on sales records.

Some limitations to the study have been identified as follows:

- Only facility-level data was provided for manufacturing processes. Sub-metering of manufacturing lines would allow for more accurate manufacturing impacts to be modeled.
- Only known and quantifiable environmental impacts are considered.
- Due to the assumptions and value choices listed above, these do not reflect real-life scenarios and hence they cannot assess actual and exact impacts, but only potential environmental impacts.

6.5 CONCLUSION

Overall, Global Warming (GWP) is the impact category of most significance. In addition to A1-A3 impacts, there are also significant GWP impacts in the C4 phase of the life cycle of the product, which includes end-of-life disposal. The raw material sourcing and manufacturing process (A1-A3) and end of life disposal (C4) are the largest contributors primarily due to the selection of raw materials used and disposal of the product.

In order to reduce the environmental impacts of the concrete's life cycle, A.C. Miller should consider reducing the amount of these materials utilized in the product or replace these substances with less carbon intensive materials.

7 REFERENCES

1. ISO 14044: 2006 Environmental Management – Life cycle assessment – Requirements and Guidelines.
2. ISO 14044: 2006/ Amd 1:2017 Environmental Management – Life cycle assessment – Requirements and Guidelines – Amendment 1.
3. ISO 14025:2006 Environmental labels and declarations – Type III environmental declarations – Principles and Procedures.
4. ISO 21930:2017 Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services.
5. European Standard DIN EN 15804: 2012.04+A1 2013. Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products (includes Amendment A1:2013)
6. CML-IA Characterization Factors. 5 September 2016. https://www.universiteitleiden.nl/en/research/research-output/science/cml-ia-characterisation-factors
7. TRACI: The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts. Version 2.1 – User Guide - https://nepis.epa.gov/Adobe/PDF/P100HN53.pdf.
8. ASTM International Precast Concrete (UN CPC 3755)

APPENDIX A SECONDARY DATASETS

Dataset	Source	Year of Last Update	Geographical Coverage	Technological Coverage	Overall Representatives	Relevant Module	Description
Concrete reinforcing steel (rebar), Commercial Metals Company (A1-A3)	Sphera -EPD	2015	US	Appropriate Technology	Excellent	A1	Component in raw material
Reinforced steel (wire) (EN15804 A1-A3)	Sphera	2020	EU-28	Appropriate Technology	Great, appropriate technology and current but a European dataset was used as a proxy for US data	A1	Component in raw material
Fly ash (EN15804 A1-A3)	Sphera	2020	DE	Appropriate Technology	Great, appropriate technology and current but a European dataset was used as a proxy for US data	A1	Component in raw material
Limestone, gravel (grain size 16/32) (EN15804 A1-A3)	Sphera	2020	EU-28	Appropriate Technology	Great, appropriate technology and current but a European dataset was used as a proxy for US data	A1	Component in raw material aggregate
Cement (CEM II 42.5) (economically allocated binders)	Sphera	2020	EU-28	Appropriate Technology	Great, appropriate technology and current but a European dataset was used as a proxy for US data	A1	Component in raw material
Calcium ammonium nitrate (CAN, solution)	Sphera	2020	US	Proxy for tetramethyl-olacethylenediurea	Great, appropriate region and time coverage but no direct match for technology was available	A1	Component in raw material
Polyester Resin (unsaturated) (UP)	Sphera	2020	US	Proxy for Rosin, malleated	Great, appropriate region and time coverage but no direct match for technology was available	A1	Component in raw material
Silica sand (Excavation and processing)	Sphera	2020	US	Appropriate Technology	Excellent	A1	Component in raw material aggregate

Dataset	Source	Year of Last Update	Geographical Coverage	Technological Coverage	Overall Representatives	Relevant Module	Description
Process water from surface water	Sphera	2020	US	Appropriate Technology	Excellent	A1	Component in raw material
Formaldehyde (HCHO; 100%)	Sphera	2020	US	Proxy for tetramethyl-olacethylenediurea	Great, appropriate region and time coverage but no direct match for technology was available	A1	Component in raw material
Diethanolamine (DEA)	Sphera	2020	US	Appropriate Technology	Excellent	A1	Component in raw material
Methyl t-Butylether (MTBE) from C4	Sphera	2020	US	Proxy for methyl pentane	Great, appropriate region and time coverage but no direct match for technology was available	A1	Component in raw material
Hydrogen cyanide (prussic acid)	Sphera	2020	US	Proxy for sodium thiocyanate	Great, appropriate region and time coverage but no direct match for technology was available	A1	Component in raw material
Sodium chlorate (from sodium chloride)	Sphera	2020	US	Proxy for cyanate salt in X Seed	Great, appropriate region and time coverage but no direct match for technology was available	A1	Component in raw material
Truck - Flatbed, platform, etc. / 34,000 lb payload - 8a	Sphera	2020	US	Appropriate Technology	Excellent	A2	Transport to manufacturing plant
Truck - Trailer, basic enclosed / 45,000 lb payload - 8b	Sphera	2020	US	Appropriate Technology	Excellent	A2	Transport to manufacturing plant
Truck - Dump Truck / 52,000 lb payload - 8b	Sphera	2020	US	Appropriate Technology	Excellent	A2	Transport to manufacturing plant
Diesel mix at filling station	Sphera	2017	US	Appropriate Technology	Excellent	A2, A4, A5, C2	Fuel for transportation and installation

Dataset	Source	Year of Last Update	Geographical Coverage	Technological Coverage	Overall Representatives	Relevant Module	Description
Truck - Heavy Heavy-duty Diesel Truck / 53,333 lb payload - 8b	Sphera	2020	US	Appropriate Technology	Excellent	A2, C2	Transport to manufacturing plant and disposal
Thermal energy from kerosene	Sphera	2017	US	Appropriate Technology	Excellent	A3	Energy for manufacturing
Thermal energy from natural gas	Sphera	2017	US	Appropriate Technology	Excellent	A3	Energy for manufacturing
Electricity grid mix – RFCE	Sphera	2018	US	Appropriate Technology	Excellent	A3	Energy for manufacturing
Tap water from surface water	Sphera	2020	US	Appropriate Technology	Excellent	A3	Manufacturing input
Truck - Flatbed, platform, etc. / 49,000 lb payload - 8b	Sphera	2020	US	Appropriate Technology	Excellent	A4	Transport to customer
Glass/inert on landfill	Sphera	2020	US	Appropriate Technology	Excellent	C4	Product Waste

APPENDIX B VERIFICATION DOCUMENTS