Environmental Product Declaration

Concrete Atlantic béton Atlantique

Atlantic Concrete Member Industry-Wide EPD for

READY-MIXED CONCRETE

ASTM International Certified Environmental Product Declaration

Declared Product	This Environmental Product Declaration (EPD) covers concrete mixes produced by Atlantic Concrete members.	
Declaration Owner	**Atlantic Concrete Association** Suite 406, 3845 Joseph Howe Dr, Halifax, NS B3L 4H9, Canada Phone: (902) 443-4456 Website: www.atlanticconcrete.ca	Atlantic Concrete Association / Association béton Atlantique
Program Operator	**ASTM International** 100 Bar Harbor Drive West Conshohocken, PA 19428-2959, USA Website: www.astm.org	ASTM INTERNATIONAL Helping our world work better
LCA and EPD Developer	**Athena Sustainable Materials Institute** 280 Albert Street, Suite 404 Ottawa, ON K1P 5G8, Canada Website: www.athenasmi.org	Athena Sustainable Materials Institute
Core PCR	ISO 21930:2017 Sustainability in Building Construction - Environmental Declaration of Building Products	
Sub-category PCR	NSF International Product Category Rule (PCR) for Concrete Version 2.1 (August 2021), Verified by Thomas P. Gloria, Ph.D., Industrial Ecology Consultants	
Independent LCA Reviewer and EPD Verifier	Independent verification of the declaration and data, according to ISO 21930:2017 and ISO 14025:2006 ☐ Internal ☒ External	
	Thomas P. Gloria, Ph.D., Industrial Ecology Consultants, ASTM International	
Date of Issue	July 27, 2022	
Period of Validity	5 Years – Valid until July 27 2027	
EPD Number	EPD 347	

The declared product meets the following product specifications:

- ACI 211: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
- CSA A3000: Cementitious materials compendium
- CSA A23.1/A23.2 Concrete materials and methods of concrete construction/Test methods and standard practices for 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

Disclaimer:
EPDs are comparable only if they comply with this document, use the same sub-category PCR where applicable, include all relevant information modules and are based on equivalent scenarios with respect to the context of construction works.

The ready mixed concrete products represented in this EPD are comprised of (in order of greatest mass per mix): natural and crushed aggregates, Portland cement, fly ash/slag cement, batch water, and admixtures.

Methodology of Underlying LCA

Declared Unit

The declared unit is 1 cubic metre of ready mixed concrete. Products covered by this EPD satisfy general purpose concrete as used in residential, commercial, and public works applications in Canada. Key product variables include:

- **28-day strength** – Different compressive strengths were considered;
- **Slag cement/Fly Ash** – Varies between 0% and 40%;
- **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, natural coarse, and natural fine aggregates varies.

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

Scope

The modeled concrete mixes included benchmarks for each strength class. This EPD is intended for use in Business to Business (B-to-B) communication. This EPD can only be used and referenced by members of Atlantic Concrete as having participated in the study. 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.

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 NSF PCR 2021

Description of Product

This EPD presents results for the range of products that are available across the Atlantic region. For each specified mix, variations were developed based on the use of GU and GUL cement as well as different SCM replacement levels. For each mix, a "baseline" mix was developed that represents the average product mix within Atlantic region. The mixes presented in this EPD utilize the following naming convention:

Mix Name: Identify the 28-day specified compressive strength of the proposed product by type of cement unless otherwise specified. Portland cement, also known as Type I/II or General Use cement is labeled as "GU". Portland limestone cement, also known as Type IL or General Use Limestone cement is labeled as "GUL". The name of the mix also notes whether it is "air entrained" and also includes other specifications of the mix recognized in the marketplace. For instance, mixes may also be tagged with an exposure class – (C) classes pertain to chloride exposure; (F) classes pertain to freezing and thawing exposure without chlorides; (N) class is exposed to neither chlorides nor freezing and thawing. For more information concerning exposure class see CSA standard A23.1..

SCM Replacement: Identify the supplementary cementing material (SCM) percentage. Fly ash is labeled in the mix designs as "FA", slag cement as "SC", and silica fume blended cement is labeled as "GUbSF". For example, a mix with 20% fly ash is denoted in the mix identifier as "20 FA".

Cut-off Rules

The cut-off criteria for all activity stage flows considered within the system boundary conform with ISO 14044:2006 and NSF PCR 2021. 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 are included.
- The cut-off rules are not applied to hazardous and toxic materials – all are included in the life cycle inventory.

Allocation

The allocation of co-products or secondary flows cross the system boundary conforms with ISO 21930: 2017 Section 7.2.4. Specifically, the allocation criteria were applied as follows:

- Allocation was not applied any of the gate-to-gate production facilities. For facilities that manufacture additional products (i.e. aggregate), the LCI flows at the facility specific to the concrete production were reported.
- For secondary data sources, the NSF PCR default allocation selection (i.e. "Cut-off" or "Alloc Rec") was applied.
- The product category rules for this EPD recognize fly ash, silica fume and slag as recovered materials and thus the environmental impacts allocated to these materials are limited to the treatment and transportation required to use as a concrete material input
- A portion (30%) of the reported fleet energy use for truck mixing plants was allocated to the mixing facility.

Participation

Participation in the concrete plant data collection was open to all members of the Atlantic Concrete Association (Atlantic Concrete). Concrete plants were randomly selected based on size of operation and geographic distribution. The results of this report are applicable to the concrete produced from all members of Atlantic Concrete and a list of certified concrete plants can be found on the Association website (www.atlanticconcrete.ca).

Data Sources and Software

This EPD is based on foreground LCI data collected from the participating companies' production facilities. A representative sample of Atlantic Concrete member facilities were selected based on technical attributes, production scale, and geographic location. In total, 22 facilities operated by Atlantic Concrete member companies completed LCI data collection questionnaires representing over 21% of all Atlantic Concrete member facilities.

All upstream material, resource and energy carrier inputs have been sourced from various industry-average datasets and literature as specified for use in NSF PCR 2021. 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.

This EPD was calculated using manufacturer specific cement data that represents 100% of the total cement used in this mix. As part of the data collection process, each participating facility provided data as to their cement supplier. All cement facilities were represented with environmental product declarations, and thus a weighted average cement profile was created for each individual region.

Table 2. A1 - Raw Material Supply

Materials	LCI Data Source	Geography	Year	Data Quality Assessment
General Use Cement **ASTM C150, C595, C1157, CSA A3000**	Weighted Average of Results Specific to Concrete Producers in Region	Canada	2020-2021	• **Technology:** very good • **Time:** very good • **Geography:** very good • **Completeness:** very good • **Reliability:** very good
General Use Limestone Cement **ASTM C150, C595, C1157, CSA A3000**	Weighted Average of Results Specific to Concrete Producers in Region	Canada	2020-2021	• **Technology:** very good • **Time:** very good • **Geography:** very good • **Completeness:** very good • **Reliability:** very good
Fly Ash **ASTM C618, CSA A3000**	None, no incoming burden, only inbound transport was considered	N/A	N/A	• **N/A** • **Recovered material**
Slag Cement **ASTM C989, CSA A3000**	Slag Cement Association N. America EPD Slag Cement, 2021	N. America	2021	• **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 *coarse and fine* **ASTM C33, CSA A23.1/A23.2**	ecoinvent 3.4: Gravel, crushed {RoW} production Cut-off, U Modified with regional electricity	EU/Canada	2004	• **Technology:** good • **Time:** fair Data Is twelve years old but technology remains consistent across the industry • **Geography:** good Swiss production (modified with regional Electricity). • **Completeness:** very good • **Reliability:** very good
Natural Aggregates *coarse and fine* **ASTM C30, CSA A23.1/A23.2**	ecoinvent 3.4: Gravel, round {RoW}| gravel and sand quarry operation Cut-off, U Modfied with regional electricity	EU/Canada	2004	
Admixtures **ASTM C494, ASTM C260**	EFCA EPDs for Air Entrainers, Plasticisers and superplasticisers (2015) Non-supported LCIA indicators estimated	EU	2015	• **Technology:** very good • **Time:** good • **Geography:** good • **Completeness:** good • **Reliability:** good
Water **ASTM C1602, CSA A23.1/A23.2**	ecoinvent 3.4: Tap water {RoW} market for Cut-off, U	Global	2011	• **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

Table 3. A2 - Transportation				
Process	**LCI Data Source**	**Geography**	**Year**	**Data Quality Assessment**
Truck Transportation	USLCI 2014: Transport, combination truck, short-haul, diesel powered/tkm/RNA	USA	2007	• **Technology:** good • **Time:** fair • **Geography:** very good • **Completeness:** good • **Reliability:** good
Rail Transportation	USLCI 2014: Transport, train, diesel powered /US U	USA	2007	• **Technology:** good • **Time:** fair • **Geography:** very good • **Completeness:** good • **Reliability:** good
Ocean Transportation	USLCI 2014: Transport, ocean freighter, average fuel mix /US U	USA	2007	• **Technology:** good • **Time:** fair • **Geography:** very good • **Completeness:** good • **Reliability:** good

Table 4. A3 - Manufacturing				
Process	**LCI Data Source**	**Geography**	**Year**	**Data Quality Assessment**
Electricity	ecoinvent 3.4:Electricity, low voltage, at grid, (CA)	Regional	2015	• **Technology:** very good • **Time:** good • **Geography:** very good • **Completeness:** good • **Reliability:** good
Natural Gas	USLCI 2014: Natural gas, combusted in industrial boiler/US	US	2008	• **Technology:** very good • **Time:** fair • **Geography:** fair • **Completeness:** good • **Reliability:** good
Diesel	USLCI 2014: Diesel, combusted in industrial equipment/US	US	2008	• **Technology:** very good • **Time:** fair • **Geography:** fair • **Completeness:** good • **Reliability:** good
Liquefied Propane Gas	USLCI 2014: Liquefied petroleum gas, combusted in industrial boiler/US	US	2008	• **Technology:** very good • **Time:** fair • **Geography:** fair • **Completeness:** good • **Reliability:** good
Hazardous Waste	ecoinvent 3.4: Hazardous waste, for incineration {ROW} treatment of hazardous waste, hazardous waste incineration Alloc Rec, U	EU	2008	• **Technology:** good • **Time:** fair • **Geography:** fair • **Completeness:** very good • **Reliability:** very good
Non-Hazardous Waste	ecoinvent 3.4: Inert waste {RoW}| treatment of, sanitary landfill Alloc Rec, U	EU	2008	• **Technology:** good • **Time:** fair • **Geography:** fair • **Completeness:** very good • **Reliability:** very good

Athena's Concrete LCA Software V2 was used to gather the facility data, mix designs, and to conduct the LCA modeling. This software was third party reviewed and found to be in conformance with the following relevant standards: ISO 14040:2006b, ISO 14044:2006c, ISO 14025:2006, ISO 21930:2017, and the NSF PCR 2021.

Life Cycle Assessment Results

The LCA results presented in this EPD are intended for use in Business to Business (B-to-B) communication. The EPD supports 25 life cycle impact assessment indicators and inventory metrics as listed in Table 5. The Impact Assessment method and other calculation methodologies are specified in Table 5. Tables 6 through 14 present the LCA results for the mixes produced at the different facilities (Information module A1-A3 accumulated). The results are presented first based on a declared unit of 1 cubic metre.

Table 5. Life Cycle Category Indicators and Inventory Metrics

Core Mandatory Impact Indicator	**Abbreviation**	**Unit**	**Method/Source**
Global warming potential	GWP	kg CO2e	TRACI 2.1 V1.02
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11e	TRACI 2.1 V1.02
Acidification potential of soil and water sources	AP	kg SO2e	TRACI 2.1 V1.02
Eutrophication potential	EP	kg Ne	TRACI 2.1 V1.02
Photochemical smog creation potential	POCP	kg O3e	TRACI 2.1 V1.02
Abiotic depletion potential (ADPfossil)*	ADPf	MJ, NCV	CML-IA Baseline V3.02
Abiotic depletion potential (ADPelements)*	ADPe	kg Sbe	CML-IA Baseline V3.02
Use of Primary Resources			
Renewable primary energy carrier used as energy*	RPRE	MJ, NCV	CED V1.10 NCV
Renewable primary energy carrier used as material*	RPRM	MJ, NCV	LCI Indicator
Non-renewable primary energy carrier used as energy*	NRPRE	MJ, NCV	CED V1.10 NCV
Non-renewable primary energy carrier used as material*	NRPRM	MJ, NCV	LCI Indicator
Secondary Material, Secondary Fuel and Recovered Energy			
Secondary material*	SM	kg	LCI Indicator
Renewable secondary fuel *	RSF	MJ, NCV	LCI Indicator
Non-renewable secondary fuel*	NRSF	MJ, NCV	LCI Indicator
Recovered energy*	RE	MJ, NCV	LCI Indicator
Mandatory Inventory Parameters			
Consumption of freshwater resources;	FW	m3	LCI Indicator
Calcination and carbonation emissions	CCE	kg CO2e	LCI Indicator
Indicators Describing Waste			
Hazardous waste disposed*	HWD	kg	LCI Indicator
Non-hazardous waste disposed*	NHWD	kg	LCI Indicator
High-level radioactive waste*	HLRW	m3	LCI Indicator
Intermediate- and low-level radioactive waste*	ILLRW	m3	LCI Indicator
Components for re-use*	CRU	kg	LCI Indicator
Materials for recycling*	MR	kg	LCI Indicator
Materials for energy recovery*	MER	kg	LCI Indicator
Recovered energy exported from the product system*	EE	MJ, NCV	LCI Indicator

Emerging LCA impact categories and inventory items are still under development and can have high levels of uncertainty that preclude international acceptance pending further development. Use caution when interpreting data in categories marked with (*) in Table 5. Additionally, EPDs are comparable only if they comply with this document, use the same sub-category PCR where applicable, include all relevant information modules and are based on equivalent scenarios with respect to the context of construction works. No regulated substances of very high concern were identified in the LCA.

Table 5. LCA Results 20 MPa concrete without air

	Unit	Baseline 20 MPa concrete without air GU 10 FA	20 MPa concrete without air GU	20 MPa concrete without air GU 10 FA	20 MPa concrete without air GU 20 FA	20 MPa concrete without air GU 30 FA	20 MPa concrete without air GU 40 FA	20 MPa concrete without air GUL	20 MPa concrete without air GUL 10 FA	20 MPa concrete without air GUL 20 FA	20 MPa concrete without air GUL 30 FA	20 MPa concrete without air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	336.63	364.04	336.63	309.22	281.81	254.41	339.04	314.13	289.22	264.31	239.41
ODP	kg CFC-11 eq.	6.37E-06	6.99E-06	6.37E-06	5.75E-06	5.13E-06	4.52E-06	6.58E-06	6.01E-06	5.43E-06	4.85E-06	4.27E-06
EP	kg N eq.	0.31	0.34	0.31	0.29	0.26	0.24	0.32	0.30	0.28	0.26	0.23
AP	kg SO_2 eq.	1.76	1.79	1.76	1.72	1.68	1.64	1.76	1.73	1.69	1.66	1.62
POCP	kg O_3 eq.	42.72	43.15	42.72	42.30	41.87	41.45	42.77	42.38	42.00	41.61	41.22
Use of primary resources												
RPR_F	MJ, NCV	105.14	114.82	105.14	95.46	85.78	76.10	112.85	103.37	93.89	84.40	74.92
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	1956.30	2027.19	1956.30	1885.41	1814.53	1743.64	1806.43	1757.62	1708.81	1660.00	1611.18
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	167.88	186.54	167.88	149.23	130.57	111.92	168.50	151.65	134.80	117.95	101.10
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1202.26	1202.82	1202.26	1201.71	1201.15	1200.60	1190.60	1191.27	1191.94	1192.60	1193.27
ADPe	kg Sb	1.22E-04	1.26E-04	1.22E-04	1.19E-04	1.16E-04	1.13E-04	1.25E-04	1.22E-04	1.19E-04	1.16E-04	1.13E-04
Consumption of freshwater resources												
FW	m^3	2.08	2.11	2.08	2.05	2.02	1.99	2.09	2.06	2.03	2.01	1.98
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	13.72	15.24	13.72	12.20	10.68	9.16	13.77	12.40	11.02	9.65	8.28
HLRW	m3	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07
ILLRW	m3	2.07E-07	2.07E-07	2.07E-07	2.07E-07	2.07E-07	2.07E-07	2.07E-07	2.07E-07	2.07E-07	2.07E-07	2.07E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	133.75	148.61	133.75	118.89	104.03	89.17	134.04	120.63	107.23	93.83	80.42

Table 6. LCA Results 20 MPa concrete with air

	Unit	Baseline 20 MPa concrete with air GU 10 FA	20 MPa concrete with air GU	25 MPa concrete with air GU 10 FA	20 MPa concrete with air GU 20 FA	20 MPa concrete with air GU 30 FA	20 MPa concrete with air GU 40 FA	20 MPa concrete with air GUL	20 MPa concrete with air GUL 10 FA	20 MPa concrete with air GUL 20 FA	20 MPa concrete with air GUL 30 FA	20 MPa concrete with air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	343.96	372.28	343.96	315.63	287.31	258.99	346.45	320.71	294.97	269.23	243.49
ODP	kg CFC-11 eq.	6.54E-06	7.18E-06	6.54E-06	5.90E-06	5.26E-06	4.62E-06	6.76E-06	6.16E-06	5.57E-06	4.97E-06	4.37E-06
EP	kg N eq.	0.32	0.34	0.32	0.29	0.27	0.24	0.33	0.31	0.28	0.26	0.24
AP	kg SO_2 eq.	1.74	1.78	1.74	1.70	1.66	1.62	1.75	1.71	1.68	1.64	1.60
POCP	kg O_3 eq.	42.13	42.56	42.13	41.69	41.25	40.81	42.17	41.77	41.37	40.97	40.58
Use of primary resources												
RPR_F	MJ, NCV	108.25	118.25	108.25	98.25	88.24	78.24	116.21	106.41	96.62	86.82	77.02
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	1967.49	2040.74	1967.49	1894.24	1820.99	1747.74	1812.63	1762.19	1711.75	1661.31	1610.87
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	173.48	192.75	173.48	154.20	134.93	115.65	174.11	156.70	139.29	121.88	104.47
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1193.64	1194.21	1193.64	1193.07	1192.49	1191.92	1181.59	1182.28	1182.97	1183.66	1184.35
ADPe	kg Sb	1.26E-04	1.29E-04	1.26E-04	1.23E-04	1.19E-04	1.16E-04	1.28E-04	1.25E-04	1.22E-04	1.19E-04	1.16E-04
Consumption of freshwater resources												
FW	m^3	2.07	2.10	2.07	2.04	2.01	1.98	2.07	2.04	2.02	1.99	1.96
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	14.18	15.75	14.18	12.61	11.04	9.47	14.23	12.81	11.39	9.97	8.55
HLRW	m3	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07
ILLRW	m3	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	138.21	153.57	138.21	122.85	107.50	92.14	138.50	124.65	110.80	96.95	83.10

Table 7. LCA Results 25 MPa concrete without air

	Unit	Baseline 25 MPa concrete without air GU 10 FA	25 MPa concrete without air GU	25 MPa concrete without air GU 10 FA	25 MPa concrete without air GU 20 FA	25 MPa concrete without air GU 30 FA	25 MPa concrete without air GU 40 FA	25 MPa concrete without air GUL	25 MPa concrete without air GUL 10 FA	25 MPa concrete without air GUL 20 FA	25 MPa concrete without air GUL 30 FA	25 MPa concrete without air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	354.02	383.26	354.02	324.79	295.55	266.32	356.59	330.02	303.45	276.89	250.32
ODP	kg CFC-11 eq.	6.74E-06	7.40E-06	6.74E-06	6.08E-06	5.42E-06	4.76E-06	6.97E-06	6.35E-06	5.73E-06	5.12E-06	4.50E-06
EP	kg N eq.	0.33	0.35	0.33	0.30	0.28	0.25	0.34	0.32	0.29	0.27	0.24
AP	kg SO_2 eq.	1.79	1.83	1.79	1.74	1.70	1.66	1.79	1.76	1.72	1.68	1.64
POCP	kg O_3 eq.	43.12	43.58	43.12	42.67	42.22	41.76	43.17	42.76	42.35	41.93	41.52
Use of primary resources												
RPR_F	MJ, NCV	111.33	121.66	111.33	101.01	90.68	80.36	119.55	109.44	99.33	89.21	79.10
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2014.89	2090.51	2014.89	1939.28	1863.67	1788.05	1855.03	1802.96	1750.90	1698.83	1646.77
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	179.07	198.97	179.07	159.18	139.28	119.38	179.73	161.76	143.78	125.81	107.84
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1217.87	1218.46	1217.87	1217.28	1216.69	1216.09	1205.43	1206.14	1206.85	1207.56	1208.28
ADPe	kg Sb	1.28E-04	1.32E-04	1.28E-04	1.25E-04	1.22E-04	1.19E-04	1.31E-04	1.28E-04	1.24E-04	1.21E-04	1.18E-04
Consumption of freshwater resources												
FW	m^3	2.09	2.13	2.09	2.06	2.03	2.00	2.10	2.07	2.04	2.01	1.99
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	14.64	16.26	14.64	13.01	11.39	9.77	14.69	13.22	11.75	10.29	8.82
HLRW	m3	1.78E-07	1.78E-07	1.78E-07	1.78E-07	1.78E-07	1.78E-07	1.78E-07	1.78E-07	1.78E-07	1.78E-07	1.78E-07
ILLRW	m3	2.06E-07	2.06E-07	2.06E-07	2.06E-07	2.06E-07	2.06E-07	2.06E-07	2.06E-07	2.06E-07	2.06E-07	2.06E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	142.67	158.52	142.67	126.82	110.96	95.11	142.97	128.67	114.38	100.08	85.78

Table 8. LCA Results 25 MPa concrete with air

	Unit	Baseline 25 MPa concrete with air GU 10 FA	25 MPa concrete with air GU	25 MPa concrete with air GU 10 FA	25 MPa concrete with air GU 20 FA	25 MPa concrete with air GU 30 FA	25 MPa concrete with air GU 40 FA	25 MPa concrete with air GUL	25 MPa concrete with air GUL 10 FA	25 MPa concrete with air GUL 20 FA	25 MPa concrete with air GUL 30 FA	25 MPa concrete with air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	360.99	391.14	360.99	330.84	300.69	270.54	363.64	336.24	308.84	281.44	254.04
ODP	kg CFC-11 eq.	6.91E-06	7.59E-06	6.91E-06	6.23E-06	5.55E-06	4.87E-06	7.14E-06	6.50E-06	5.87E-06	5.23E-06	4.60E-06
EP	kg N eq.	0.33	0.36	0.33	0.31	0.28	0.25	0.35	0.32	0.30	0.27	0.25
AP	kg SO_2 eq.	1.77	1.81	1.77	1.72	1.68	1.64	1.77	1.74	1.70	1.66	1.62
POCP	kg O_3 eq.	42.30	42.77	42.30	41.83	41.37	40.90	42.35	41.92	41.50	41.07	40.65
Use of primary resources												
RPR_F	MJ, NCV	114.53	125.18	114.53	103.88	93.23	82.58	123.01	112.57	102.14	91.71	81.28
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2021.55	2099.52	2021.55	1943.57	1865.59	1787.62	1856.69	1802.99	1749.30	1695.61	1641.92
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	184.67	205.19	184.67	164.15	143.63	123.11	185.35	166.81	148.28	129.74	111.21
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1205.14	1205.74	1205.14	1204.53	1203.92	1203.31	1192.31	1193.04	1193.78	1194.51	1195.24
ADPe	kg Sb	1.33E-04	1.36E-04	1.33E-04	1.29E-04	1.26E-04	1.23E-04	1.35E-04	1.32E-04	1.29E-04	1.25E-04	1.22E-04
Consumption of freshwater resources												
FW	m^3	2.07	2.11	2.07	2.04	2.01	1.98	2.08	2.05	2.02	1.99	1.96
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	15.09	16.77	15.09	13.42	11.75	10.07	15.14	13.63	12.12	10.61	9.10
HLRW	m3	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07
ILLRW	m3	2.01E-07	2.01E-07	2.01E-07	2.01E-07	2.01E-07	2.01E-07	2.01E-07	2.01E-07	2.01E-07	2.01E-07	2.01E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	147.13	163.47	147.13	130.78	114.43	98.08	147.44	132.70	117.95	103.21	88.46

Table 9. LCA Results 25 MPa concrete with air & 0.55 w/cm (C-4, F-2)

	Unit	Baseline 25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GU 10 FA	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GU	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GU 10 FA	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GU 20 FA	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GU 30 FA	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GU 40 FA	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GUL	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GUL 10 FA	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GUL 20 FA	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GUL 30 FA	25 MPa concrete with air & 0.55 w/cm (C-4, F-2) GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	370.25	401.32	370.25	339.19	308.13	277.06	372.98	344.75	316.52	288.29	260.06
ODP	kg CFC-11 eq.	7.10E-06	7.80E-06	7.10E-06	6.40E-06	5.70E-06	4.99E-06	7.34E-06	6.68E-06	6.03E-06	5.37E-06	4.72E-06
EP	kg N eq.	0.34	0.37	0.34	0.31	0.29	0.26	0.35	0.33	0.30	0.28	0.25
AP	kg SO_2 eq.	1.79	1.84	1.79	1.75	1.70	1.66	1.80	1.76	1.72	1.68	1.64
POCP	kg O_3 eq.	42.86	43.34	42.86	42.38	41.90	41.42	42.91	42.47	42.03	41.60	41.16
Use of primary resources												
RPR_F	MJ, NCV	117.48	128.45	117.48	106.51	95.54	84.57	126.22	115.47	104.72	93.98	83.23
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2057.88	2138.22	2057.88	1977.54	1897.20	1816.86	1888.02	1832.70	1777.38	1722.06	1666.74
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	190.27	211.41	190.27	169.13	147.98	126.84	190.96	171.87	152.77	133.67	114.58
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1219.29	1219.92	1219.29	1218.66	1218.03	1217.40	1206.07	1206.83	1207.58	1208.34	1209.10
ADPe	kg Sb	1.34E-04	1.37E-04	1.34E-04	1.30E-04	1.27E-04	1.24E-04	1.36E-04	1.33E-04	1.30E-04	1.26E-04	1.23E-04
Consumption of freshwater resources												
FW	m^3	2.09	2.12	2.09	2.06	2.02	1.99	2.10	2.07	2.04	2.01	1.98
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	15.55	17.27	15.55	13.83	12.10	10.38	15.60	14.04	12.49	10.93	9.37
HLRW	m3	1.75E-07	1.75E-07	1.75E-07	1.75E-07	1.75E-07	1.75E-07	1.75E-07	1.75E-07	1.75E-07	1.75E-07	1.75E-07
ILLRW	m3	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	151.58	168.43	151.58	134.74	117.90	101.06	151.91	136.72	121.53	106.34	91.14

Table 10. LCA Results 30 MPa concrete without air

	Unit	Baseline 30 MPa concrete without air GU 10 FA	30 MPa concrete without air GU	30 MPa concrete without air GU 10 FA	30 MPa concrete without air GU 20 FA	30 MPa concrete without air GU 30 FA	30 MPa concrete without air GU 40 FA	30 MPa concrete without air GUL	30 MPa concrete without air GUL 10 FA	30 MPa concrete without air GUL 20 FA	30 MPa concrete without air GUL 30 FA	30 MPa concrete without air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	379.12	411.09	379.12	347.14	315.16	283.19	381.93	352.87	323.81	294.75	265.69
ODP	kg CFC-11 eq.	7.28E-06	8.01E-06	7.28E-06	6.56E-06	5.84E-06	5.12E-06	7.53E-06	6.86E-06	6.18E-06	5.51E-06	4.83E-06
EP	kg N eq.	0.35	0.38	0.35	0.32	0.29	0.26	0.36	0.34	0.31	0.28	0.26
AP	kg SO_2 eq.	1.81	1.86	1.81	1.77	1.72	1.68	1.82	1.78	1.74	1.70	1.66
POCP	kg O_3 eq.	43.21	43.70	43.21	42.71	42.22	41.72	43.26	42.81	42.36	41.91	41.46
Use of primary resources												
RPR_E	MJ, NCV	120.34	131.63	120.34	109.05	97.75	86.46	129.33	118.27	107.20	96.14	85.08
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_E$	MJ, NCV	2088.55	2171.26	2088.55	2005.85	1923.15	1840.45	1913.70	1856.76	1799.81	1742.86	1685.92
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	195.86	217.62	195.86	174.10	152.34	130.57	196.58	176.92	157.26	137.61	117.95
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1228.27	1228.92	1228.27	1227.62	1226.98	1226.33	1214.66	1215.44	1216.22	1217.00	1217.78
ADPe	kg Sb	1.34E-04	1.38E-04	1.34E-04	1.31E-04	1.27E-04	1.24E-04	1.37E-04	1.34E-04	1.30E-04	1.27E-04	1.23E-04
Consumption of freshwater resources												
FW	m^3	2.10	2.13	2.10	2.07	2.03	2.00	2.11	2.08	2.04	2.01	1.98
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	16.01	17.78	16.01	14.23	12.46	10.68	16.06	14.46	12.85	11.25	9.65
HLRW	m3	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07	1.76E-07
ILLRW	m3	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	156.04	173.38	156.04	138.70	121.37	104.03	156.38	140.74	125.10	109.46	93.83

Table 11. LCA Results 30 MPa concrete with air

	Unit	Baseline 30 MPa concrete with air GU 10 FA	30 MPa concrete with air GU	30 MPa concrete with air GU 10 FA	30 MPa concrete with air GU 20 FA	30 MPa concrete with air GU 30 FA	30 MPa concrete with air GU 40 FA	30 MPa concrete with air GUL	30 MPa concrete with air GUL 10 FA	30 MPa concrete with air GUL 20 FA	30 MPa concrete with air GUL 30 FA	30 MPa concrete with air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	394.38	428.18	394.38	360.58	326.77	292.97	397.35	366.63	335.91	305.19	274.47
ODP	kg CFC-11 eq.	7.63E-06	8.39E-06	7.63E-06	6.87E-06	6.11E-06	5.34E-06	7.89E-06	7.18E-06	6.47E-06	5.75E-06	5.04E-06
EP	kg N eq.	0.36	0.39	0.36	0.33	0.30	0.27	0.38	0.35	0.32	0.29	0.26
AP	kg SO_2 eq.	1.80	1.85	1.80	1.75	1.71	1.66	1.81	1.77	1.72	1.68	1.63
POCP	kg O_3 eq.	42.38	42.90	42.38	41.86	41.33	40.81	42.43	41.96	41.48	41.00	40.53
Use of primary resources												
RPR_F	MJ, NCV	126.54	138.48	126.54	114.60	102.67	90.73	136.05	124.35	112.66	100.96	89.27
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2118.77	2206.20	2118.77	2031.35	1943.92	1856.49	1933.93	1873.73	1813.53	1753.33	1693.13
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	207.05	230.06	207.05	184.05	161.04	138.04	207.81	187.03	166.25	145.47	124.69
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1218.21	1218.89	1218.21	1217.52	1216.84	1216.16	1203.82	1204.65	1205.47	1206.29	1207.12
ADPe	kg Sb	1.41E-04	1.45E-04	1.41E-04	1.37E-04	1.34E-04	1.30E-04	1.44E-04	1.40E-04	1.37E-04	1.33E-04	1.29E-04
Consumption of freshwater resources												
FW	m^3	2.08	2.12	2.08	2.05	2.01	1.97	2.09	2.06	2.02	1.99	1.96
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	16.92	18.79	16.92	15.04	13.17	11.29	16.97	15.28	13.59	11.89	10.20
HLRW	m3	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07
ILLRW	m3	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	164.96	183.29	164.96	146.63	128.30	109.97	165.31	148.78	132.25	115.72	99.19

Table 12. LCA Results 32 MPa concrete with air & 0.45 w/cm (C-2)

	Unit	Baseline 32 MPa concrete with air & 0.45 w/cm (C-2) GU 10 FA	32 MPa concrete with air & 0.45 w/cm (C-2) GU	32 MPa concrete with air & 0.45 w/cm (C-2) GU 10 FA	32 MPa concrete with air & 0.45 w/cm (C-2) GU 20 FA	32 MPa concrete with air & 0.45 w/cm (C-2) GU 30 FA	32 MPa concrete with air & 0.45 w/cm (C-2) GU 40 FA	32 MPa concrete with air & 0.45 w/cm (C-2) GUL	32 MPa concrete with air & 0.45 w/cm (C-2) GUL 10 FA	32 MPa concrete with air & 0.45 w/cm (C-2) GUL 20 FA	32 MPa concrete with air & 0.45 w/cm (C-2) GUL 30 FA	32 MPa concrete with air & 0.45 w/cm (C-2) GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	438.78	477.15	438.78	400.40	362.03	323.66	442.15	407.28	372.40	337.53	302.66
ODP	kg CFC-11 eq.	8.56E-06	9.43E-06	8.56E-06	7.70E-06	6.83E-06	5.97E-06	8.86E-06	8.05E-06	7.24E-06	6.43E-06	5.62E-06
EP	kg N eq.	0.40	0.43	0.40	0.36	0.33	0.30	0.42	0.38	0.35	0.32	0.29
AP	kg SO_2 eq.	1.90	1.95	1.90	1.84	1.79	1.74	1.91	1.86	1.81	1.76	1.71
POCP	kg O_3 eq.	44.05	44.64	44.05	43.45	42.86	42.26	44.11	43.57	43.03	42.48	41.94
Use of primary resources												
RPR_F	MJ, NCV	141.35	154.90	141.35	127.80	114.24	100.69	152.14	138.86	125.59	112.31	99.03
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2275.15	2374.39	2275.15	2175.90	2076.66	1977.42	2065.33	1996.99	1928.66	1860.32	1791.98
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	235.03	261.15	235.03	208.92	182.80	156.69	235.90	212.31	188.72	165.13	141.54
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1266.02	1266.79	1266.02	1265.24	1264.47	1263.69	1249.69	1250.63	1251.56	1252.50	1253.43
ADPe	kg Sb	1.49E-04	1.53E-04	1.49E-04	1.44E-04	1.40E-04	1.36E-04	1.52E-04	1.48E-04	1.43E-04	1.39E-04	1.35E-04
Consumption of freshwater resources												
FW	m^3	2.13	2.18	2.13	2.09	2.05	2.01	2.14	2.10	2.07	2.03	1.99
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	19.20	21.33	19.20	17.07	14.94	12.81	19.26	17.34	15.42	13.49	11.57
HLRW	m3	1.72E-07	1.72E-07	1.72E-07	1.72E-07	1.72E-07	1.72E-07	1.72E-07	1.72E-07	1.72E-07	1.72E-07	1.72E-07
ILLRW	m3	1.97E-07	1.97E-07	1.97E-07	1.97E-07	1.97E-07	1.97E-07	1.97E-07	1.97E-07	1.97E-07	1.97E-07	1.97E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	187.25	208.06	187.25	166.45	145.64	124.83	187.65	168.89	150.12	131.36	112.59

Table 13. LCA Results 35 MPa concrete withoutair

	Unit	Baseline 35 MPa concrete without air GU 10 FA	35 MPa concrete without air GU	35 MPa concrete without air GU 10 FA	35 MPa concrete without air GU 20 FA	35 MPa concrete without air GU 30 FA	35 MPa concrete without air GU 40 FA	35 MPa concrete without air GUL	35 MPa concrete without air GUL 10 FA	35 MPa concrete without air GUL 20 FA	35 MPa concrete without air GUL 30 FA	35 MPa concrete without air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	422.25	458.80	422.25	385.71	349.16	312.62	425.46	392.25	359.04	325.83	292.62
ODP	kg CFC-11 eq.	8.20E-06	9.03E-06	8.20E-06	7.38E-06	6.55E-06	5.73E-06	8.48E-06	7.71E-06	6.94E-06	6.17E-06	5.40E-06
EP	kg N eq.	0.38	0.42	0.38	0.35	0.32	0.29	0.40	0.37	0.34	0.31	0.28
AP	kg SO_2 eq.	1.88	1.93	1.88	1.83	1.78	1.73	1.89	1.85	1.80	1.75	1.70
POCP	kg O_3 eq.	44.04	44.61	44.04	43.48	42.91	42.35	44.10	43.59	43.07	42.56	42.04
Use of primary resources												
RPR_F	MJ, NCV	135.64	148.55	135.64	122.74	109.83	96.92	145.92	133.27	120.63	107.99	95.34
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2229.80	2324.32	2229.80	2135.28	2040.77	1946.25	2029.97	1964.89	1899.81	1834.73	1769.64
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	223.84	248.71	223.84	198.97	174.10	149.23	224.66	202.20	179.73	157.26	134.80
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1262.53	1263.27	1262.53	1261.80	1261.06	1260.32	1246.99	1247.88	1248.77	1249.66	1250.55
ADPe	kg Sb	1.47E-04	1.51E-04	1.47E-04	1.43E-04	1.39E-04	1.35E-04	1.50E-04	1.46E-04	1.43E-04	1.39E-04	1.35E-04
Consumption of freshwater resources												
FW	m^3	2.13	2.17	2.13	2.09	2.05	2.01	2.14	2.10	2.07	2.03	1.99
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	18.29	20.31	18.29	16.26	14.23	12.20	18.35	16.52	14.69	12.85	11.02
HLRW	m3	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07	1.74E-07
ILLRW	m3	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	178.33	198.15	178.33	158.52	138.70	118.89	178.71	160.84	142.97	125.10	107.23

Table 14. LCA Results 35 MPa concrete with air

	Unit	Baseline 35 MPa concrete with air GU 10 FA	35 MPa concrete with air GU	35 MPa concrete with air GU 10 FA	35 MPa concrete with air GU 20 FA	35 MPa concrete with air GU 30 FA	35 MPa concrete with air GU 40 FA	35 MPa concrete with air GUL	35 MPa concrete with air GUL 10 FA	35 MPa concrete with air GUL 20 FA	35 MPa concrete with air GUL 30 FA	35 MPa concrete with air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	447.25	486.53	447.25	407.96	368.67	329.39	450.70	415.00	379.29	343.59	307.89
ODP	kg CFC-11 eq.	8.74E-06	9.63E-06	8.74E-06	7.85E-06	6.97E-06	6.08E-06	9.04E-06	8.22E-06	7.39E-06	6.56E-06	5.73E-06
EP	kg N eq.	0.41	0.44	0.41	0.37	0.34	0.30	0.42	0.39	0.36	0.33	0.29
AP	kg SO_2 eq.	1.90	1.96	1.90	1.84	1.79	1.73	1.91	1.86	1.81	1.76	1.71
POCP	kg O_3 eq.	43.80	44.41	43.80	43.19	42.58	41.97	43.86	43.31	42.75	42.20	41.65
Use of primary resources												
RPR_F	MJ, NCV	144.68	158.56	144.68	130.81	116.93	103.06	155.73	142.14	128.55	114.95	101.36
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2302.72	2404.32	2302.72	2201.11	2099.50	1997.90	2087.90	2017.94	1947.97	1878.01	1808.05
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	240.63	267.37	240.63	213.89	187.16	160.42	241.51	217.36	193.21	169.06	144.91
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1272.40	1273.20	1272.40	1271.61	1270.81	1270.02	1255.69	1256.64	1257.60	1258.56	1259.51
ADPe	kg Sb	1.49E-04	1.54E-04	1.49E-04	1.45E-04	1.41E-04	1.36E-04	1.53E-04	1.48E-04	1.44E-04	1.40E-04	1.36E-04
Consumption of freshwater resources												
FW	m^3	2.13	2.17	2.13	2.09	2.04	2.00	2.14	2.10	2.06	2.02	1.98
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	19.66	21.84	19.66	17.48	15.30	13.12	19.72	17.75	15.78	13.82	11.85
HLRW	m3	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07
ILLRW	m3	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	191.71	213.01	191.71	170.41	149.11	127.81	192.12	172.91	153.69	134.48	115.27

Table 15. LCA Results 35 MPa concrete with air & 0.40 w/cm (C-1)

	Unit	Baseline 35 MPa concrete with air & 0.40 w/cm (C-1) GU 10 FA	35 MPa concrete with air & 0.40 w/cm (C-1) GU	35 MPa concrete with air & 0.40 w/cm (C-1) GU 10 FA	35 MPa concrete with air & 0.40 w/cm (C-1) GU 20 FA	35 MPa concrete with air & 0.40 w/cm (C-1) GU 30 FA	35 MPa concrete with air & 0.40 w/cm (C-1) GU 40 FA	35 MPa concrete with air & 0.40 w/cm (C-1) GUL	35 MPa concrete with air & 0.40 w/cm (C-1) GUL 10 FA	35 MPa concrete with air & 0.40 w/cm (C-1) GUL 20 FA	35 MPa concrete with air & 0.40 w/cm (C-1) GUL 30 FA	35 MPa concrete with air & 0.40 w/cm (C-1) GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	474.24	516.26	474.24	432.21	390.18	348.15	477.93	439.74	401.54	363.35	325.15
ODP	kg CFC-11 eq.	9.30E-06	1.02E-05	9.30E-06	8.35E-06	7.40E-06	6.45E-06	9.62E-06	8.73E-06	7.85E-06	6.96E-06	6.07E-06
EP	kg N eq.	0.43	0.46	0.43	0.39	0.36	0.32	0.45	0.41	0.38	0.34	0.31
AP	kg SO_2 eq.	1.95	2.01	1.95	1.89	1.83	1.77	1.96	1.91	1.86	1.80	1.75
POCP	kg O_3 eq.	44.59	45.24	44.59	43.94	43.29	42.64	44.66	44.07	43.47	42.88	42.29
Use of primary resources												
RPR_F	MJ, NCV	153.64	168.49	153.64	138.80	123.96	109.12	165.46	150.92	136.38	121.84	107.30
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2402.13	2510.83	2402.13	2293.44	2184.74	2076.05	2172.33	2097.49	2022.64	1947.80	1872.95
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	257.42	286.02	257.42	228.82	200.21	171.61	258.36	232.53	206.69	180.85	155.02
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1306.36	1307.21	1306.36	1305.51	1304.66	1303.81	1288.48	1289.50	1290.53	1291.55	1292.57
ADPe	kg Sb	1.48E-04	1.52E-04	1.48E-04	1.43E-04	1.38E-04	1.34E-04	1.51E-04	1.47E-04	1.42E-04	1.37E-04	1.33E-04
Consumption of freshwater resources												
FW	m^3	2.15	2.20	2.15	2.11	2.06	2.02	2.16	2.12	2.08	2.04	1.99
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	21.02	23.36	21.02	18.69	16.36	14.03	21.09	18.99	16.88	14.78	12.67
HLRW	m3	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07
ILLRW	m3	1.94E-07	1.94E-07	1.94E-07	1.94E-07	1.94E-07	1.94E-07	1.94E-07	1.94E-07	1.94E-07	1.94E-07	1.94E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	205.08	227.87	205.08	182.30	159.51	136.72	205.52	184.97	164.42	143.87	123.31

Table 16. LCA Results 40 MPa concrete without air

	Unit	Baseline 40 MPa concrete without air GU 10 FA	40 MPa concrete without air GU	40 MPa concrete without air GU 10 FA	40 MPa concrete without air GU 20 FA	40 MPa concrete without air GU 30 FA	40 MPa concrete without air GU 40 FA	40 MPa concrete without air GUL	40 MPa concrete without air GUL 10 FA	40 MPa concrete without air GUL 20 FA	40 MPa concrete without air GUL 30 FA	40 MPa concrete without air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	449.16	488.45	449.16	409.88	370.59	331.31	452.62	416.91	381.21	345.51	309.81
ODP	kg CFC-11 eq.	8.76E-06	9.65E-06	8.76E-06	7.87E-06	6.98E-06	6.10E-06	9.06E-06	8.23E-06	7.40E-06	6.58E-06	5.75E-06
EP	kg N eq.	0.41	0.44	0.41	0.37	0.34	0.31	0.43	0.39	0.36	0.33	0.30
AP	kg SO_2 eq.	1.94	1.99	1.94	1.88	1.83	1.77	1.95	1.90	1.85	1.79	1.74
POCP	kg O_3 eq.	44.86	45.47	44.86	44.25	43.64	43.04	44.93	44.37	43.82	43.26	42.71
Use of primary resources												
RPR_F	MJ, NCV	144.54	158.41	144.54	130.66	116.79	102.91	155.59	141.99	128.40	114.81	101.22
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2327.72	2429.32	2327.72	2226.11	2124.51	2022.90	2112.90	2042.94	1972.98	1903.01	1833.05
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	240.63	267.37	240.63	213.89	187.16	160.42	241.51	217.36	193.21	169.06	144.91
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1295.07	1295.86	1295.07	1294.27	1293.48	1292.69	1278.35	1279.31	1280.27	1281.22	1282.18
ADPe	kg Sb	1.46E-04	1.51E-04	1.46E-04	1.42E-04	1.37E-04	1.33E-04	1.49E-04	1.45E-04	1.41E-04	1.37E-04	1.32E-04
Consumption of freshwater resources												
FW	m^3	2.16	2.20	2.16	2.11	2.07	2.03	2.16	2.13	2.09	2.05	2.01
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	19.66	21.84	19.66	17.48	15.30	13.12	19.72	17.75	15.78	13.82	11.85
HLRW	m3	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07
ILLRW	m3	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07	2.00E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	191.71	213.01	191.71	170.41	149.11	127.81	192.12	172.91	153.69	134.48	115.27

Table 17. LCA Results 40 MPa concrete with air

	Unit	Baseline 40 MPa concrete with air GU 10 FA	40 MPa concrete with air GU	40 MPa concrete with air GU 10 FA	40 MPa concrete with air GU 20 FA	40 MPa concrete with air GU 30 FA	40 MPa concrete with air GU 40 FA	40 MPa concrete with air GUL	40 MPa concrete with air GUL 10 FA	40 MPa concrete with air GUL 20 FA	40 MPa concrete with air GUL 30 FA	40 MPa concrete with air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	474.19	516.21	474.19	432.16	390.13	348.11	477.88	439.69	401.49	363.30	325.11
ODP	kg CFC-11 eq.	9.30E-06	1.02E-05	9.30E-06	8.35E-06	7.40E-06	6.45E-06	9.63E-06	8.74E-06	7.85E-06	6.97E-06	6.08E-06
EP	kg N eq.	0.43	0.46	0.43	0.39	0.36	0.32	0.45	0.41	0.38	0.34	0.31
AP	kg SO_2 eq.	1.96	2.02	1.96	1.90	1.84	1.79	1.98	1.92	1.87	1.81	1.76
POCP	kg O_3 eq.	44.95	45.60	44.95	44.30	43.65	43.00	45.02	44.43	43.83	43.24	42.65
Use of primary resources												
RPR_F	MJ, NCV	153.18	168.03	153.18	138.34	123.50	108.66	165.00	150.46	135.92	121.38	106.84
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2399.52	2508.21	2399.52	2290.82	2182.13	2073.43	2169.72	2094.87	2020.03	1945.18	1870.34
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	257.42	286.02	257.42	228.82	200.21	171.61	258.36	232.53	206.69	180.85	155.02
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1303.77	1304.62	1303.77	1302.92	1302.08	1301.23	1285.89	1286.92	1287.94	1288.96	1289.99
ADPe	kg Sb	1.48E-04	1.53E-04	1.48E-04	1.43E-04	1.39E-04	1.34E-04	1.51E-04	1.47E-04	1.42E-04	1.38E-04	1.33E-04
Consumption of freshwater resources												
FW	m^3	2.16	2.20	2.16	2.11	2.07	2.02	2.17	2.12	2.08	2.04	2.00
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	21.02	23.36	21.02	18.69	16.36	14.03	21.09	18.99	16.88	14.78	12.67
HLRW	m3	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07	1.71E-07
ILLRW	m3	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07	1.96E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	205.08	227.87	205.08	182.30	159.51	136.72	205.52	184.97	164.42	143.87	123.31

Table 18. LCA Results 45 MPa concrete without air

	Unit	Baseline 45 MPa concrete without air GU 10 FA	45 MPa concrete without air GU	45 MPa concrete without air GU 10 FA	45 MPa concrete without air GU 20 FA	45 MPa concrete without air GU 30 FA	45 MPa concrete without air GU 40 FA	45 MPa concrete without air GUL	45 MPa concrete without air GUL 10 FA	45 MPa concrete without air GUL 20 FA	45 MPa concrete without air GUL 30 FA	45 MPa concrete without air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	501.86	546.63	501.86	457.09	412.33	367.56	505.80	465.11	424.43	383.74	343.06
ODP	kg CFC-11 eq.	9.87E-06	1.09E-05	9.87E-06	8.86E-06	7.85E-06	6.84E-06	1.02E-05	9.27E-06	8.33E-06	7.38E-06	6.44E-06
EP	kg N eq.	0.45	0.49	0.45	0.41	0.38	0.34	0.47	0.44	0.40	0.36	0.33
AP	kg SO_2 eq.	2.04	2.10	2.04	1.97	1.91	1.85	2.05	1.99	1.93	1.88	1.82
POCP	kg O_3 eq.	46.40	47.09	46.40	45.70	45.01	44.32	46.47	45.84	45.21	44.58	43.95
Use of primary resources												
RPR_F	MJ, NCV	161.18	176.99	161.18	145.37	129.56	113.75	173.77	158.28	142.79	127.30	111.81
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2504.31	2620.09	2504.31	2388.53	2272.74	2156.96	2259.52	2179.80	2100.07	2020.34	1940.62
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	274.21	304.67	274.21	243.74	213.27	182.80	275.21	247.69	220.17	192.65	165.13
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1342.25	1343.15	1342.25	1341.34	1340.44	1339.53	1323.20	1324.29	1325.38	1326.47	1327.56
ADPe	kg Sb	1.37E-04	1.42E-04	1.37E-04	1.32E-04	1.27E-04	1.22E-04	1.41E-04	1.36E-04	1.31E-04	1.27E-04	1.22E-04
Consumption of freshwater resources												
FW	m^3	2.20	2.25	2.20	2.15	2.10	2.05	2.21	2.16	2.12	2.07	2.03
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	22.39	24.88	22.39	19.91	17.42	14.94	22.47	20.22	17.98	15.74	13.49
HLRW	m3	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07	1.73E-07
ILLRW	m3	1.99E-07	1.99E-07	1.99E-07	1.99E-07	1.99E-07	1.99E-07	1.99E-07	1.99E-07	1.99E-07	1.99E-07	1.99E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	218.46	242.73	218.46	194.19	169.91	145.64	218.93	197.03	175.14	153.25	131.36

Table 19. LCA Results 45 MPa concrete with air

	Unit	Baseline 45 MPa concrete with air GU 10 FA	45 MPa concrete with air GU	45 MPa concrete with air GU 10 FA	45 MPa concrete with air GU 20 FA	45 MPa concrete with air GU 30 FA	45 MPa concrete with air GU 40 FA	45 MPa concrete with air GUL	45 MPa concrete with air GUL 10 FA	45 MPa concrete with air GUL 20 FA	45 MPa concrete with air GUL 30 FA	45 MPa concrete with air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	528.55	576.51	528.55	480.58	432.62	384.65	532.76	489.17	445.58	401.99	358.40
ODP	kg CFC-11 eq.	1.05E-05	1.16E-05	1.05E-05	9.40E-06	8.31E-06	7.23E-06	1.08E-05	9.84E-06	8.83E-06	7.81E-06	6.80E-06
EP	kg N eq.	0.47	0.52	0.47	0.43	0.39	0.35	0.50	0.46	0.42	0.38	0.34
AP	kg SO_2 eq.	2.02	2.09	2.02	1.96	1.89	1.82	2.04	1.98	1.91	1.85	1.79
POCP	kg O_3 eq.	45.19	45.93	45.19	44.44	43.70	42.96	45.26	44.59	43.91	43.24	42.56
Use of primary resources												
RPR_F	MJ, NCV	170.79	187.73	170.79	153.85	136.91	119.97	184.28	167.69	151.09	134.50	117.90
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2552.67	2676.72	2552.67	2428.61	2304.56	2180.51	2290.39	2204.97	2119.55	2034.13	1948.71
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	293.79	326.44	293.79	261.15	228.51	195.86	294.87	265.38	235.90	206.41	176.92
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1320.33	1321.30	1320.33	1319.36	1318.39	1317.42	1299.92	1301.09	1302.25	1303.42	1304.59
ADPe	kg Sb	1.36E-04	1.42E-04	1.36E-04	1.31E-04	1.26E-04	1.21E-04	1.40E-04	1.35E-04	1.30E-04	1.25E-04	1.20E-04
Consumption of freshwater resources												
FW	m^3	2.17	2.22	2.17	2.12	2.07	2.01	2.18	2.13	2.08	2.04	1.99
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	23.99	26.65	23.99	21.33	18.67	16.01	24.07	21.67	19.26	16.86	14.46
HLRW	m3	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07	1.64E-07
ILLRW	m3	1.88E-07	1.88E-07	1.88E-07	1.88E-07	1.88E-07	1.88E-07	1.88E-07	1.88E-07	1.88E-07	1.88E-07	1.88E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	234.06	260.07	234.06	208.06	182.05	156.04	234.56	211.11	187.65	164.19	140.74

Table 20. LCA Results 50 MPa concrete without air

	Unit	Baseline 50 MPa concrete without air GU 10 FA	50 MPa concrete without air GU	50 MPa concrete without air GU 10 FA	50 MPa concrete without air GU 20 FA	50 MPa concrete without air GU 30 FA	50 MPa concrete without air GU 40 FA	50 MPa concrete without air GUL	50 MPa concrete without air GUL 10 FA	50 MPa concrete without air GUL 20 FA	50 MPa concrete without air GUL 30 FA	50 MPa concrete without air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	536.01	584.43	536.01	487.59	439.16	390.74	540.26	496.26	452.25	408.25	364.24
ODP	kg CFC-11 eq.	1.06E-05	1.17E-05	1.06E-05	9.50E-06	8.41E-06	7.32E-06	1.10E-05	9.95E-06	8.93E-06	7.91E-06	6.89E-06
EP	kg N eq.	0.48	0.52	0.48	0.44	0.40	0.36	0.50	0.46	0.42	0.38	0.34
AP	kg SO_2 eq.	2.08	2.15	2.08	2.02	1.95	1.88	2.10	2.04	1.97	1.91	1.85
POCP	kg O_3 eq.	46.78	47.53	46.78	46.03	45.28	44.53	46.86	46.18	45.49	44.81	44.13
Use of primary resources												
RPR_F	MJ, NCV	173.11	190.22	173.11	156.01	138.91	121.81	186.73	169.98	153.22	136.47	119.72
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2611.58	2736.81	2611.58	2486.34	2361.11	2235.87	2346.80	2260.57	2174.34	2088.10	2001.87
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	296.59	329.55	296.59	263.64	230.68	197.73	297.68	267.91	238.14	208.37	178.61
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1364.46	1365.44	1364.46	1363.48	1362.50	1361.52	1343.85	1345.03	1346.21	1347.39	1348.57
ADPe	kg Sb	1.42E-04	1.48E-04	1.42E-04	1.37E-04	1.32E-04	1.26E-04	1.46E-04	1.41E-04	1.36E-04	1.31E-04	1.25E-04
Consumption of freshwater resources												
FW	m^3	2.22	2.27	2.22	2.16	2.11	2.06	2.23	2.18	2.13	2.08	2.04
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	24.22	26.91	24.22	21.53	18.84	16.16	24.30	21.87	19.45	17.02	14.59
HLRW	m3	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07
ILLRW	m3	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	236.29	262.55	236.29	210.04	183.78	157.53	236.80	213.12	189.44	165.76	142.08

Table 21. LCA Results 50 MPa concrete with air

	Unit	Baseline 50 MPa concrete with air GU 10 FA	50 MPa concrete with air GU	50 MPa concrete with air GU 10 FA	50 MPa concrete with air GU 20 FA	50 MPa concrete with air GU 30 FA	50 MPa concrete with air GU 40 FA	50 MPa concrete with air GUL	50 MPa concrete with air GUL 10 FA	50 MPa concrete with air GUL 20 FA	50 MPa concrete with air GUL 30 FA	50 MPa concrete with air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	551.01	601.26	551.01	500.76	450.51	400.26	555.43	509.76	464.09	418.43	372.76
ODP	kg CFC-11 eq.	1.09E-05	1.21E-05	1.09E-05	9.81E-06	8.68E-06	7.54E-06	1.13E-05	1.03E-05	9.21E-06	8.15E-06	7.09E-06
EP	kg N eq.	0.49	0.54	0.49	0.45	0.41	0.36	0.52	0.48	0.43	0.39	0.35
AP	kg SO_2 eq.	2.07	2.14	2.07	2.00	1.93	1.86	2.09	2.02	1.96	1.89	1.82
POCP	kg O_3 eq.	45.96	46.74	45.96	45.18	44.40	43.62	46.04	45.33	44.62	43.91	43.21
Use of primary resources												
RPR_F	MJ, NCV	178.44	196.19	178.44	160.70	142.95	125.20	192.57	175.19	157.80	140.42	123.03
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2635.48	2765.44	2635.48	2505.52	2375.56	2245.60	2360.71	2271.23	2181.74	2092.25	2002.76
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	307.78	341.98	307.78	273.59	239.39	205.19	308.91	278.02	247.13	216.24	185.35
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1348.45	1349.47	1348.45	1347.44	1346.42	1345.40	1327.07	1328.29	1329.52	1330.74	1331.97
ADPe	kg Sb	1.40E-04	1.45E-04	1.40E-04	1.34E-04	1.29E-04	1.23E-04	1.44E-04	1.38E-04	1.33E-04	1.28E-04	1.22E-04
Consumption of freshwater resources												
FW	m^3	2.19	2.25	2.19	2.14	2.08	2.03	2.20	2.15	2.10	2.05	2.00
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	25.13	27.92	25.13	22.34	19.55	16.77	25.21	22.70	20.18	17.66	15.14
HLRW	m3	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07
ILLRW	m3	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07	1.89E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	245.21	272.46	245.21	217.96	190.72	163.47	245.73	221.16	196.59	172.01	147.44

Table 22. LCA Results 60 MPa concrete without air

	Unit	Baseline 60 MPa concrete without air GU 10 FA	60 MPa concrete without air GU	60 MPa concrete without air GU 10 FA	60 MPa concrete without air GU 20 FA	60 MPa concrete without air GU 30 FA	60 MPa concrete without air GU 40 FA	60 MPa concrete without air GUL	60 MPa concrete without air GUL 10 FA	60 MPa concrete without air GUL 20 FA	60 MPa concrete without air GUL 30 FA	60 MPa concrete without air GUL 40 FA
Environmental impacts												
GWP	kg CO_2 eq.	580.21	633.20	580.21	527.22	474.23	421.24	584.87	536.71	488.55	440.40	392.24
ODP	kg CFC-11 eq.	1.15E-05	1.27E-05	1.15E-05	1.03E-05	9.13E-06	7.93E-06	1.19E-05	1.08E-05	9.70E-06	8.58E-06	7.46E-06
EP	kg N eq.	0.52	0.57	0.52	0.47	0.43	0.38	0.54	0.50	0.46	0.41	0.37
AP	kg SO_2 eq.	2.17	2.25	2.17	2.10	2.02	1.95	2.19	2.12	2.05	1.98	1.91
POCP	kg O_3 eq.	48.10	48.92	48.10	47.28	46.46	45.64	48.19	47.44	46.69	45.95	45.20
Use of primary resources												
RPR_F	MJ, NCV	188.55	207.26	188.55	169.83	151.12	132.40	203.45	185.11	166.78	148.45	130.11
RPR_M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$NRPR_F$	MJ, NCV	2767.78	2904.83	2767.78	2630.73	2493.68	2356.63	2478.03	2383.66	2289.29	2194.92	2100.55
$NRPR_M$	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources												
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	324.57	360.64	324.57	288.51	252.44	216.38	325.76	293.18	260.61	228.03	195.46
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	1412.31	1413.39	1412.31	1411.24	1410.17	1409.10	1389.77	1391.06	1392.35	1393.64	1394.93
ADPe	kg Sb	1.54E-04	1.60E-04	1.54E-04	1.48E-04	1.43E-04	1.37E-04	1.59E-04	1.53E-04	1.47E-04	1.42E-04	1.36E-04
Consumption of freshwater resources												
FW	m^3	2.25	2.31	2.25	2.20	2.14	2.08	2.27	2.21	2.16	2.11	2.06
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	26.50	29.44	26.50	23.56	20.62	17.68	26.59	23.93	21.28	18.62	15.97
HLRW	m3	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07
ILLRW	m3	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07	1.95E-07
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO_2 eq.	258.58	287.32	258.58	229.85	201.12	172.39	259.14	233.22	207.31	181.40	155.48

References

American Concrete Institute (ACI) 211: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

American Concrete Institute (ACI) 318: Building Code Requirements for Structural Concrete ASTM International

(ASTM) C94: Standard Specification for Ready-Mixed Concrete

Athena Sustainable Materials Institute A Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Manufactured by CRMCA Members – Version 2.0; Prepared by the Athena Sustainable Materials Institute: May 2022.

Canadian Standards Association (CSA) A3000: Cementitious materials compendium

Canadian Standards Association (CSA) A23.1/A23.2: Concrete materials and methods of concrete construction/Test methods and standard practices for concrete

Construction Specifications Institute (CSI) MasterFormat Division 03-30-00 Cast-in-Place Concrete

EN 15804:2012 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.

European Federation of Concrete Admixture Associations (2006). EFCA Environmental Declarations for Admixtures. https://www.efca.info/efca-publications/environmental/

ISO 21930: 2017 Building construction – Sustainability in building construction – Environmental declaration of building products.

ISO 14025: 2006 Environmental labeling and declarations - Type III environmental declarations - Principles and procedures.

ISO 14044: 2006 Environmental management - Life cycle assessment - Requirements and guidelines. ISO 14040:

2006 Environmental management - Life cycle assessment - Principles and framework.

National Renewable Energy Laboratory 2014. U.S. Life Cycle Inventory Database. https://www.lcacommons.gov/

NSF International (2015) NSF Program Operator Rules

NSF International, Product Category Rule Environmental Product Declarations, PCR for Concrete, V2.1, August 2021. https://www.nsf.org/standards-development/product-category-rules