

Environmental Product Declaration



CRMCA Member Industry-Wide EPD for Canadian **READY-MIXED CONCRETE**



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Declared Product:	This Environmental Product Declaration (EPD) covers concrete mixes produced by CRMCA members.	
Declaration Owner:	Canadian Ready Mixed Concrete Association 365 Brunel Road, Unit #3 Mississauga, Ontario L4Z 1Z5 (905) 507-1122 www.crmca.ca	
Program Operator:	NSF International 789 N. Dixboro Ann Arbor, MI 48105 www.nsf.org	
LCA and EPD Developer:	Athena Sustainable Materials Institute 119 Ross Ave. #100 Ottawa, ON K1Y 0N6 613-729-9996 www.athenasmi.org	
Product Category Rule:	The Carbon Leadership Forum PCR: Product Category Rules (PCR) for ISO 14025 Type III Environmental Product Declarations (EPDs) for Concrete Version 1.1 dated December 4, 2013, Serves as the PCR for this EPD. www.carbonleadershipforum.org .	
	PCR review was conducted by: Nicholas Santero, PE International; Holly Lahd, EL Analytics and Medgar Marceau, Morrison Hershfield; December 4, 2013	
Independent LCA Reviewer and EPD Verifier:	This EPD was independently verified by NSF International in accordance with ISO 14025 and ISO 21930. The life cycle assessment was independently reviewed in accordance ISO 14044 and the referenced PCR. Independent verification of the declaration, according to ISO 14025: 2006 <input type="checkbox"/> Internal <input checked="" type="checkbox"/> External	
		Third Party Verifier Paula Bernstein, PRe Phone: 202-460-0280
Date of Issue:	January 6, 2017	
Period of Validity:	5 Years – Valid until January 6, 2022	
EPD Number	EPD10092	



Description of Organization

The Canadian Ready Mixed Concrete Association (CRMCA) is a non-profit association established in 1981 to represent federally legislated issues impacting the ready mixed concrete industry. CRMCA is an association whose membership comprises each of Canada's provincial/regional ready mixed concrete associations and national cement industry. They are:

Atlantic Concrete Association (ACA)

Telephone (902) 443-4456
Fax (902) 404-8074
Email info@atlanticconcrete.ca
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Association béton Québec (ABQ)

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Concrete Ontario

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Concrete Manitoba

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Concrete Saskatchewan

Telephone (306) 757-2788
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Concrete Alberta

Telephone (780) 436-5645
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BC Ready-Mixed Concrete Association (BCRMCA)

Telephone (604) 626-4141
Fax (604) 626-4143
Email ckelly@bcrmca.ca
Web Site www.bcrmca.ca

Cement Association of Canada

Telephone (613) 236-9471
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Email info@cement.ca
Web Site www.cement.ca

Description of Product

Products covered by this EPD satisfy general purpose concrete as used in residential, commercial and public works applications in Canada. This EPD reports the impacts for different ready-mixed concrete products (listed in Table 1 on the following page) in accordance with the following:

- CSA A23.1-14 Concrete materials and methods of concrete construction/Test methods and standard practices for concrete
- ACI 211: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
- ACI 318: Building Code Requirements for Structural Concrete
- ASTM C94: Standard Specification for Ready-Mixed Concrete
- CSI MasterFormat Division 03-30-00: Cast-in-Place Concrete
- UNSPSC Code 30111500: Ready Mix Concrete

The modeled concrete mixes included benchmarks for each strength class. These are highlighted in blue in Table 1. CRMCA members may use Table 1 to claim compliance with this EPD. A list of members can be found on each provincial/regional association's website.



How to Use Table 1

Most proposed ready mixed concrete products for a project will likely not match up exactly with the specified compressive strength and mix design proportions listed in this EPD. One can use Table 1 to classify a proposed product to match one of the products listed in the EPD as follows:

Step 1: Identify the 28-day specified compressive strength of the proposed product by type of cement (GU or GUL), the percentage of fly ash and/or slag cement (e.g., $100 \times \text{fly ash quantity} / \text{total cementitious materials quantity}$) and whether it is or isn't an air entrained product.

Step 2: In Table 1 identify the specified compressive strength range that captures the proposed products compressive strength (Column 2 – header label) and whether it is or isn't air entrained (see last column "Air Ent (Y/N)").

Step 3: Then identify the supplementary cementing material (SCM) percentage that matches the proposed products SCM percentage by type (fly ash % or slag cement %) within that specified compressive strength range and whether it is or isn't air entrained. For mixes containing silica fume match the proposed product to the appropriate slag cement percentage. For ternary mixes (mixtures containing GU or GUL cements, fly ash, slag cement and/or silica fume) between 15% and 35% SCM (fly ash plus slag cement) combine the percentage of each SCM and use that value to select the SCM range to use. For example, if the proposed ternary mix design has 15% fly ash and 25% slag cement (total SCM=40%), use the 35% slag mix design to conservatively identify the appropriate mix design.

Step 4: In that row, move to column 1 (Mix #) to identify the product that can be used to look up the life cycle impacts listed in Tables 6 to 13 per m^3 of product. Reference this EPD and the appropriate Mix # and mix description in any compliance statement/literature (e.g., weigh bill) accompanying the product.

Illustrative example 1 – for a proposed 24 MPa air entrained mix design employing GU cement and incorporating 22% fly ash, the appropriate mix to select for compliance purposes is Mix #4-25 GU with air 15-29% FA.

Illustrative example 2 – for a proposed 24 MPa non-air entrained mix design employing GUL cement and incorporating 30% slag cement, the appropriate mix to select for compliance purposes is Mix #15-25 GUL without air 25-34% SC.

All mix designs highlighted in blue for any compressive strength class range is solely provided for purposes of industry benchmarking and incorporates GU cement and 10% SCM use. Note: All LCIA results are calculated at the upper bound of each strength class range and the lower indicated SCM percent range to be conservative.



Table 1: Declared Product Range Classification

Mix #	Mix Designs: 0-25 MPa	Comp Strength (MPa)	Fly Ash %	Slag Cement %	Air Entrained (Y/N)
1	25 GU with air 0-14% FA/SC	25	0	0	Y
2	25 GU without air 0-14% FA/SC	25	0	0	N
3	25 Industry Average Benchmark	25	4	6	Y
4	25 GU with air 15-29% FA	25	15	0	Y
5	25 GUL with air 15-29% FA	25	15	0	Y
6	25 GU without air 15-29% FA	25	15	0	N
7	25 GUL without air 15-29% FA	25	15	0	N
8	25 GU with air 30-40% FA	25	30	0	Y
9	25 GUL with air 30-40% FA	25	30	0	Y
10	25 GU without air 30-40% FA	25	30	0	N
11	25 GUL without air 30-40% FA	25	30	0	N
12	25 GU with air 25-34% SC	25	0	25	Y
13	25 GUL with air 25-34% SC	25	0	25	Y
14	25 GU without air 25-34% SC	25	0	25	N
15	25 GUL without air 25-34% SC	25	0	25	N
16	25 GU with air 35-50% SC	25	0	35	Y
17	25 GUL with air 35-50% SC	25	0	35	Y
18	25 GU without air 35-50% SC	25	0	35	N
19	25 GUL without air 35-50% SC	25	0	35	N
Mix #	Mix Designs: 26-30 MPa	Comp Strength (MPa)	Fly Ash %	Slag Cement %	Air Entrained (Y/N)
20	30 GU with air 0-14% FA/SC	30	0	0	Y
21	30 GU without air 0-14% FA/SC	30	0	0	N
22	30 Industry Average Benchmark	30	4	6	Y
23	30 GU with air 15-29% FA	30	15	0	Y
24	30 GUL with air 15-29% FA	30	15	0	Y
25	30 GU without air 15-29% FA	30	15	0	N
26	30 GUL without air 15-29% FA	30	15	0	N
27	30 GU with air 30-40% FA	30	30	0	Y
28	30 GUL with air 30-40% FA	30	30	0	Y
29	30 GU without air 30-40% FA	30	30	0	N
30	30 GUL without air 30-40% FA	30	30	0	N
31	30 GU with air 25-34% SC	30	0	25	Y
32	30 GUL with air 25-34% SC	30	0	25	Y
33	30 GU without air 25-34% SC	30	0	25	N
34	30 GUL without air 25-34% SC	30	0	25	N
35	30 GU with air 35-50% SC	30	0	35	Y
36	30 GUL with air 35-50% SC	30	0	35	Y
37	30 GU without air 35-50% SC	30	0	35	N
38	30 GUL without air 35-50% SC	30	0	35	N



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Table 1 Continued: Declared Product Range Classification

Mix #	Mix Designs: 31-35 MPa	Comp Strength (MPa)	Fly Ash %	Slag Cement %	Air Entrained (Y/N)
39	35 GU with air 0-14% FA/SC	35	0	0	Y
40	35 GU without air 0-14% FA/SC	35	0	0	N
41	35 Industry Average Benchmark	35	4	6	Y
42	35 GU with air 15-29% FA	35	15	0	Y
43	35 GUL with air 15-29% FA	35	15	0	Y
44	35 GU without air 15-29% FA	35	15	0	N
45	35 GUL without air 15-29% FA	35	15	0	N
46	35 GU with air 30-40% FA	35	30	0	Y
47	35 GUL with air 30-40% FA	35	30	0	Y
48	35 GU without air 30-40% FA	35	30	0	N
49	35 GUL without air 30-40% FA	35	30	0	N
50	35 GU with air 25-34% SC	35	0	25	Y
51	35 GUL with air 25-34% SC	35	0	25	Y
52	35 GU without air 25-34% SC	35	0	25	N
53	35 GUL without air 25-34% SC	35	0	25	N
54	35 GU with air 35-50% SC	35	0	35	Y
55	35 GUL with air 35-50% SC	35	0	35	Y
56	35 GU without air 35-50% SC	35	0	35	N
57	35 GUL without air 35-50% SC	35	0	35	N
Mix #	Mix Designs: 36-40 MPa	Comp Strength (MPa)	Fly Ash %	Slag Cement %	Air Entrained (Y/N)
58	40 GU with air 0-14% FA/SC	40	0	0	Y
59	40 GU without air 0-14% FA/SC	40	0	0	N
60	40 Industry Average Benchmark	40	4	6	Y
61	40 GU with air 15-29% FA	40	15	0	Y
62	40 GUL with air 15-29% FA	40	15	0	Y
63	40 GU without air 15-29% FA	40	15	0	N
64	40 GUL without air 15-29% FA	40	15	0	N
65	40 GU with air 30-40% FA	40	30	0	Y
66	40 GUL with air 30-40% FA	40	30	0	Y
67	40 GU without air 30-40% FA	40	30	0	N
68	40 GUL without air 30-40% FA	40	30	0	N
69	40 GU with air 25-34% SC	40	0	25	Y
70	40 GUL with air 25-34% SC	40	0	25	Y
71	40 GU without air 25-34% SC	40	0	25	N
72	40 GUL without air 25-34% SC	40	0	25	N
73	40 GU with air 35-50% SC	40	0	35	Y
74	40 GUL with air 35-50% SC	40	0	35	Y
75	40 GU without air 35-50% SC	40	0	35	N
76	40 GUL without air 35-50% SC	40	0	35	N



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Table 1 Continued: Declared Product Range Classification

Mix #	Mix Designs: 41-45 MPa	Comp Strength (MPa)	Fly Ash %	Slag Cement %	Air Entrained (Y/N)
77	45 GU without air 0-14% FA/SC	45	0	0	N
78	45 Industry Average Benchmark	45	4	6	N
79	45 GU without air 15-29% FA	45	15	0	N
80	45 GUL without air 15-29% FA	45	15	0	N
81	45 GU without air 30-40% FA	45	30	0	N
82	45 GUL without air 30-40% FA	45	30	0	N
83	45 GU without air 25-34% SC	45	0	25	N
84	45 GUL without air 25-34% SC	45	0	25	N
85	45 GU without air 35-50% SC	45	0	35	N
86	45 GUL without air 35-50% SC	45	0	35	N
Mix #	Mix Designs: 46-50 MPa	Comp Strength (MPa)	Fly Ash %	Slag Cement %	Air Entrained (Y/N)
87	50 GU with air 0-14% FA/SC	50	0	0	Y
88	50 GU without air 0-14% FA/SC	50	0	0	N
89	50 Industry Average Benchmark	50	4	6	Y
90	50 GU with air 15-29% FA	50	15	0	Y
91	50 GUL with air 15-29% FA	50	15	0	Y
92	50 GU without air 15-29% FA	50	15	0	N
93	50 GUL without air 15-29% FA	50	15	0	N
94	50 GU with air 30-40% FA	50	30	0	Y
95	50 GUL with air 30-40% FA	50	30	0	Y
96	50 GU without air 30-40% FA	50	30	0	N
97	50 GUL without air 30-40% FA	50	30	0	N
98	50 GU with air 25-34% SC	50	0	25	Y
99	50 GUL with air 25-34% SC	50	0	25	Y
100	50 GU without air 25-34% SC	50	0	25	N
101	50 GUL without air 25-34% SC	50	0	25	N
102	50 GU with air 35-50% SC	50	0	35	Y
103	50 GUL with air 35-50% SC	50	0	35	Y
104	50 GU without air 35-50% SC	50	0	35	N
105	50 GUL without air 35-50% SC	50	0	35	N
#	Mix Designs: 51-55 MPa	Comp Strength (MPa)	Fly Ash %	Slag Cement %	Air Entrained (Y/N)
106	55 GU without air 0-14% FA/SC	55	0	0	N
107	55 Industry Average Benchmark	55	4	6	N
108	55 GU without air 15-29% FA	55	15	0	N
109	55 GUL without air 15-29% FA	55	15	0	N
110	55 GU without air 30-40% FA	55	30	0	N
111	55 GUL without air 30-40% FA	55	30	0	N
112	55 GU without air 25-34% SC	55	0	25	N
113	55 GUL without air 25-34% SC	55	0	25	N
114	55 GU without air 35-50% SC	55	0	35	N
115	55 GUL without air 35-50% SC	55	0	35	N



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Table 1 Continued: Declared Product Range Classification

Mix #	Mix Designs: 56-60 MPa	Comp Strength (MPa)	Fly Ash %	Slag Cement %	Air Entrained (Y/N)
116	60 GU without air 0-14% FA/SC	60	0	0	N
117	60 Industry Average Benchmark	60	4	6	N
118	60 GU without air 15-29% FA	60	15	0	N
119	60 GUL without air 15-29% FA	60	15	0	N
120	60 GU without air 30-40% FA	60	30	0	N
121	60 GUL without air 30-40% FA	60	30	0	N
122	60 GU without air 25-34% SC	60	0	25	N
123	60 GUL without air 25-34% SC	60	0	25	N
124	60 GU without air 35-50% SC	60	0	35	N
125	60 GUL without air 35-50% SC	60	0	35	N

This EPD is intended for use in Business to Business (B-to-B) communication. The scope of this EPD is cradle-to-gate and considers the following life cycle stages.

- **A1 - Raw Material Supply:** Includes all upstream processes related to extraction, handling, and processing of the raw materials and intermediate component products as well as fuels used in the production of concrete. Component products include cement, supplementary cementitious materials, aggregate (coarse and fine), water, admixtures and other materials or chemicals used in concrete mixtures.
- **A2 - Transportation:** Accounts for the transportation of all input materials and fuels from the supplier to the gate of the concrete plant.
- **A3 - Manufacturing (Core Processes):** Includes all core processes and the energy and water used to store, move, batch and mix the concrete and operate the concrete plant as well as the transportation and processing of wastes from these core processes.

As per CLF PCR 2013 clarification note #3, a portion of truck/transit fleet fuel use (A4) is captured in A3 to reflect and equate the mixing of concrete for these operations with that of central mix plants.

Methodology of Underlying LCA

Declared Unit

The declared unit is 1 cubic meter of ready mixed concrete product. Key product variables include:

- **28-day strength** – Eight different specified compressive strengths were considered: 25 MPa, 30 MPa, 35 MPa, 40 MPa, 45 MPa, 50 MPa, 55 MPa, 60 MPa;
- **Slag cement** – Varies between 0% and 35%;
- **Fly ash** – Varies between 0 and 30%;
- **Admixture use** – The use of air-entraining, water reducing, and high range water reducing admixture varies;
- **Aggregate use** – The use of crushed coarse, crushed fine, and natural fine aggregates varies.

Product (mix design) components include: Portland cement (GU), Portland limestone cement (GUL), slag cement, fly ash, natural and crushed aggregates, admixtures and batch water.



Scope of LCA

A summary of life cycle stages included in the EPD is as follows:

1. Raw Material Supply (upstream processes): Extraction, handling and processing of the raw materials used in the production of concrete: cement, supplementary cementitious materials, aggregate (coarse and fine), water, admixtures and other materials or chemicals used in concrete mixtures.
2. Transportation: Transportation of these materials from the supplier to the 'gate' of the concrete producer.
3. Manufacturing (core processes): The energy used to store, batch, mix and distribute the concrete and operate the facility (concrete plant)
4. Water use in mixing and distributing concrete.

A summary of life cycle stages excluded from the EPD is as follows:

1. Production, manufacture and construction of buildings capital goods and infrastructure
2. Production and manufacture of concrete production equipment, concrete delivery vehicles, earthmoving equipment, and laboratory equipment
3. Personnel---related activities (travel, furniture, office supplies).
4. Energy use related to company management and sales activities.

Building Life Cycle Information Modules																
Product stage			Construction Process stage		Use stage							End-of-life stage				
Raw Material supply	Transport	Manufacturing	Transport	Construction/Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	De-Construction/ Demolition	Transport	Waste processing	Disposal	
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	

Figure 1. Life cycle stage schematic – alpha-numeric designations as per CLF PCR 2013 - adapted from CEN 15978:2011



Cut-off Rules

The cut-off criteria for all activity stage flows considered within the system boundary conform with ISO 14044:2006 and section 3.3 of CLF PCR 2013. Specifically, the cut-off criteria were applied as follows:

- All inputs and outputs for which data are available are included in the calculated effects and no collected core process data are excluded.
- A one percent cut-off is considered for renewable and non-renewable primary energy consumption and the total mass of inputs within a unit process. The sum of the total neglected flows does not exceed 5% of all energy consumption and mass of inputs.
- All flows known to contribute a significant impact or to uncertainty (e.g., GU and GUL cements, admixtures) are included.
- The cut-off rules are not applied to hazardous and toxic materials – all are included in the life cycle inventory.

Allocation

The applied allocation procedures conform with ISO 14044:2006 clause 4.3.4.

Limitations

A summary of the limitations of this EPD include:

- This EPD does not report all environmental impacts due to manufacturing of the product, but rather reports the environmental impacts for those categories with established life-cycle assessment based methods to track and report. Unreported environmental impacts include (but are not limited to) factors attributable to human health, land use change, and habitat destruction.
- This EPD reports the results of an LCA or the "cradle-to-gate analysis. Thus, declarations themselves are not comparative assertions, defined as an environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function. An EPD does not make any statements that the product covered by the EPD is better or worse than any other product.
- In order to assess the local impacts of product manufacturing, additional analysis is required.
- Life Cycle Impact Assessment results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.
- This EPD was created using industry average data for upstream materials. Variation can result from differences in supplier locations, manufacturing processes, manufacturing efficiency and fuel type used.
- The EPD participants may participate in other sustainability or environmental best practice programs. However, no such additional environmental claim or declaration is conveyed in this EPD.
- EPDs of concrete mixtures may not be comparable if they do not comply with this standard and data from this EPD. The data cannot be used to compare between concrete mixes, construction products or concrete mixtures used in different concrete products unless the data is integrated into a comprehensive LCA. For example, precast concrete, concrete masonry units and site cast concrete all have different manufacturing processes whose impacts are attributed to different LCA stages. This precludes direct comparison between mixtures used in these different products unless all lifecycle phases are included.



Data Sources and Data Quality Assessment

This EPD is based on foreground LCI data collected from the participating companies' production facilities. All upstream material, resource and energy carrier inputs have been sourced from various industry-average datasets and literature. Many of these data sets are defaulted to those specified for use in CLF PCR 2013. Tables 2 to 4 describe each LCI data source for raw materials (A1), transportation by mode (A2), the core manufacture process (A3), and descriptions of data quality for each data source.

Table 2. A1 - Raw Material Supply

Materials	LCI Data Source	Geography	Year	Data Quality Assessment
General Use Cement (kg)	Cement Association of Canada EPD of General Use Cement, 2016	Canada	2016	<ul style="list-style-type: none"> • Technology: good Process models Canadian industry average Portland cement production • Time: good Data is within 2 years • Geography: very good • Completeness: good • Reliability: very good, third-party verified EPD
General Use Limestone Cement (kg)	Cement Association of Canada EPD of General Use Limestone Cement, 2016	Canada	2016	<ul style="list-style-type: none"> • Technology: good Process models Canadian industry average Portland cement production • Time: good Data is within 2 years • Geography: very good • Completeness: good • Reliability: very good, third-party verified EPD
Fly Ash (kg)	None, no incoming burden, only inbound transport was considered	N/A	N/A	<ul style="list-style-type: none"> • N/A • Recovered material
Slag Cement (kg)	Slag Cement Association N. America EPD Slag Cement, 2015	N. America	2013-2014	<ul style="list-style-type: none"> • Technology: good Process models ground granulated blast furnace slag • Time: good Data is within 3 years • Geography: good • Completeness: good • Reliability: very good, third-party verified EPD
Crushed Aggregates (kg) <i>coarse and fine</i>	ecoinvent process: "Gravel, crushed, at mine" ecoinvent 2.2 Modified with Canadian electricity	EU/Canada	2004	<p>*CLF PCR 2013 Default Data</p> <ul style="list-style-type: none"> • Technology: good Processes represent aggregate, with and without crushing. Dust emissions are estimated from limestone mining. • Time: fair Data is twelve years old but technology remains consistent across the industry • Geography: good Swiss production (modified with Canadian Electricity). • Completeness: very good • Reliability: very good Data is verified by ecoinvent.
Natural Aggregates (kg) <i>fine</i>	ecoinvent process: "Gravel, round, at mine", ecoinvent 2.2 Modified with Canadian electricity	EU/Canada	2004	
Admixtures (kg) High-range water reducing admixture (superplasticizer)	EFCA EcoProfile (325) CLF PCR Default	EU	2006	<p>*CLF PCR 2013 Default Data</p> <ul style="list-style-type: none"> • Technology: very good Processes represents admixture production for use in concrete • Time: fair Data is within eleven years • Geography: good • Completeness: good Data from a federation of European admixture producers • Reliability: good Profiles have undergone an independent review process. Compliance with ISO standards (unknown)



Table 3. A2 - Transportation

Process	LCI Data Source	Geography	Year	Data Quality Assessment
Rail, ocean freighter and barge (t*km)	USLCI - rail transport, diesel powered; ocean freighter, average fuel mix; barge, average fuel mix	USA	2008	<ul style="list-style-type: none"> • Technology: very good Processes represents U.S average transportation profiles • Time: fair Data is within ten years • Geography: good • Completeness: good (all data place holders filled) Data is representative of US conditions • Reliability: good Data is from USLCI database
Road (t*km)	USLCI 2014 – single unit truck transport, diesel powered, short haul US avg.;	USA	2014	<ul style="list-style-type: none"> • Technology: very good Processes represents U.S average transportation profiles • Time: very good Data is within two years • Geography: good (all data place holders filled) • Completeness: good (all data place holders filled) Data is representative of US conditions • Reliability: good Data is from USLCI database

Table 4. A3 - Manufacturing

Process	LCI Data Source	Geography	Year	Data Quality Assessment
Electricity (kWh)	CRMCA purchased electricity grid mix Electricity, medium voltage, at grid, (CA - ##) (ecoinvent v3.01)	US	2008/ 2015	<ul style="list-style-type: none"> • Technology: very good Process represents production of electricity in the appropriate Canadian electricity grid regions. An average CRMCA electricity grid was developed based on total purchased electricity by surveyed plants weighted by production in various provinces. Data includes line losses and conversion efficiencies. (See % contribution by region below) • Time: fair/good Electricity production data is within ten years. Regional production breakdown from 2015. • Geography: very good • Completeness: good (all data place holders filled) Data is representative of Canadian production • Reliability: good ecoinvent has verified the data
Natural Gas (m³)	USLCI, Natural gas, combusted in industrial boiler/US	US	2008	<ul style="list-style-type: none"> • Technology: very good Process represents combustion of natural gas in an industrial boiler. • Time: fair Data is within ten years • Geography: fair • Completeness: good (all data place holders filled) Data is representative of US conditions • Reliability: good Data is from USLCI database



Table 4. A3 - Manufacturing

Process	LCI Data Source	Geography	Year	Data Quality Assessment
Fuel Oil other than diesel (l)	US LCI: Residual fuel oil, combusted in industrial boiler/US	US	2008	<ul style="list-style-type: none"> Technology: very good Process represents combustion of RFO in an industrial boiler. Time: fair Data is within ten years Geography: fair Completeness: good (all data place holders filled) Data is representative of US conditions Reliability: good Data is from USLCI database
Diesel (l)	US LCI: Diesel, combusted in industrial equipment/US	US	2008	<ul style="list-style-type: none"> Technology: very good Process represents combustion of diesel in industrial equipment. Time: fair Data is within ten years Geography: fair Completeness: good (all data place holders filled) Data is representative of US conditions Reliability: good Data is from USLCI database
Liquefied Propane Gas (l)	US LCI: Liquefied petroleum gas, combusted in industrial boiler/US	US	2008	<ul style="list-style-type: none"> Technology: very good Process represents combustion of LPG in industrial boiler. Time: fair Data is within ten years Geography: fair Completeness: good (all data place holders filled) Data is representative of US conditions Reliability: good Data is from USLCI database
Secondary Fuels, Liquid (waste solvents, etc.), (kg)	ecoinvent 3.1, 2014 - Spent solvent mixture {US} treatment of, hazardous waste incineration Alloc Def, U -Combustion emissions are only included	EU	2008	<ul style="list-style-type: none"> Technology: good combustion emissions only Time: fair Data is within ten years. Geography: fair Processes model Swiss production (no US process in USLCI database). Completeness: very good Reliability: very good Data is verified by Ecoinvent.
Secondary Fuels, Solid (tires, etc.), (kg)	ecoinvent 3.01: Waste rubber, unspecified {US} treatment of, municipal incineration Alloc Def, U	EU	2008	<ul style="list-style-type: none"> Technology: good combustion emissions only Time: fair Data is within ten years. Geography: fair Processes model Swiss production (no US process in USLCI database). Completeness: very good Reliability: very good Data is verified by Ecoinvent.



Table 4. A3 - Manufacturing

Process	LCI Data Source	Geography	Year	Data Quality Assessment
Hazardous Solid Waste, (kg)	ecoinvent 3.1, 2014 - Hazardous waste, for incineration {US} treatment of hazardous waste, hazardous waste incineration Alloc Def, U	EU	2008	<ul style="list-style-type: none"> • Technology: good • Time: fair Data is within ten years. • Geography: fair Processes model Swiss production (no US process in USLCI database). • Completeness: very good • Reliability: very good Data is verified by Ecoinvent.
Non-Hazardous Solid Waste, (kg)	ecoinvent 3.1, 2014 - Waste concrete {US} treatment of, inert material landfill Alloc Def, U	EU	2008	<ul style="list-style-type: none"> • Technology: good • Time: fair Data is within ten years. • Geography: fair Processes model Swiss production (no US process in USLCI database). • Completeness: very good • Reliability: very good Data is verified by Ecoinvent.
Canadian Purchased Electricity source grid mix (as modeled)			% of grid included in Canadian average mix	
Electricity, medium voltage {CA-AB} market for Alloc Def, U			24.66%	
Electricity, medium voltage {CA-BC} market for Alloc Def, U			12.44%	
Electricity, medium voltage {CA-MB} market for Alloc Def, U			2.59%	
Electricity, medium voltage {CA-NB} market for Alloc Def, U			1.23%	
Electricity, medium voltage {CA-NF} market for Alloc Def, U			0.25%	
Electricity, medium voltage {CA-NS} market for Alloc Def, U			1.45%	
Electricity, medium voltage {CA-ON} market for Alloc Def, U			40.28%	
Electricity, medium voltage {CA-PE} market for Alloc Def, U			0.15%	
Electricity, medium voltage {CA-QC} market for Alloc Def, U			15.08%	
Electricity, medium voltage {CA-SK} market for Alloc Def, U			1.87%	
Total			100.00%	



Data Quality

Data quality/variability requirements, as specified in the CLF PCR 2013 sections 3.5 and 3.6, are applied. This section describes the achieved data quality relative to the ISO 14044:2006 requirements. Data quality is judged based on 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: Through measurement and calculation, the manufacturers collected and provided primary data on their annual production. For accuracy, the LCA team validated the plant gate-to-gate data.

Completeness: All relevant specific processes, including inputs (raw materials, energy and ancillary materials) and outputs (emissions and production volume) were considered and modeled to represent the specified and declared products. The relevant background materials and processes were taken from ecoinvent v 2.2 and v3.0 LCI databases and were modified with Canadian-specific electricity inputs before they were modeled in SimaPro software v.8.0.1, 2014.

Consistency: To ensure consistency, the LCI modeling of the production weighted input and output LCI data for the declared products used the same modeling structure across the respective product systems, which consisted of input raw and ancillary material, energy flows, water resource inputs, product and co-products outputs, returned and recovered concrete materials, emissions to air, water and soil, and waste recycling and treatment. The same background LCI datasets from the SimaPro LCI database were used across all product systems. Crosschecks concerning the plausibility of mass and energy flows were continuously conducted. The LCA team conducted mass and energy balances at the plant and selected process level to maintain a high level of consistency.

Reproducibility: Internal reproducibility is possible since the data and the models are stored and available in a SimaPro project file for all background processes, and in Athena's proprietary concrete LCA calculator* for all production facility and mix-specific calculations. A considerable level of transparency is provided throughout the LCA report as the specifications and material quantity make-up for the declared products are presented and key primary and secondary LCI data sources are summarized. The provision of more detailed data to allow full external reproducibility was not possible due to reasons of confidentiality. * *Athena has developed a proprietary tool that allows the calculation of PCR-compliant LCA results for ready-mixed concrete product mix designs. The tool scales results for base-unit technosphere inputs (i.e. 1 kg portland cement, 1 kWh electricity, etc.) to replicate the reference flow conversions that take place in SimaPro. The tool was tested against the NRMCA average LCA results (Athena SMI, 2014) that were developed exclusively in SimaPro and generated results within 1% in every impact category and inventory metric.*

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

- Time related coverage of the manufacturing processes' primary collected data: 2015 (12 months).
- Upstream (background) LCI data was either the CLF PCR 2013 specified default or more appropriate LCI datasets as found in the Canadian-adjusted ecoinvent v.2.2 and v.3.0 database, 2014.
- Geographical coverage for the cement and concrete plant operations is Canada; other upstream and background processes are based on US, North American, or global average data.
- Technological coverage is typical or average – specific to the participating facilities for all primary data.



Life Cycle Assessment Results

Environmental Indicators and Inventory Metrics

Per the CLF PCR 2013, this EPD supports 15 life cycle impact assessment indicators and inventory metrics as listed in Table 5. Table 6 reports the LCA results for each product produced at participating plants. As specified in the CLF PCR 2013, Section 8., the US EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI), version 2.1, 2012 impact categories shall be used as they provide a North American context for the mandatory category indicators to be included in the EPD. Additionally, the CLF PCR 2013 requires a set of inventory metrics to be reported with the LCIA indicators (see Table 5).

Table 5. Life Cycle Category Indicators and Inventory Metrics

#	LCIA Indicators	Abbreviations	Units
1	Global Warming Potential (climate change)	GWP	kg CO2-eq
2	Ozone Depletion Potential	ODP	kg CFC-11-eq
3	Acidification Potential	AP	kg SO2-eq
4	Eutrophication Potential	EP	kg N-eq
5	Photochemical Ozone Creation/Smog Potential	POCP	kg O3-eq
Inventory Metrics			
6	Total primary energy consumption	PEC	MJ (HHV)
7	Depletion of non-renewable energy resources	NRE	MJ (HHV)
8	Use of renewable primary energy	RE	MJ (HHV)
9	Depletion of non-renewable material resources	NRM	kg
10	Use of renewable material resources	RM	kg
11	Concrete batching water consumption	CBW	m3
12	Concrete washing water consumption	CWW	m3
13	Total water consumption	TW	m3
14	Concrete hazardous waste	CHW	kg
15	Concrete non-hazardous waste	CNHW	kg

*HHV, higher heating value (also called gross calorific value) is the heat of combustion of a given amount of fuel that includes the calorific value of condensing the water content of the fuel (the heat of vaporization). The lower heating value (LHV) excludes the heat of vaporization of the water content and thus the HHV is equal to the LHV plus the heat of vaporization.



Impact Assessment Results

Tables 6-13 show results per cubic meter of ready mixed concrete. The benchmark mixes for each strength class are highlighted in blue. This EPD was created using industry-average data for upstream materials. Variations can result from differences in supplier locations, manufacturing processes, manufacturing efficiency and fuel type used.

Table 6. Summary Results (A1-A3): 0-25 MPa ready mixed concrete product, per cubic meter

Indicator/LCI Metric Unit (equivalent)	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	214.41	3.19E-06	1.03	0.11	18.68	2161.11	1982.19	165.21	2279.41	5.12	0.16	0.14	0.87	0.85	8.89
Maximum	327.33	4.88E-06	1.45	0.15	26.46	2823.85	2582.06	241.79	2527.16	7.68	0.16	0.14	1.08	0.88	8.99
#1-25 GU with air 0-14% FA/SC	327.33	4.16E-06	1.45	0.15	26.46	2823.85	2582.06	241.79	2463.80	7.68	0.16	0.14	1.08	0.86	8.99
#2-25 GU without air 0-14% FA/SC	313.45	4.03E-06	1.39	0.14	25.57	2727.29	2496.32	230.97	2527.16	7.30	0.16	0.14	1.06	0.86	8.98
#3-25 Industry Average Benchmark	304.52	4.19E-06	1.38	0.14	25.15	2678.60	2454.90	223.70	2414.43	7.06	0.16	0.14	1.03	0.86	8.97
#4-25 GU with air 15-29% FA	295.20	3.82E-06	1.32	0.13	24.27	2587.19	2370.43	216.76	2391.48	6.82	0.16	0.14	1.01	0.86	8.96
#5-25 GUL with air 15-29% FA	266.72	3.61E-06	1.18	0.12	21.10	2464.10	2250.69	213.41	2380.01	6.87	0.16	0.14	0.98	0.86	8.96
#6-25 GU without air 15-29% FA	283.03	3.70E-06	1.27	0.13	23.49	2503.26	2295.99	207.27	2459.05	6.49	0.16	0.14	1.00	0.86	8.95
#7-25 GUL without air 15-29% FA	256.05	3.51E-06	1.14	0.12	20.49	2386.61	2182.52	204.09	2447.82	6.54	0.16	0.14	0.97	0.86	8.95
#8-25 GU with air 30-40% FA	260.47	3.45E-06	1.18	0.12	21.90	2331.35	2141.65	189.70	2313.30	5.90	0.16	0.14	0.95	0.86	8.93
#9-25 GUL with air 30-40% FA	236.07	3.27E-06	1.06	0.11	19.19	2225.97	2039.14	186.83	2303.95	5.94	0.16	0.14	0.92	0.86	8.93
#10-25 GU without air 30-40% FA	250.14	3.36E-06	1.14	0.11	21.25	2261.07	2079.43	181.64	2385.41	5.61	0.16	0.14	0.94	0.85	8.91
#11-25 GUL without air 30-40% FA	227.03	3.19E-06	1.03	0.11	18.68	2161.11	1982.19	178.92	2375.79	5.65	0.16	0.14	0.91	0.85	8.91
#12-25 GU with air 25-34% SC	267.59	4.67E-06	1.32	0.14	23.41	2477.80	2283.85	193.95	2337.50	6.03	0.16	0.14	0.95	0.88	8.92
#13-25 GUL with air 25-34% SC	243.41	4.50E-06	1.20	0.13	20.72	2373.36	2182.26	191.11	2328.25	6.08	0.16	0.14	0.92	0.88	8.92
#14-25 GU without air 25-34% SC	256.89	4.51E-06	1.27	0.13	22.68	2399.76	2214.09	185.67	2408.34	5.74	0.16	0.14	0.94	0.88	8.91
#15-25 GUL without air 25-34% SC	233.98	4.35E-06	1.16	0.12	20.13	2300.69	2117.72	182.97	2398.80	5.78	0.16	0.14	0.91	0.88	8.91
#16-25 GU with air 35-50% SC	243.70	4.88E-06	1.26	0.13	22.18	2339.38	2164.56	174.81	2286.98	5.38	0.16	0.14	0.90	0.88	8.90
#17-25 GUL with air 35-50% SC	222.75	4.72E-06	1.16	0.13	19.86	2248.97	2076.61	172.35	2279.41	5.41	0.16	0.14	0.87	0.88	8.90
#18-25 GU without air 35-50% SC	234.27	4.71E-06	1.22	0.13	21.52	2268.74	2101.20	167.55	2360.81	5.12	0.16	0.14	0.89	0.88	8.89
#19-25 GUL without air 35-50% SC	214.41	4.56E-06	1.12	0.12	19.31	2182.89	2017.67	165.21	2352.55	5.15	0.16	0.14	0.87	0.88	8.89



Table 7. Summary Results (A1-A3): 26-30 MPa ready mixed concrete product, per cubic meter

Indicator/LCI Metric Unit (equivalent)	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	233.82	3.40E-06	1.11	0.12	20.12	2331.12	2135.17	180.68	2270.51	5.66	0.16	0.14	0.91	0.86	8.91
Maximum	376.48	5.49E-06	1.65	0.17	29.99	3191.90	2913.08	278.82	2554.94	8.95	0.16	0.14	1.17	0.89	9.04
#20-30 GU with air 0-14% FA/SC	376.48	4.65E-06	1.65	0.17	29.99	3191.90	2913.08	278.82	2487.15	8.95	0.16	0.14	1.17	0.87	9.04
#21-30 GU without air 0-14% FA/SC	344.12	4.33E-06	1.52	0.15	27.80	2961.66	2707.75	253.91	2554.94	8.08	0.16	0.14	1.12	0.86	9.01
#22-30 Industry Average Benchmark	349.68	4.69E-06	1.57	0.16	28.45	3021.25	2763.68	257.57	2429.15	8.22	0.16	0.14	1.12	0.87	9.01
#23-30 GU with air 15-29% FA	338.73	4.25E-06	1.50	0.15	27.42	2913.85	2664.44	249.41	2402.19	7.95	0.16	0.14	1.10	0.86	9.00
#24-30 GUL with air 15-29% FA	305.27	4.01E-06	1.33	0.14	23.69	2769.23	2523.75	245.48	2388.71	8.01	0.16	0.14	1.06	0.86	9.00
#25-30 GU without air 15-29% FA	310.24	3.97E-06	1.38	0.14	25.49	2712.17	2484.65	227.52	2479.08	7.18	0.16	0.14	1.06	0.86	8.97
#26-30 GUL without air 15-29% FA	280.19	3.76E-06	1.24	0.13	22.14	2582.26	2358.28	223.98	2466.58	7.24	0.16	0.14	1.02	0.86	8.97
#27-30 GU with air 30-40% FA	297.92	3.82E-06	1.33	0.13	24.63	2613.26	2395.64	217.62	2310.34	6.86	0.16	0.14	1.02	0.86	8.96
#28-30 GUL with air 30-40% FA	269.25	3.61E-06	1.19	0.13	21.44	2489.45	2275.20	214.25	2299.34	6.91	0.16	0.14	0.99	0.86	8.96
#29-30 GU without air 30-40% FA	273.61	3.59E-06	1.24	0.12	22.99	2442.45	2243.47	198.98	2397.08	6.21	0.16	0.14	0.98	0.86	8.94
#30-30 GUL without air 30-40% FA	247.87	3.40E-06	1.11	0.12	20.12	2331.12	2135.17	195.95	2386.36	6.25	0.16	0.14	0.96	0.86	8.94
#31-30 GU with air 25-34% SC	306.29	5.25E-06	1.49	0.16	26.40	2785.32	2562.71	222.62	2338.76	7.02	0.16	0.14	1.02	0.88	8.96
#32-30 GUL with air 25-34% SC	277.88	5.04E-06	1.36	0.15	23.24	2662.62	2443.35	219.28	2327.90	7.07	0.16	0.14	0.99	0.88	8.96
#33-30 GU without air 25-34% SC	281.13	4.87E-06	1.38	0.14	24.58	2596.90	2393.43	203.46	2422.61	6.35	0.16	0.14	0.98	0.88	8.94
#34-30 GUL without air 25-34% SC	255.62	4.69E-06	1.26	0.14	21.74	2486.57	2286.11	200.46	2411.99	6.40	0.16	0.14	0.96	0.88	8.94
#35-30 GU with air 35-50% SC	278.22	5.49E-06	1.43	0.15	24.96	2622.69	2422.56	200.13	2279.40	6.25	0.16	0.14	0.96	0.89	8.93
#36-30 GUL with air 35-50% SC	253.61	5.31E-06	1.31	0.14	22.23	2516.47	2319.22	197.24	2270.51	6.29	0.16	0.14	0.93	0.89	8.93
#37-30 GU without air 35-50% SC	255.94	5.09E-06	1.33	0.14	23.29	2450.99	2267.71	183.28	2369.68	5.66	0.16	0.14	0.93	0.89	8.91
#38-30 GUL without air 35-50% SC	233.82	4.93E-06	1.22	0.13	20.83	2355.37	2174.69	180.68	2360.48	5.70	0.16	0.14	0.91	0.89	8.91



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Table 8. Summary Results (A1-A3): 31-35 MPa ready mixed concrete product, per cubic meter

Indicator/LCI Metric Unit (equivalent)	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	260.49	3.69E-06	1.23	0.13	22.07	2558.11	2338.42	202.24	2244.44	6.41	0.16	0.14	0.95	0.86	8.94
Maximum	449.79	6.40E-06	1.95	0.20	35.25	3745.89	3412.16	333.73	2576.75	10.84	0.16	0.14	1.30	0.90	9.12
#39-35 GU with air 0-14% FA/SC	449.79	5.37E-06	1.95	0.20	35.25	3745.89	3412.16	333.73	2509.04	10.84	0.16	0.14	1.30	0.87	9.12
#40-35 GU without air 0-14% FA/SC	386.61	4.76E-06	1.69	0.17	30.85	3279.16	2993.18	285.98	2576.75	9.18	0.16	0.14	1.20	0.87	9.05
#41-35 Industry Average Benchmark	417.05	5.42E-06	1.85	0.19	33.37	3537.46	3229.68	307.77	2438.20	9.95	0.16	0.14	1.24	0.88	9.08
#42-35 GU with air 15-29% FA	403.68	4.88E-06	1.76	0.18	32.11	3406.28	3108.47	297.81	2405.27	9.61	0.16	0.14	1.21	0.87	9.07
#43-35 GUL with air 15-29% FA	362.81	4.59E-06	1.57	0.17	27.56	3229.64	2936.63	293.00	2388.81	9.69	0.16	0.14	1.17	0.87	9.07
#44-35 GU without air 15-29% FA	347.87	4.35E-06	1.54	0.16	28.20	2993.85	2738.06	255.79	2490.00	8.15	0.16	0.14	1.12	0.86	9.01
#45-35 GUL without air 15-29% FA	313.52	4.10E-06	1.37	0.14	24.38	2845.30	2593.54	251.75	2475.70	8.22	0.16	0.14	1.08	0.86	9.01
#46-35 GU with air 30-40% FA	353.84	4.36E-06	1.56	0.16	28.71	3039.14	2780.16	258.98	2293.08	8.29	0.16	0.14	1.12	0.86	9.02
#47-35 GUL with air 30-40% FA	318.82	4.10E-06	1.40	0.15	24.81	2887.92	2633.06	254.86	2279.66	8.35	0.16	0.14	1.08	0.86	9.02
#48-35 GU without air 30-40% FA	305.99	3.90E-06	1.37	0.14	25.35	2685.42	2462.25	223.16	2396.23	7.04	0.16	0.14	1.04	0.86	8.97
#49-35 GUL without air 30-40% FA	276.55	3.69E-06	1.23	0.13	22.07	2558.11	2338.42	219.70	2383.97	7.09	0.16	0.14	1.01	0.86	8.97
#50-35 GU with air 25-34% SC	364.06	6.11E-06	1.76	0.18	30.87	3249.29	2984.22	265.08	2327.80	8.48	0.16	0.14	1.12	0.90	9.02
#51-35 GUL with air 25-34% SC	329.36	5.86E-06	1.59	0.17	27.01	3099.43	2838.43	261.00	2314.53	8.54	0.16	0.14	1.08	0.90	9.02
#52-35 GU without air 25-34% SC	314.59	5.38E-06	1.53	0.16	27.16	2862.04	2633.75	228.29	2425.43	7.20	0.16	0.14	1.04	0.89	8.97
#53-35 GUL without air 25-34% SC	285.41	5.16E-06	1.39	0.15	23.92	2735.87	2511.02	224.86	2413.28	7.25	0.16	0.14	1.01	0.89	8.97
#54-35 GU with air 35-50% SC	329.77	6.40E-06	1.68	0.18	29.11	3050.66	2813.04	237.62	2255.30	7.54	0.16	0.14	1.04	0.90	8.98
#55-35 GUL with air 35-50% SC	299.71	6.18E-06	1.54	0.17	25.77	2920.92	2686.83	234.09	2244.44	7.59	0.16	0.14	1.01	0.90	8.98
#56-35 GU without air 35-50% SC	285.78	5.62E-06	1.47	0.15	25.69	2695.19	2489.98	205.21	2364.90	6.41	0.16	0.14	0.98	0.89	8.94
#57-35 GUL without air 35-50% SC	260.49	5.44E-06	1.35	0.15	22.88	2585.84	2383.61	202.24	2354.37	6.45	0.16	0.14	0.95	0.89	8.94



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Table 9. Summary Results (A1-A3): 36-40 MPa ready mixed concrete product, per cubic meter

Indicator/LCI Metric Unit (equivalent)	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	287.90	3.98E-06	1.35	0.14	24.13	2805.48	2562.23	223.62	2247.67	7.15	0.16	0.14	0.99	0.86	8.96
Maximum	495.29	6.96E-06	2.14	0.22	38.59	4107.11	3740.08	367.04	2612.40	11.98	0.16	0.14	1.39	0.91	9.16
#58-40 GU with air 0-14% FA/SC	495.29	5.82E-06	2.14	0.22	38.59	4107.11	3740.08	367.04	2541.23	11.98	0.16	0.14	1.39	0.88	9.16
#59-40 GU without air 0-14% FA/SC	429.66	5.18E-06	1.87	0.19	34.00	3615.88	3298.14	317.74	2612.40	10.27	0.16	0.14	1.27	0.87	9.09
#60-40 Industry Average Benchmark	458.98	5.88E-06	2.04	0.21	36.51	3875.88	3537.64	338.24	2462.63	11.00	0.16	0.14	1.31	0.88	9.12
#61-40 GU with air 15-29% FA	444.14	5.28E-06	1.94	0.20	35.10	3730.36	3403.17	327.19	2426.10	10.62	0.16	0.14	1.29	0.87	9.11
#62-40 GUL with air 15-29% FA	398.80	4.95E-06	1.72	0.18	30.06	3534.39	3212.53	321.86	2407.84	10.71	0.16	0.14	1.24	0.87	9.11
#63-40 GU without air 15-29% FA	386.12	4.72E-06	1.70	0.17	31.02	3295.22	3011.41	283.81	2514.90	9.11	0.16	0.14	1.18	0.87	9.05
#64-40 GUL without air 15-29% FA	347.50	4.44E-06	1.51	0.16	26.73	3128.25	2848.98	279.27	2498.83	9.18	0.16	0.14	1.14	0.87	9.05
#65-40 GU with air 30-40% FA	388.85	4.69E-06	1.72	0.17	31.33	3323.05	3038.95	284.11	2301.64	9.15	0.16	0.14	1.18	0.87	9.05
#66-40 GUL with air 30-40% FA	350.00	4.41E-06	1.53	0.16	27.01	3155.29	2875.75	279.54	2286.75	9.22	0.16	0.14	1.14	0.87	9.05
#67-40 GU without air 30-40% FA	339.04	4.22E-06	1.51	0.15	27.81	2948.56	2701.42	247.14	2409.50	7.86	0.16	0.14	1.09	0.86	9.00
#68-40 GUL without air 30-40% FA	305.96	3.98E-06	1.35	0.14	24.13	2805.48	2562.23	243.24	2395.73	7.92	0.16	0.14	1.06	0.86	9.00
#69-40 GU with air 25-34% SC	400.19	6.63E-06	1.93	0.20	33.73	3556.20	3265.32	290.87	2340.15	9.37	0.16	0.14	1.18	0.90	9.05
#70-40 GUL with air 25-34% SC	361.70	6.36E-06	1.75	0.19	29.45	3389.94	3103.59	286.35	2325.44	9.44	0.16	0.14	1.14	0.90	9.05
#71-40 GU without air 25-34% SC	348.70	5.88E-06	1.70	0.18	29.86	3147.07	2894.17	252.90	2442.32	8.05	0.16	0.14	1.09	0.89	9.00
#72-40 GUL without air 25-34% SC	315.91	5.64E-06	1.54	0.17	26.21	3005.27	2756.22	249.04	2428.67	8.10	0.16	0.14	1.06	0.89	9.00
#73-40 GU with air 35-50% SC	362.15	6.96E-06	1.85	0.20	31.78	3335.83	3075.42	260.41	2259.73	8.32	0.16	0.14	1.10	0.91	9.01
#74-40 GUL with air 35-50% SC	328.80	6.72E-06	1.69	0.19	28.07	3191.90	2935.40	256.49	2247.67	8.38	0.16	0.14	1.06	0.91	9.01
#75-40 GU without air 35-50% SC	316.32	6.16E-06	1.62	0.17	28.20	2959.54	2732.58	226.96	2374.29	7.15	0.16	0.14	1.02	0.90	8.96
#76-40 GUL without air 35-50% SC	287.90	5.95E-06	1.49	0.16	25.04	2836.65	2613.03	223.62	2362.46	7.21	0.16	0.14	0.99	0.90	8.96



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Table 10. Summary Results (A1-A3): 41-45 MPa ready mixed concrete product, per cubic meter															
Indicator/LCI Metric Unit (equivalent)	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	306.60	4.19E-06	1.43	0.15	25.46	2960.97	2700.83	238.94	2331.41	7.69	0.16	0.14	1.03	0.86	8.98
Maximum	459.74	6.53E-06	1.99	0.20	36.11	3836.46	3495.84	340.62	2601.42	11.06	0.16	0.14	1.33	0.91	9.13
#77-45 GU without air 0-14% FA/SC	459.74	5.48E-06	1.99	0.20	36.11	3836.46	3495.84	340.62	2601.42	11.06	0.16	0.14	1.33	0.87	9.13
#78-45 Industry Average Benchmark	426.33	5.53E-06	1.90	0.19	34.20	3623.77	3309.63	314.14	2529.13	10.16	0.16	0.14	1.26	0.88	9.09
#79-45 GU without air 15-29% FA	412.70	4.98E-06	1.81	0.18	32.90	3490.04	3186.07	303.97	2496.10	9.81	0.16	0.14	1.24	0.87	9.08
#80-45 GUL without air 15-29% FA	370.98	4.68E-06	1.60	0.17	28.26	3309.66	3010.60	299.06	2478.73	9.89	0.16	0.14	1.19	0.87	9.08
#81-45 GU without air 30-40% FA	361.84	4.44E-06	1.60	0.16	29.43	3115.54	2851.19	264.35	2382.23	8.46	0.16	0.14	1.14	0.86	9.02
#82-45 GUL without air 30-40% FA	326.10	4.19E-06	1.43	0.15	25.46	2960.97	2700.83	260.14	2367.35	8.52	0.16	0.14	1.10	0.86	9.02
#83-45 GU without air 25-34% SC	372.28	6.23E-06	1.80	0.19	31.64	3329.99	3059.42	270.57	2417.69	8.66	0.16	0.14	1.14	0.90	9.02
#84-45 GUL without air 25-34% SC	336.86	5.97E-06	1.63	0.18	27.70	3176.80	2910.40	266.41	2402.94	8.72	0.16	0.14	1.10	0.90	9.02
#85-45 GU without air 35-50% SC	337.30	6.53E-06	1.73	0.18	29.85	3127.40	2884.85	242.55	2344.19	7.69	0.16	0.14	1.07	0.91	8.98
#86-45 GUL without air 35-50% SC	306.60	6.31E-06	1.58	0.17	26.44	2994.64	2755.70	238.94	2331.41	7.75	0.16	0.14	1.03	0.91	8.98



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Table 11. Summary Results (A1-A3): 46-50 MPa ready mixed concrete product, per cubic meter

Indicator/LCI Metric Unit (equivalent)	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	332.00	4.45E-06	1.55	0.16	27.42	3201.23	2920.00	258.09	2243.80	8.36	0.15	0.14	1.07	0.87	9.01
Maximum	558.92	7.76E-06	2.40	0.25	43.17	4582.68	4167.79	414.89	2642.38	13.63	0.16	0.14	1.49	0.92	9.23
#87-50 GU with air 0-14% FA/SC	558.92	6.45E-06	2.40	0.25	43.17	4582.68	4167.79	414.89	2579.15	13.63	0.15	0.14	1.49	0.88	9.23
#88-50 GU without air 0-14% FA/SC	499.15	5.86E-06	2.16	0.22	39.05	4156.81	3787.74	369.07	2642.38	12.04	0.16	0.14	1.40	0.88	9.16
#89-50 Industry Average Benchmark	517.43	6.52E-06	2.28	0.23	40.79	4318.52	3936.53	382.00	2489.37	12.50	0.15	0.14	1.41	0.89	9.18
#90-50 GU with air 15-29% FA	500.49	5.83E-06	2.17	0.22	39.19	4152.28	3782.91	369.37	2447.63	12.08	0.15	0.14	1.38	0.88	9.17
#91-50 GUL with air 15-29% FA	448.69	5.46E-06	1.92	0.20	33.43	3928.41	3565.13	363.28	2426.77	12.17	0.15	0.14	1.32	0.88	9.17
#92-50 GU without air 15-29% FA	447.81	5.32E-06	1.96	0.20	35.54	3778.70	3449.63	329.07	2527.42	10.67	0.16	0.14	1.30	0.87	9.11
#93-50 GUL without air 15-29% FA	402.28	4.99E-06	1.74	0.18	30.48	3581.82	3258.11	323.71	2508.47	10.76	0.16	0.14	1.25	0.87	9.11
#94-50 GU with air 30-40% FA	437.32	5.16E-06	1.91	0.19	34.87	3686.99	3366.83	320.15	2305.45	10.40	0.15	0.14	1.26	0.87	9.10
#95-50 GUL with air 30-40% FA	392.94	4.84E-06	1.70	0.18	29.94	3495.34	3180.40	314.94	2288.44	10.48	0.15	0.14	1.21	0.87	9.10
#96-50 GU without air 30-40% FA	392.30	4.73E-06	1.74	0.17	31.76	3369.94	3084.12	285.82	2403.14	9.20	0.16	0.14	1.19	0.87	9.05
#97-50 GUL without air 30-40% FA	353.29	4.45E-06	1.55	0.16	27.42	3201.23	2920.00	281.23	2386.90	9.27	0.16	0.14	1.15	0.87	9.05
#98-50 GU with air 25-34% SC	450.28	7.38E-06	2.16	0.23	37.61	3953.32	3625.44	327.88	2349.45	10.64	0.15	0.14	1.26	0.91	9.10
#99-50 GUL with air 25-34% SC	406.30	7.07E-06	1.95	0.21	32.72	3763.40	3440.68	322.72	2332.64	10.72	0.15	0.14	1.21	0.91	9.10
#100-50 GU without air 25-34% SC	403.70	6.69E-06	1.96	0.20	34.16	3604.01	3311.39	292.62	2441.84	9.41	0.16	0.14	1.19	0.90	9.05
#101-50 GUL without air 25-34% SC	365.03	6.40E-06	1.77	0.19	29.86	3436.81	3148.74	288.07	2425.74	9.48	0.16	0.14	1.15	0.90	9.05
#102-50 GU with air 35-50% SC	406.82	7.76E-06	2.07	0.22	35.39	3701.58	3408.50	293.08	2257.57	9.45	0.15	0.14	1.16	0.92	9.05
#103-50 GUL with air 35-50% SC	368.72	7.48E-06	1.88	0.21	31.15	3537.16	3248.55	288.61	2243.80	9.52	0.15	0.14	1.12	0.92	9.05
#104-50 GU without air 35-50% SC	365.51	7.01E-06	1.87	0.20	32.21	3382.89	3120.86	262.03	2361.62	8.36	0.16	0.14	1.11	0.91	9.01
#105-50 GUL without air 35-50% SC	332.00	6.77E-06	1.71	0.19	28.48	3237.98	2979.89	258.09	2347.67	8.42	0.16	0.14	1.07	0.91	9.01



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Table 12. Summary Results (A1-A3): 51-55 MPa ready mixed concrete product, per cubic meter															
Indicator/LCI Metric	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
Unit (equivalent)	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	343.80	4.59E-06	1.59	0.17	28.26	3286.80	2994.22	268.41	2371.86	8.72	0.16	0.14	1.09	0.87	9.02
Maximum	518.42	7.27E-06	2.24	0.23	40.41	4285.11	3900.76	384.35	2679.74	12.56	0.16	0.14	1.43	0.92	9.18
#106-55 GU without air 0-14% FA/SC	518.42	6.07E-06	2.24	0.23	40.41	4285.11	3900.76	384.35	2679.74	12.56	0.16	0.14	1.43	0.88	9.18
#107-55 Industry Average Benchmark	480.33	6.13E-06	2.13	0.22	38.23	4042.59	3688.44	354.15	2597.31	11.53	0.16	0.14	1.35	0.88	9.14
#108-55 GU without air 15-29% FA	464.77	5.50E-06	2.02	0.21	36.75	3889.96	3547.40	342.56	2559.00	11.13	0.16	0.14	1.33	0.87	9.13
#109-55 GUL without air 15-29% FA	417.22	5.15E-06	1.79	0.19	31.46	3684.42	3347.45	336.96	2539.84	11.22	0.16	0.14	1.28	0.87	9.13
#110-55 GU without air 30-40% FA	406.78	4.89E-06	1.79	0.18	32.79	3462.76	3165.39	297.37	2428.46	9.59	0.16	0.14	1.22	0.87	9.07
#111-55 GUL without air 30-40% FA	366.04	4.59E-06	1.59	0.17	28.26	3286.80	2994.22	292.58	2412.84	9.67	0.16	0.14	1.17	0.87	9.07
#112-55 GU without air 25-34% SC	418.68	6.92E-06	2.02	0.21	35.31	3707.29	3402.82	304.47	2468.85	9.82	0.16	0.14	1.22	0.91	9.07
#113-55 GUL without air 25-34% SC	378.30	6.63E-06	1.82	0.20	30.82	3532.92	3233.19	299.73	2453.42	9.89	0.16	0.14	1.17	0.91	9.07
#114-55 GU without air 35-50% SC	378.78	7.27E-06	1.93	0.20	33.27	3476.16	3203.64	272.52	2384.50	8.72	0.16	0.14	1.13	0.92	9.02
#115-55 GUL without air 35-50% SC	343.80	7.01E-06	1.76	0.19	29.38	3325.20	3056.79	268.41	2371.86	8.78	0.16	0.14	1.09	0.92	9.02

Table 13. Summary Results (A1-A3): 56-60 MPa ready mixed concrete product, per cubic meter															
Indicator/LCI Metric	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
Unit (equivalent)	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	352.37	4.68E-06	1.63	0.17	28.87	3364.88	3065.00	275.00	2334.88	8.96	0.16	0.14	1.10	0.87	9.03
Maximum	532.07	7.43E-06	2.29	0.23	41.37	4392.23	3997.91	394.32	2651.73	12.91	0.16	0.14	1.45	0.92	9.20
#116-60 GU without air 0-14% FA/SC	532.07	6.19E-06	2.29	0.23	41.37	4392.23	3997.91	394.32	2651.73	12.91	0.16	0.14	1.45	0.88	9.20
#117-60 Industry Average Benchmark	492.87	6.26E-06	2.18	0.22	39.12	4142.65	3779.41	363.24	2566.90	11.85	0.16	0.14	1.37	0.89	9.15
#118-60 GU without air 15-29% FA	476.86	5.61E-06	2.07	0.21	37.61	3985.58	3634.27	351.31	2527.47	11.44	0.16	0.14	1.34	0.88	9.14
#119-60 GUL without air 15-29% FA	427.92	5.26E-06	1.84	0.20	32.16	3774.06	3428.51	345.55	2507.76	11.53	0.16	0.14	1.29	0.88	9.14
#120-60 GU without air 30-40% FA	417.18	4.98E-06	1.84	0.18	33.53	3545.95	3241.15	304.81	2393.13	9.85	0.16	0.14	1.23	0.87	9.08
#121-60 GUL without air 30-40% FA	375.25	4.68E-06	1.63	0.17	28.87	3364.88	3065.00	299.88	2377.05	9.93	0.16	0.14	1.18	0.87	9.08
#122-60 GU without air 25-34% SC	429.43	7.08E-06	2.07	0.22	36.12	3797.60	3485.49	312.11	2434.70	10.09	0.16	0.14	1.23	0.91	9.08
#123-60 GUL without air 25-34% SC	387.88	6.77E-06	1.87	0.20	31.50	3618.15	3310.92	307.23	2418.82	10.16	0.16	0.14	1.18	0.91	9.08
#124-60 GU without air 35-50% SC	388.37	7.43E-06	1.98	0.21	34.02	3559.74	3280.52	279.23	2347.89	8.96	0.16	0.14	1.14	0.92	9.03
#125-60 GUL without air 35-50% SC	352.37	7.17E-06	1.81	0.20	30.02	3404.39	3129.39	275.00	2334.88	9.02	0.16	0.14	1.10	0.92	9.03

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