Life Cycle Assessment of C-2000 NF, Concrete Admixture

Background Report in Support of Environmental Product Declarations

November 19, 2025

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Acronyms

EPD: Environmental Product Declaration

GWP: Global Warming Potential

LCA: Life Cycle Assessment

LCI: Life Cycle Inventory

LCIA: Life Cycle Impact Assessment

PCR: Product Category Rules

Executive Summary

Xypex manufactures concrete admixture products to provide further longevity of concrete through crystallization and waterproofing within the structure. One way that Xypex strives to advance durability of concrete structures is by promoting the use of concrete admixture By creating a publicly available Environmental Product Declarations (EPD) for C-2000 NF, Concrete Admixture , Xypex provides greater transparency regarding the environmental profile of the concrete admixture products.

The results of the study are intended for public distribution as part of a greater effort to update and clarify the environmental profile of concrete admixture products at a time when other potential concrete materials are competing for an environmental advantage in the market.

The intended audience for this report includes the program operator, CSA and its reviewer who will be assessing the EPD for conformance to ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services as the reference Product Category Rules (PCR), as well as Xypex internal stakeholders involved in marketing and communications, in operations, and in design. The intended audience for the resulting EPD is the building and construction technical community.

The goal and scope of the LCA conform to to ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services as the reference Product Category Rules (PCR), which describes the format and requirements for creating EPDs for construction products (ISO 21930:2017).

The study uses a combination of primary data collected by Xypex and its respective key suppliers and secondary data. Production data for 2023, a representative 12-month was provided. Manufacturing inventories were assigned using a mass allocation approach based on provided data of production volumes. Where primary data were not available, ecoinvent v3.10.1, Cut-off at Classification, which contains detailed peer reviewed LCI data, was used.

This report represents an LCA model and resulting EPD for C-2000 NF, Concrete Admixture.

1. Project Overview

Xypex Chemical Corporation (Xypex) manufactures concrete admixture products to provide increased longevity and more sustainable performance of concrete products. The admixture products from Xypex are added to the concrete during batching. The ease of installation allows for efficiency and less labour than traditional methods. Xypex' C-2000 NF product, once installed, allows for crystallization in the concrete with the reaction of moisture. This reaction generates a non-soluble crystalline formation throughout the pores and capillary tracts of the concrete that permanently seals the concrete and prevents the penetration of water and other liquids from any direction. The crystalline structure increases the lifetime of the concrete compared to other competitor products. Xypex commissioned TrueNorth Collective to conduct a Life Cycle Assessment (LCA) and Environmental Product Declaration (EPD) on its C-2000 NF, Concrete Admixture product. LCA is a credible framework to evaluate environmental impacts and identify low impact/ high benefit practices and support decisions that lead to reduced environmental impacts across multiple categories- from ecosystem health to resource depletion. In this study, LCA is applied to assess environmental performance and populate EPD's following applicable Product Category Rules (PCR) and ISO standards.

The LCA will be conducted in accordance with the following standards:

- *ISO 21930: Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services. International Organization for Standardization International Organization for Standardization, 2017.*
- *ISO 14025: Environmental labels and declarations — Type III environmental declarations — Principles and procedures, International Organization for Standardization, 2006.*
- *ISO 14040: Environmental management – Life cycle assessment – Principles and framework, International Organization for Standardization, 2006.*
- *ISO 14044: Environmental management – Life cycle assessment – Requirements and Guidelines, International Organization for Standardization, 2006.*
- ISO 14071. (2014). *ISO/TS 14071:2014, Environmental management — Life cycle assessment — Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006.*
- *European Committee for Standardization. EN 15804:2012+A2:2019 Sustainability of Construction Works – Environmental Product Declarations – Core Rules for the Product Category of Construction Products. Brussels, CEN, 2019.*

This report is intended as an LCA background report and will support the creation of EPDs. TrueNorth will then be conducting one EPD for Xypex on its C-2000 NF, Concrete Admixture product.

The results of the LCA and EPD are intended to be communicated externally. This study is undergoing verification through CSA, the EPD program operator selected by Xypex. The program operator, CSA, requires verification to ISO 21930:2017 in addition to the existing EN15804 and PCR.

2. Goal and Scope Definition

The first phase of an LCA defines the goal and scope of the study. According to ISO 14044 (ISO 14040, 2006), the goal of the study should clearly specify the intended application, reasons for carrying out the study, the intended audience, and whether the results are intended to be disclosed to the public. The scope describes the most important aspects of the study, including the declared unit, system boundaries, cut-off criterion, allocation, impact assessment method assumptions and limitations.

In the case of this study, many of these components are specified in the Product Category Rules (PCR):

- *ISO 21930 Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services. International Organization for Standardization International Organization for Standardization, 2017.*

2.1. Objectives

The goal of this study is to understand the environmental impacts associated with each stage in the life cycle of C-2000 NF, Concrete Admixture products manufactured by Xypex. The target audience includes the program operator CSA, its reviewer who will be assessing the EPD for conformance to the PCR, Xypex, and their stakeholders. The primary intended application includes providing Xypex with LCA results and informing purchasers of C-2000 NF, Concrete Admixture environmental impact data to assist in their purchasing decisions. The report will be made available as deemed appropriate by Xypex. It is important to note that impacts described here are estimates of potential impacts, rather than direct measurements of real impacts. These EPDs will be made available primarily for business-to-business (B2B) communications. The results of this study are not intended to be used in comparative assertions intended to be disclosed to the public.

The second goal of this study is to publish an EPD, which transparently communicates the environmental impacts associated with concrete admixture over their lifetime. Having the product EPDs will support fulfillment of customer product transparency requests with credible, third-party verified documentation and enable a competitive advantage for Xypex and concrete admixture products.

This study is based on the attributional LCA approach, which describes the physical reality of an existing supply chain by quantifying the energy and material flows to and from an existing life cycle.

2.2. System Description Overview

The product under study is a concrete admixture product, C-2000 NF, Concrete Admixture. Xypex C-2000, NF Concrete Admixture consists of Portland cement and various active, proprietary ingredients. This product is used to increase longevity in concrete products as well as other applications. C-2000, NF Concrete Admixture provides waterproofing, protection, and improvement to concrete with the reaction to moisture within the active chemicals. The reactions allow for crystallization of the concrete structure increasing the lifetime of the concrete products.

Previous EPD reports have been developed for other Xypex admixture products. In reference to Xypex Admix C-1000 NF EPD issued on 28 August 2023, once the admixture is incorporated into the concrete mixture the following modules will follow that of the concrete. With this assumption modules B1-B7 are equal to zero since concrete does not require inputs throughout the use phase of its lifecycle.

The Xypex C-2000 NF, Concrete Admixture products are manufactured at facility in Richmond, British Columbia, Canada. The admixture will be added to the batching of cement production. In this study some assumptions are based on the use of concrete since the admixture product is bonded to that product and cannot be removed for a separate study.

Throughout this report LCI and LCIA values are declared per kg of concrete admixture product.

2.3. Declared Unit

A declared unit identifies the primary function(s) of a system based on which alternative systems are considered functionally equivalent (ISO 14040, 2006). This facilitates the determination of reference flows for each system, which in turn enables the comparison of two or more systems.

The declared unit being evaluated, as specified by the PCR, is:

1 kg of admixture product.

The reference flow is the mass of material required to provide the equivalent product mass for the declared unit. The total production mass is provided as primary data from Xypex for the declared unit of 1 kg. The primary data is provided for the reference year of 2023.

The lifespan for the admixture product is assumed to be equal to that of the building service life (75 years) since the product is inseparable from the other components of concrete within the building. This assumes the admixture remains active and stable throughout the life of the concrete. The lifespan only applies to these reference in-use conditions. If used in environments with aggressive exposure where concrete does not last the lifetime of the building, the lifespan of the additive may differ.

2.4. Study Boundaries

As per the guiding PCR, the system boundaries of the LCA and EPD shall follow the modular structure for life cycle stages in line with ISO 21930 (ISO 21930, 2017), as shown in Table 1. Other products of similar function to C-2000 NF have impact greater than 0 in B modules therefore module B. All modules of the products life cycle are included for ease of comparison to comparable Xypex products.

Table 1: System Boundary Modules

	PRODUCT STAGE			CONSTRUCTION STAGE		USE STAGE							END OF LIFE STAGE				LOADS AND BENEFITS
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
	Extraction and upstream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational water use	De-construction / Demolition	Transport to waste processing or disposal	Waste processing	Disposal of waste	Potential net benefits from reuse, recycling and/or energy recovery beyond the system boundary
Modules Declared	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Share of specific data	>90%	50%	-	-	-	-	-	-	-	-	-	-	-	-
Variation - Products	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-	-
Variation - sites	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-	-

*MND: module not declared;

The system boundary for the LCA and EPDs is cradle to gate with options, modules C1-C4, module D and with optional modules (A1–A3 + C + D and additional modules). The additional modules A4–A5 and B1–B7 are selected.

The percentage of specific data is assumed to be larger than 60%, but it cannot be proved since one or several EPDs that are used as data sources lack information on the percentage of specific data used. This EPD covers a single product from a single facility; therefore, variations in products or manufacturing sites are not applicable.

Figure 1 illustrates the C-2000 NF, Concrete Admixture board’s process flow within the system boundary along with major material/energy flows.

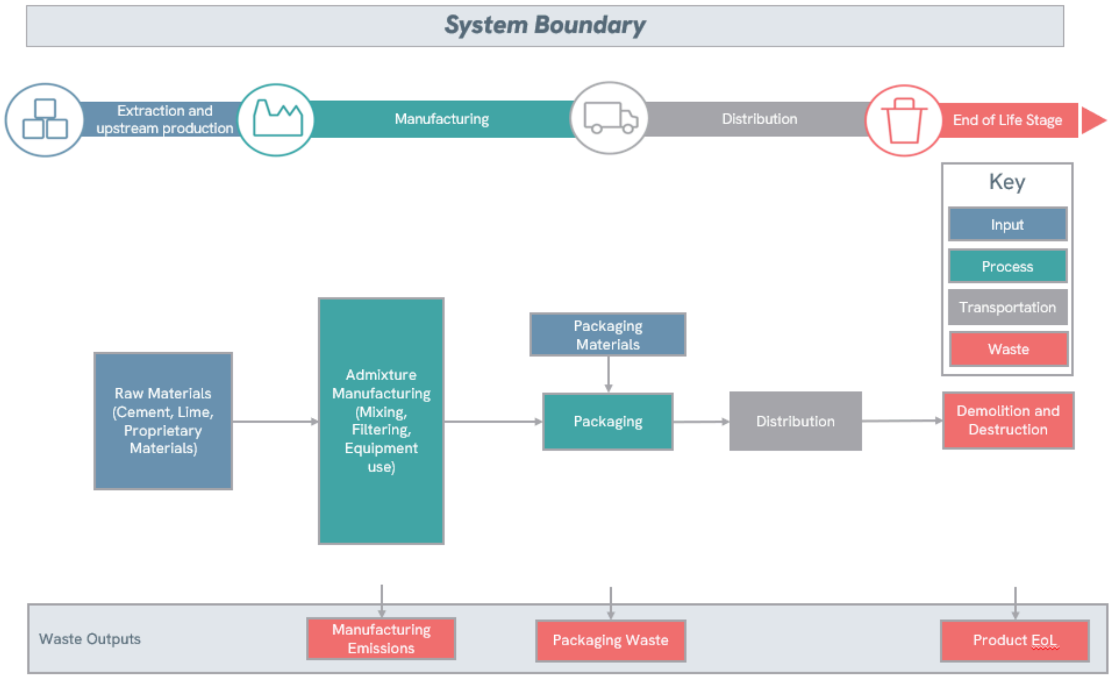


Figure 1: System boundary process flow diagram for C-2000 NF, Concrete Admixture

The life cycles of C-2000 NF, Concrete Admixture products begin with raw material extraction and processing. These materials are mixed with other cement materials and packaged for distribution to the customer. Once mixed the concrete admixture product is inseparable from the other concrete materials. The following stages of the life cycle are assumed to have the same use and end of life treatment as concrete.

Following the same assumptions as concrete as described in section 2.2, modules B1-B7 are assumed to be zero. A lifetime of 75 years is assumed for the product. End of life treatment for the product follows the same treatment as concrete based on EPA 2020 C&D Debris Management by Material and Destination. Concrete is disposed of at 82.4% recycling and 17.6% landfilling.

2.5. Excluded Processes

A number of processes are excluded from the study as allowed by the PCR ISO 21930:2017. Typically, in an LCA, some aspects within the set boundaries are excluded due to statistical insignificance or irrelevancy to the goal and scope. The following activities were excluded from the scope and boundaries for this study:

- Human activities (e.g., employee travel to and from work)
- R&D (i.e., the laboratory and inputs related to the development of technologies)
- Services (e.g., the use of purchased marketing, consultancy services and business travel).
- Construction of capital equipment and maintenance and operation of support equipment
- Maintenance and operation of support equipment

Capital equipment and plant infrastructure are not included in the foreground data however, background data from ecoinvent include the infrastructure components.

2.6. Cut-Off Criteria

For the processes within the system boundary, described in section 2.4, all energy and material flows have been included in the model. No known flows are excluded. All upstream and downstream activities are included using a combination of primary and secondary data. While the majority of inventory data is sourced from primary resources, representative proxies are used to close gaps in the absence of primary data.

The cut-off criteria for the PCR defaults to EN 15804 section 6.3.6. The model follows this criteria by including all known and available processes in the calculations filling data gaps with conservative assumptions, using a 1% cut-off criteria with a 5% maximum total, and using a mass balance to ensure correct calculation of material and energy flows.

2.7. Allocation & Recycling

While conducting an LCA, if the life cycles of more than one product are connected, allocation of the process inputs should be avoided by using the system boundary expansion approach. In accordance with the guiding PCR, mass should be used as the primary basis for co-product allocation. The allocations of relevance for calculation (appropriation of impacts across various products) shall be indicated, at least:

- Allocation in the use of recycled and/or secondary raw materials.
- Allocation of energy, ancillary and operating materials used for individual products in a factory.

No multi-output allocation was necessary in the foreground of the study. Allocation of secondary data taken from ecoinvent v3.10.1 cut-off by classification has allocation applied to it.

This study uses the cut-off approach method for recycling. According to this approach, the first life of a material bears the environmental burdens of its production (e.g., raw material extraction and processing) and the second life (e.g., scrap input) bears the burdens of refurbishment (e.g., collection and refining of scrap). The burdens from waste treatment are taken on by the next life of the product and not included in this study. For all materials treated as waste in the model the end-of-waste boundary ends after processing. Specific datasets for waste treatment can be described in Appendix B: Background Datasets. End-of-waste state for final use materials ends with the treatment of the waste whereas the burdens of materials intended to be used in a second process will end after the transportation to the waste treatment facility.

2.8. Impact Assessment Method

Impact assessment methods are used to convert LCI data (environmental emissions and raw material extractions) into a set of environmental impacts.

In compliance with the PCR, Xypex C-2000 NF, Concrete Admixture products are assessed based on multiple impact categories listed in Table 2. Results are calculated using the EN15804 + A2 (adapted) V1.01/EF 3.1 method.

Table 2: Core Environmental Impact Categories

Impact Category	Description	Unit	Method
GWP - total	Global Warming Potential total (GWP - total)	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
GWP - fossil	Global Warming Potential fossil fuels (GWP - fossil)	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013

GWP - biogenic	Global Warming Potential biogenic (GWP - biogenic)	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
GWP - GHG	Global Warming Potential GHG	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
GWP - Land use and LU change	Global Warming Potential fossil fuels (GWP - luluc)	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
ODP	Depletion potential of the stratospheric ozone layer (ODP)	kg CFC 11 eq.	Steady-state ODPs, WMO 2014
AP	Acidification Potential	mol H^+ eq.	Accumulated Exceedance, Seppälä et al. 2006, Posch et al., 2008
EP - freshwater	Eutrophication potential, fraction of nutrients reaching freshwater end compartment	kg N eq.	EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe
EP - aquatic marine	Eutrophication potential, fraction of nutrients reaching freshwater end compartment	kg N eq.	EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe
EP - terrestrial	Eutrophication potential, Accumulated Exceedance	mol N eq.	Accumulated Exceedance, Seppälä et al. 2006, Posch et al.
POCP	Formation potential of tropospheric ozone	kg NMVOC eq.	LOTOS-EUROS ,Van Zelm et al., 2008, as applied in ReCiPe
ADP - minerals&metals	Abiotic depletion potential for non-fossil resources	kg Sb eq.	CML 2002, Guinée et al., 2002, and van Oers et al. 2002.
ADP - fossil	Abiotic depletion for fossil resources potential	MJ, net calorific value	CML 2002, Guinée et al., 2002, and van Oers et al. 2002.
WDP	Waster (user) deprivation potential, deprivation-weighted water consumption	m^3 world eq. deprived	Available WAter REmaining (AWARE) Boulay et al., 2016

Table 3: Core Environmental Impact Categories (TRACI 2.1)

Impact Category	Description	Unit
Ozone depletion	Depletion potential of the stratospheric ozone layer (ODP)	kg CFC 11 eq.
Global warming	Global Warming Potential GHG	kg CO_2 eq.
Smog	Smog formation	kg O_3 eq.
Acidification	Acidification Potential	mol H^+ eq.
Eutrophication	Eutrophication potential, fraction of nutrients reaching freshwater end compartment	kg N eq
Carcinogenics	Human toxicity related to cancer	CTUh
Non carcinogenics	Human Toxicity related to contaminants other than cancer	CTUh

Respiratory effects	Human health related to particulate matter	kg PM2.5 eq
Ecotoxicity	Potential of chemicals released into the environment	CTUe
ADP - fossil	Abiotic depletion for fossil resources potential	MJ surplus

These impact categories are required based on EN 15804:2012+A2:2019 standards. These standards are the basis of calculation methodology for the chosen PCR, ISO 21930:2017. Other categories are being developed and defined and LCA should continue making advances in their development. However, the EPD users shall not use additional measures for comparative purposes.

Global Warming Potential (GWP): Aligned with the purpose of low carbon energy sources and high priority environmental issues, this impact category is deemed to be of high interest and relevance. Biogenic, land transformation, and fossil categories are assessed and included in estimating GWP values.

Ozone depletion potential and Photochemical Ozone Creation Potential: To include potential environmental impacts associated with stratospheric ozone depletion and atmospheric ozone creation, mentioned categories are added to the study.

Acidification and Eutrophication: These two categories are considered relevant to the study due to potential release of chemicals to air and water through processing and fuel combustion.

Fossil fuel depletion: Certain raw materials could be used as nonrenewable sources of power generation, this category is deemed relevant and therefore, is added to the assessment.

Water use: This category is defined by the available water left after the demand of the process

A more detailed description of the impact categories is provided in Appendix A.

Each impact category above was characterized by a unit of measure to which the resource and emission flows have been normalized. To aggregate the substances into the impact categories, substances are multiplied by their characterization factor to convert into an equivalent substance (e.g., CO_2) and then added together to create a total for each impact category (e.g., global warming potential).

The following resource inventory metrics are included, as required by the specified PCR (Section 7.2.3.1, Part A). For this study only foreground data was considered. Results are calculated using the EN15804 + A2 (adapted) V1.01/EF 3.1 method.

Table 4: Additional environmental impact indicators

Resource Category Indicators	Description	Unit
Particulate Matter emissions	Potential incidence of disease due to PM emissions (PM)	Disease Incidence
Ionizing radiation, human health	Potential Human exposure efficiency relative to U235 (IRP)	kBq U235
Eco-toxicity (freshwater)	Potential Comparative Toxic Unit for ecosystems (ETP-fw)	CTUe
Human toxicity, cancer	Potential Comparative Toxic Unit for humans (HTP-c)	CTUh
Human toxicity, non-cancer effects	Potential Comparative Toxic Unit for humans (HTP-nc)	CTUh

Land use related impacts/ Soil quality	Potential soil quality index (SQP)	dimensionless

Table 5: Inventory Metrics

Resource Category Indicators	Description	Unit
RPRE	Use of renewable primary energy excluding renewable primary energy resources used as raw materials	MJ, LHV
RPRM	Use of renewable primary energy resources used as raw materials	MJ, LHV
RPRT	Total use of renewable primary resources with energy content	MJ, LHV
NRPRE	Use of non-renewable primary energy excluding nonrenewable primary energy resources used as raw materials	MJ, LHV
NRPRM	Use of non-renewable primary energy resources used as raw materials	MJ, LHV
NRPRT	Total non-renewable primary resources with energy content	MJ, LHV
SM	Use of secondary material	kg
RSF	Use of renewable secondary fuels	MJ, LHV
NRSF	Use of non-renewable secondary fuels	MJ, LHV
RE	Recovered energy from disposal of waste	MJ, LHV
ADP_{fossil}	Abiotic depletion potential for fossil resources	MJ, LHV
FW	Net use of fresh water	m^3

Following the ACLCA guidance document, the RPR_M and $NRPR_M$ inventory metrics in this report were calculated manually using net calorific value (lower heating value, MJ/kg) for the raw materials with energy content that were used as materials (ACLCA, 2019). The RPR_E and $NRPR_E$ were calculated as the difference between the total renewable and non-renewable primary energy, provided by the Cumulative Energy Demand (LHV) method, and the RPR_M and $NRPR_M$ inventory metrics, respectively (Weidema B P, 2013).

Net use of fresh water was determined by calculating the ReCiPe midpoint (h) method for water use from the life cycle inventory.

The following output flows and waste category indicators were included, as required by EN15804.

Table 6: Output flows and Waste Category Indicators

Output Flows and Waste Category Indicators	Description	Unit
HWD	Hazardous waste disposed	kg
NHWD	Non-hazardous waste disposed	kg
HLRW	High level radioactive waste	kg
ILLRW	Low level radioactive waste	kg
CRU	Components for re-use	kg
MR	Materials for recycling	kg
MER	Materials for energy recovery	kg
EE	Recovered energy exported from the product system	MJ, LHV per energy carrier

The Biogenic Carbon Removal and Emission from Packaging Carbon Emissions and Removals category indicators were included, as required by EN15804. The Biogenic Carbon Removal and Emission from Product Carbon Emissions and Removals category indicators are included for completion.

Table 7: Carbon Emissions and Removals Category Indicators

Category Indicators	Description	Unit
BCRK	Biogenic Carbon Removal from Packaging	kg CO2
BCEK	Biogenic Carbon Emission from Packaging	kg CO2
BCRP	Biogenic Carbon Removal from Product	kg CO2
BCEP	Biogenic Carbon Emission from Product	kg CO2

The biogenic removals are determined following the ACLCA guidelines by calculating the biogenic carbon content of raw materials used to manufacture the product or packaging. Any materials leaving the system through recycling contribute a negative carbon removal calculated in the same manner. Biogenic carbon emissions from incineration are also equated to the carbon content of the material since combustion is assumed to be complete. It is assumed that all remaining biogenic carbon is released as an emission of biogenic CO2 from the technosphere to nature.

2.9. Type and Format of the report

In order to comply with the ISO 14044 (ISO, 2006) requirements, this study reports the results and conclusions of the LCA completely and accurately without bias to the intended audience. The results, data, methods, assumptions, and limitations are presented in a transparent manner and in sufficient details to allow the reader to comprehend the complexities and trade-offs inherent in the LCA. This report allows the results and interpretation to be used in a manner consistent with the goals of the study supporting comparative assertions.

2.10. Limitations of the Study

The results of the study are only applicable to the defined scenarios. Any adjustment of the study boundaries or processes may change the results. The study limitations include:

- Per the PCR requirements, this study did not calculate the potential impact reductions of extending the lifetime of concrete by Xypex. It is possible that when compared to a building that does not use C-2000 NF, Concrete Admixture the savings would vary from the extended lifetime.
- Once the admixture product is mixed with the other concrete materials the product becomes inseparable. Following the mixture of these materials the admixture product is assumed to be treated the same as concrete for all subsequent modules.
- The results of this study apply to Xypex and do not represent potential impacts of concrete admixture products from other companies.

Environmental declarations from different programs may not be comparable (ISO 14025, 2006). Even when the same PCR is followed, different LCA software and background LCI datasets may lead to different results for upstream or downstream of the life cycle stages declared. EPD’s produced under this PCR do not include the operational impacts of the whole building or end of life impacts.

2.11. Limitations of LCA Methodology

LCA’s ability to consider the entire life cycle of a product makes it an attractive tool for the assessment of potential environmental impacts. Nevertheless, like other environmental management analysis tools, LCA has several limitations.

With the current availability of data, it is nearly impossible to follow the entire supply chain associated with the product in a company-specific way. Many of the processes within the supply chains are modeled using average industry data with varying amounts of specificity (e.g., data on a more-or-less specific technology or region). This makes it difficult to accurately determine how well the unit process data represents the actual factors in the product's life cycle.

Furthermore, LCA is based on a linear extrapolation of emissions with the assumption that all the emissions contribute to an environmental effect. This is contrary to threshold-driven environmental and toxicological mechanisms. Thus, while linear extrapolation is a reasonable approach for more global and regional impact categories such as Global Warming Potential (GWP) and Acidification, it may not accurately represent the actual on-the-ground human- and ecotoxicity-related impacts.

Additionally, even if the study has been critically reviewed, it should be noted that, as for any LCA, the impact assessment results generated for this study are relative expressions and do not predict impacts on category endpoints, exceeding thresholds, or risks (ISO 14040, 2006). It should also be noted that, even though LCA covers a wide range of environmental impact categories, some types of environmental impacts (e.g., noise, social, and economic impacts) are typically not included in LCA.

3. Life Cycle Inventory Data

The second phase of an LCA involves collection of LCI data. LCI data contains the details of the resources flowing into a process and the emissions flowing from a process to air, soil and water.

3.1. Calculation Tool

Once all the required data was obtained and the associated flows were normalized to the reference flows based on the functional unit (1 kg of product), system modeling was performed using the commercial LCA software SimaPro (version 9.6), developed by PRé Sustainability, the Netherlands. This software allows the calculation of life cycle inventories and impact assessment, contribution analysis, parameterization, and related sensitivity analysis.

3.2. LCI Data Collection

The study uses a combination of primary and secondary data. Where primary data was not available, default datasets were used from ecoinvent v3.10.1, Cut-off at Classification. This dataset contains detailed peer reviewed LCI data. Secondary data is sourced from a variety of literature sources, verified public reports and widely used databases. Each data point was reviewed and verified individually.

Under the direction of TrueNorth, Xypex collected primary manufacturing data and data from key suppliers. Representative unit processes were customized based on the type of material and recycled content, to represent the characteristics of actual input raw materials to the greatest extent possible. Primary data was collected through customizable templates and reviewed internally to ensure completeness and credibility. Common practices such as mass balance, energy balance and stoichiometry were considered. Final model inputs were reviewed by the client to verify key assumptions.

Annual facility-wide manufacturing and production data was provided by Xypex for a 12-month reference year, 2023. Manufacturing inventories were assigned using a mass allocation approach based on provided data of production volumes. In Table 7 - Table 13 below, the LCI data is shown for the C-2000 NF, Concrete Admixture product.

The scenarios included are currently in use and are representative of one of the most probable alternatives. Detailed description of processes and further documentation is provided in subsequent sections.

3.3. Extraction and upstream production (A1)

The supplied raw material detail was provided by Xypex and included within the model. Processes representing the materials are detailed in the forthcoming table and the input amounts shown refer to quantities required to manufacture 1 kg of product.

Table 8: Supplied Raw Materials per kg of product

Material	Amount	Unit
Cement	0.5-1	kg
Lime	0.1-0.2	kg
Proprietary Ingredient 1-3	0.01-0.2	kg
Tracer	>0.01	kg

3.4. Manufacturing - Packaging (A3)

Concrete admixture packaging consists of pallets, plastic, and cardboard. The input amount shown refers to average quantity required to package 1 kg of products and processes representing the material are listed in the Appendix B: Background Datasets. This information was provided by Xypex and included within the model.

Table 9: Packaging Materials per kg of product

Material	Amount	Unit	Biogenic Content (%)	Biogenic Content (kg C)	Biogenic Content (kg CO2e)
Pallets	0.017	kg	40.98%	7.09E-03	2.60E-02
Cardboard	0.035	kg	45.02%	1.56E-02	5.71E-02
Plastic sheet	5.54E-05	kg	0	0	0
Plastic wrap	0.003	kg	0	0	0

Biogenic carbon is included in the pallets (0.00709 kg of carbon per kg of product) and cardboard (0.0156 kg of carbon per kg of product).

3.5. Transportation to factory (A2)

Transportation modes and distances representing concrete admixture product supply chain network are found in the table below. These refer to the average distances that each material type travels from supplier to the Xypex manufacturing site, inclusive of the distance required to transport the excess weight required to account for yield losses. This detail was provided by Xypex and included within the model. Processes representing the transportation are listed in the corresponding appendix. Tracer distances are separated into three stages to account for the material transferring to different transportation types throughout the distribution.

Table 10: Transportation Modes and Distances of Inputs

Material and Link	Transportation Mode	Distance	Unit
Cement	Truck	16	km
Lime	Truck	8	km
Proprietary Ingredients 1-3	Truck	16-32	km
Tracer	Truck	32	km
Tracer	Freight	8531	km
Tracer	Truck	16	km

3.6. Manufacturing (A3)

Manufacturing of concrete admixture products include several processing steps.

1. Cement is blown into silos, which are augered into a weigh hopper above the mixer.
2. Lime is received in super sacks and suspended above a feeder. The lime is then sent through a weigh hopper.
3. Smaller constituents are added to the top of the mixer by hand.
4. The batcher selects the recipe from the panel and the PLC determines how much of each material is fed into the mixer.
5. The batch is mixed,
6. The batch is dispensed into the appropriate container and added to a pallet

The manufacturing module includes manufacturing of products and co-products:

- A3, use of various fuel sources within the manufacturing process
- A3, generation of electricity from primary energy resources used in manufacturing including their extraction, refining and transport
- A3, water use within the manufacturing process
- A3, emissions from the combustion of secondary fuels and waste used in the manufacturing process
- A3, waste management from manufacturing and manufacturing wastages transport up to the recycler or disposal

Concrete admixture manufacturing impacts and emissions are disclosed in the subsequent table. Amounts refer to inputs required, and outputs generated from manufacturing 1 kg of product. This detail was provided by Xypex and is included within the model. For transportation of packaging materials to Xypex and of waste from Xypex to treatment centers, 60 km was used as an estimate.

Emissions data refers to combustion onsite but may not track all relevant substance emissions. Ecoinvent proxies were used to estimate combustion emissions not measured directly by Xypex (including CO2). Substances which are measured by Xypex were removed from these proxies and modelled separately, to avoid double counting. Only the directly measured emissions are disclosed in the table.

Emissions listed only account for on-site emissions and do not include any upstream energy production. Background data in the form of Ecoinvent library processes account for upstream emissions. Processes representing the manufacturing activities are listed in the appendix. The manufacturing input totals for C-2000 NF, Concrete Admixture production is provided by Xypex. The electricity totals for operations and office use are modeled with the conservative estimate for local energy grid using ecoinvent library process for CA-BC grid mix.

Table 11: Manufacturing Processes per kg product

Manufacturing Processes	Amount	Unit
Inputs		
Electricity	0.034	kWh
Propane - Super Save	0.001	kg
City of Richmond Water	1.85E-06	Cubic Meters
Waste		
Recycle	4.00E-05	Cubic Meters
Organics Waste (food)	1.35E-05	Gallons
General Waste	6.15E-05	Cubic Meters

3.7. Transport to site (A4)

This module is optionally disclosed following the PCR guidance. Transportation modes and distances representing concrete admixture product distribution are included in module A4. This detail is estimated by Xypex to be 60 km. This estimation is based on previous assumptions in similar product specific EPD's from Xypex. Utilization factors for transportation of product are provided by Xypex to be 85%.

3.8. Assembly/Installation of Products (A5)

This module is optionally disclosed following the PCR guidance. Assembly and installation for concrete admixture products include water and power used in installation, packaging waste, and transportation of packaging waste to the treatment facility.

The end of life for packaging materials (both for installed product and product loss) is included in this stage and was based on disposal assumptions documented in the PCR for paper and plastic packaging. The following assumptions are included in module A5.

- An estimated 50 km is used for the transport of packaging waste to the treatment facilities.
- Waste assumptions for packaging materials follow the following material type percentages based on EPA end-of-life assumptions in the Advancing Sustainable Materials Management: 2018 Fact Sheet.
    - Paper and paperboard: 68.2% Recycling; 6.2% Combustion; and 25.6% Landfill
    - Plastic: 8.7% Recycling; 15.8% Combustion; and 75.5% Landfill

Processes representing the assembly and installation are listed in Table 12 below. Amounts refer to the functional unit of 1 kg of concrete admixture. Disposal and transportation may vary based on product category. Processes representing the auxiliary materials and packaging disposal are listed in the appendix.

Table 12: Assembly/Installation Inventory per kg of product

Process Descriptions	LD Amount	Unit
Product Loss		
Installation Water	0.530	litre
Auxiliary Materials		
Installation Power	2.00E-04	MJ
Disposal of Packaging Waste		
Packaging Waste pallets	0.017	kg
Packaging Waste pulp	0.035	kg

Packaging waste plastic	0.003	kg
Waste Transport		
Packaging waste transport	2.760	kgkm

3.9. Product Use (B1-B7)

These modules are optionally disclosed following the PCR guidance. The concrete admixture product is assumed to follow the same assumptions as concrete considering the product is inseparable from the other components of concrete. Concrete assumptions require no maintenance, repair, or operation inputs throughout the lifetime of the product as referenced in the EPD developed for Xypex Admix C-1000 NF, a similar product to C-2000 NF, Concrete Admixture. Under these assumptions, modules B1-B7 are assumed to be equal to zero. Similar products in the market include product use phases therefore B1-B7 are included in this report and are assumed to be zero.

3.10. End of Life (C1-C4)

Removal at the end of life requires only human labor and does not contribute to lifetime environmental impacts. The modules included in end of life are described below.

- C1 - Default data for modelling module C1 are used for demolition and destruction (Erlandsson et al. (2015)

Table 13: End of Life Inventory per kg of product

Process Descriptions	LD Amount	Unit
Demolition and Deconstruction	0.010	kwh

- C2 - A transportation distance of 50 km is assumed for distance travelled from Xypex to the waste treatment facility.
- C3 - Included in this analysis but will have zero impacts by following the cut-off method.
- C4 - The product is recycled at an 82.4% rate in accordance with EPA 2020 C&D Debris Management by Material and Destination with the remaining 17.6% disposed of in a landfill.

These assumptions fulfill the end-of-waste state described in section 2.7. The waste treatment of final use materials is modeled with waste treatment for the material disposed in the landfill. The recycled material burden ends with transportation to the waste treatment facility.

3.11. Module D: Potential Loads and Benefits Beyond the System Boundary

Module D provides information on potential loads and benefits of secondary material, secondary fuel or recovered energy leaving the product system. LCA results in Module D are based on the net output flow for all products for reuse, secondary materials, secondary fuels and/or recovered energy leaving the product system: that is the output flows minus any input flows.

In the concrete admixture studied in this project, no secondary fuel or recovered energy are produced, no secondary materials are integrated into the product, and no scrap material is recovered in manufacturing. Net benefit and load are calculated from the replacement of new aggregate materials with recycled aggregate materials. A load is applied to account for the transformation of recycled materials for use. Concrete recycling and replaced aggregate materials are determined from modification of the ecoinvent processes described in the section labelled D Datasets. The portion of cement in concrete is determined from the ecoinvent description, 281.8 kg of cement per 2309 kg of concrete. Using the specifications for C-2000 NF, Concrete Admixture, a 2% assumption of the amount of admixture per cement is used. The potential loads and benefits are determined from the impact of admixture in recycled concrete compared to the admixture in aggregate being replaced.

ISO 21930 provides the following procedure for calculating potential benefits in Module D:

- Identify the point of substituted functional equivalence where the secondary material or fuel or recovered energy substitutes primary production.
- Add the loads associated with any further processing occurring beyond the system boundary that is required to reach the point of substituted functional equivalence.
- Subtract the impacts resulting from the substituted production of the product or generation of the energy.
- Apply a justified correction factor to reflect the difference in functional equivalence where the processed net output flow does not reach the functional equivalence of the substituting process.

Further details are provided for each product type in Table 14 below.

Table 14: Primary Production Potentially Substituted by Recovered Materials from C-2000 NF, Concrete Admixture

Life Cycle States	Flow Type	Material	Admixture	Unit, per kg of final product
A1 Raw Materials consumption	(-) Secondary Material used	None	0	Kg
A3 Scrap and excess materials recovered	(+) Material recovery	None	0	kg
C4 Materials recovered	(+) Material recovery	Crushed Concrete	0.824*	kg
Net Material flow		Crushed Concrete	0.824	kg

** Includs a load associated with transformation*

Additionally, a portion of the product and packaging is recycled at the end-of-life. The associated biogenic emission from this recycled material is added to module D following the ACLCA 21930 calculation guidance of products in module C3 and packaging in module A5. Any remaining biogenic carbon not accounted for may result from average or generic background datasets for landfilling and incineration and may have to be corrected to match the specific carbon content of the disposed waste.

3.12. Fuels and Energy

Electricity consumption and other sources of fuels and energy are modeled based on the most representative fuel mix and technology from Ecoinvent v.3.10.1, 2024. Processes representing energy use are listed in the appendix. Energy used in A3 is modeled using the dataset described in Appendix B: Background Datasets. The dataset for grid electricity, Electricity, medium voltage {CA-BC}| market for electricity, medium voltage | Cut-off, U, in the CA-BC region was used in the model. In SimaPro the ecoinvent process included regional data for CA-BC specific electricity. The GWP-GHG impact for this process is 0.074 kg CO_2e/kWh. The process used for electricity in the model is calculated from the following sources: hydroelectricity (94.02%), natural gas (2.50%), oil (0.08%), wind (2.64%), wood (0.69%), and biogas (0.07%).

3.13. Data Quality

Life cycle inventory data used in this study are evaluated based on three categories: precision and completeness, consistency and reproducibility, and representativeness.

Precision and completeness: Foreground data are sourced from primary information provided by the client and has been reviewed internally to ensure precision and completeness. In order to balance out seasonal variations, operations data over a 12-month period is used to represent production activities. In addition, key model input such as mass balance, energy balance and emission inventory are reviewed by TrueNorth Collective team.

Ecoinvent v3.10.1 is used as the main database for background data. This version is published in 2023. Ecoinvent is widely used in research and industry to support life cycle assessment practices. Each version of this database goes through thorough review process and documentation of precision and completeness is available by the provider.

Consistency and reproducibility: To ensure consistency, primary data were collected at the same level of granularity. All input and output information, modelling assumptions and dataset choices are provided in this report for the purpose of reproducibility.

Representativeness: Refer to the sections above for details about representativeness.

3.13.1. Exceptions

There are no exceptions in inclusion of value-added activities and all flows are included in this study.

3.13.2. Technology Coverage

This study uses a mix of primary and secondary data modeled using Ecoinvent v3.10.1 database to represent the raw material supply, transportation and manufacturing energy inputs.

Technology coverage for this study is determined to be very good following the guidance in EN15804. The data represents that from processes and products under study. Same state of technology applied as defined in goal and scope (i.e. identical technology)

3.13.3. Geographic Coverage

The end-to-end process is fully developed and implemented in Richmond, British Columbia, Canada.

Input and output flows are selected to represent Canadian-specific activities where granular inventory is available. Regional electricity process for Canada was chosen. Canadian-specific inventory flows and proxies are used where available to represent the production pathways in Canada. For processes following the manufacturing of the product global average data is used to represent the concrete materials.

Geographic coverage for this study is determined as good following the guidance in EN15804. The data represented includes average data from larger areas in which the area under study is included.

3.13.4. Time Coverage

Primary data from section 3 represents operations in the year 2023. In addition, secondary data are modeled using Ecoinvent v3.10.1.

Time coverage for this study is determined as very good following the guidance in EN15804. The data represented is less than 3 years difference between the reference year according to the documentation, and the time period for which data are representative.

3.13.5. Treatment of Missing data

No known data was excluded in this study.

3.14. Assumptions & Estimations

Assumptions and estimations used within the LCA are described below:

- Lifetime
- o All concrete admixture products are assumed to last the building service life of 75 years.
    - Provided data for raw material inputs from Xypex included unused inventory. Mass-balance was performed using produced material to account for this unused inventory.
- Transportation
    - Transportation distances of packaging materials are estimated by Xypex as 60 km.
    - No data was collected regarding transport distance to disposal (in A5 for packaging waste and C2 for product End of Life). In all cases, 50 kilometers by truck was assumed.
    - Utilization rates were used to determine the capacity of the truck used in concrete admixture transport. A transport capacity of 85% is provided by Xypex.
- End of Life
    - Waste assumptions for packaging materials follow the following material type percentages based on EPA end-of-life assumptions in the Advancing Sustainable Materials Management: 2018 Fact Sheet
    - Default data for modelling module C1 are used for demolition and destruction (Erlandsson et al. (2015)
    - The concrete admixture assumes the disposal scenarios of concrete. The product is recycled at an 82.4% rate in accordance with EPA 2020 C&D Debris Management by Material and Destination with the remaining 17.621% disposed of in a landfill.

4. Life Cycle Assessment Results

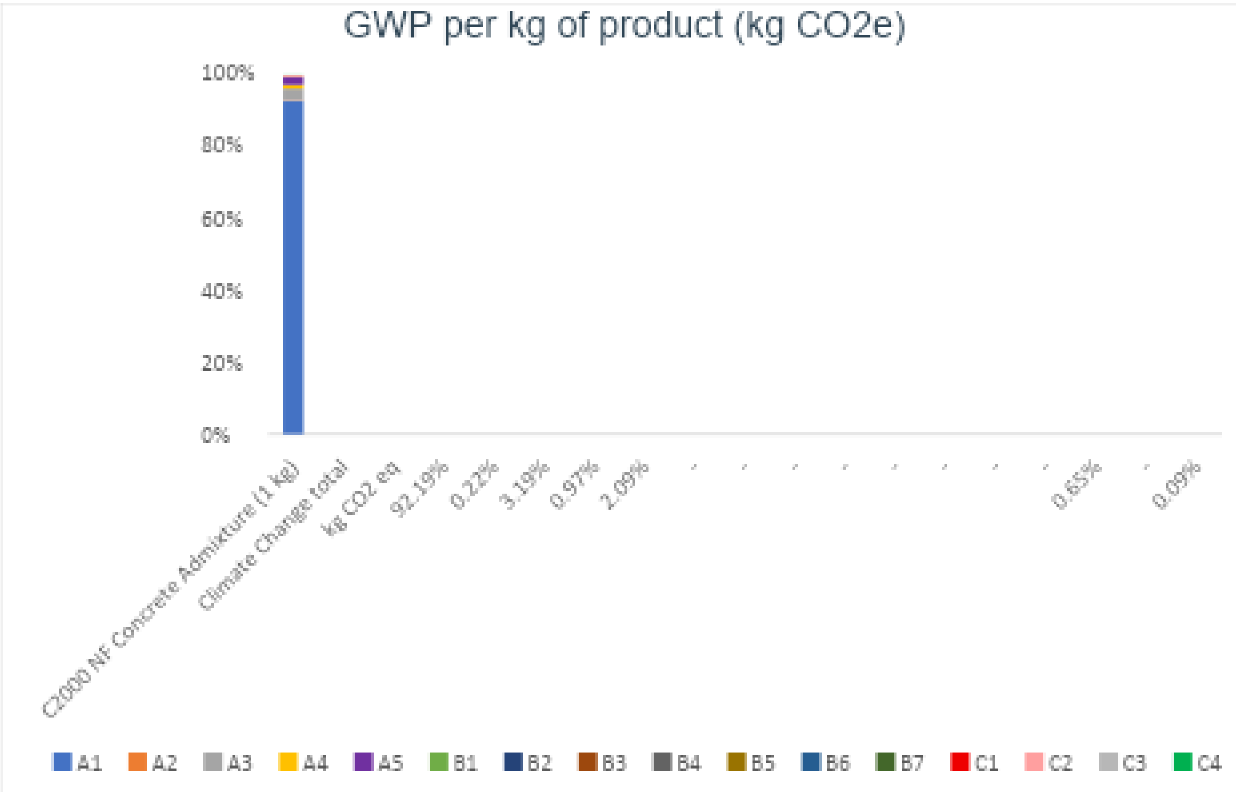
This section includes environmental impact assessment results C-2000 NF, Concrete Admixture. Results are declared per kg of concrete admixture. Refer to the EPD for all inventory and potential environmental results tables pertaining to the product in study. LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

4.1. Contribution Results

Figure 2 shows a breakdown of the impact categories for C-2000 NF, Concrete Admixture. Life cycle stages are described in section 2.4. Modules B1-B7 and C3 are assumed to have no impact based on the concrete assumptions and cut-off method used in the study. The contribution analysis indicates that the majority of the potential impacts occur as a result of raw material supply (A1), ranging from 32% to 96%

among all categories, and manufacturing impacts (A3), ranging from 1% to 45% among all categories. The climate change impact for cradle-to-gate for the product is 1.08 kg CO2e/kg.

Figure 2: Product Contribution Results



The tables below indicate specific results for the impact assessment, resource category indicators, output flows and waste category indicators for 1 kg of concrete admixture product. Output Flows and Waste totals for all concrete admixture products are 0 therefore are not included in the tables within this section.

Table 15 displays the calculated results for C-2000 NF, Concrete Admixture.

Table 15: Impact Assessment Results per kg of product

Impact Category	Unit	A1-A3	A4	A5	C1	C2	C4	D
GWP - total	kg CO2 eq.	1.12E+00	1.13E-02	8.60E-02	7.25E-03	7.60E-03	3.74E-02	2.20E-05
GWP - fossil	kg CO2 eq.	1.24E+00	1.13E-02	2.90E-03	7.24E-03	7.57E-03	1.10E-03	2.20E-05
GWP - biogenic	kg CO2 eq.	-1.19E-01	0.00E+00	8.31E-02	0.00E+00	0.00E+00	3.63E-02	0.00E+00
GWP - GHG*	kg CO2 eq.	1.24E+00	1.13E-02	2.91E-03	7.25E-03	7.60E-03	1.10E-03	2.20E-05
GWP - Land use and LU change	kg CO2 eq.	6.41E-03	3.76E-05	2.19E-06	9.71E-06	2.53E-05	5.66E-07	1.89E-08
ODP	kg CFC 11 eq.	1.49E-08	1.90E-10	1.36E-10	4.66E-11	1.28E-10	3.18E-11	3.60E-13
AP	mol H+ eq.	4.24E-03	5.16E-05	9.21E-06	3.52E-05	3.46E-05	7.79E-06	1.90E-07
EP - freshwater	kg P eq	2.03E-04	9.20E-07	3.60E-07	3.13E-06	6.17E-07	9.13E-08	5.17E-09

EP - aquatic marine	kg N eq.	1.36E-03	1.97E-05	2.09E-05	7.04E-06	1.32E-05	2.97E-06	8.81E-08
EP - terrestrial	mol N eq.	1.20E-02	2.12E-04	2.75E-05	7.09E-05	1.42E-04	3.24E-05	9.52E-07
POCP	kg NMVOC eq.	3.98E-03	7.32E-05	1.28E-05	2.10E-05	4.91E-05	1.16E-05	2.86E-07
ADP - minerals&metals	kg Sb eq.	6.55E-06	3.54E-08	5.02E-09	6.56E-09	2.38E-08	1.72E-09	-1.28E-11
ADP - fossil	MJ, net calorific value	1.29E+01	1.61E-01	1.92E-02	9.33E-02	1.08E-01	2.69E-02	3.12E-04
WDP	m3 world eq. deprived	9.24E-03	2.46E-05	4.92E-04	4.44E-05	1.65E-05	2.80E-05	-2.93E-06

*There are no methane emissions included in this impact calculation

Table 16: Impact Assessment Results per kg of product (TRACI 2.1)

Impact Category	Unit	A1-A3	A4	A5	C1	C2	C4	D
Ozone depletion	kg CFC-11 eq	1.73E-08	2.06E-10	1.67E-10	8.32E-11	1.38E-10	3.40E-11	3.96E-13
Global warming	kg CO2 eq.	1.12E+00	1.13E-02	8.60E-02	7.25E-03	7.60E-03	3.74E-02	2.20E-05
Smog	kg O3 eq	6.11E-02	1.22E-03	1.50E-04	4.04E-04	8.19E-04	1.87E-04	5.58E-06
Acidification	kg SO2 eq	3.58E-03	4.65E-05	8.64E-06	3.02E-05	3.12E-05	7.02E-06	1.76E-07
Eutrophication	kg N eq	2.55E-03	1.23E-05	4.27E-04	3.15E-05	8.28E-06	1.32E-06	5.29E-08
Carcinogenics	CTUh	1.78E-07	3.01E-09	1.78E-09	1.12E-09	2.02E-09	2.76E-10	2.81E-12
Non carcinogenics	CTUh	2.80E-07	2.72E-09	4.25E-09	1.79E-09	1.83E-09	1.11E-10	3.16E-11
Respiratory effects	kg PM2.5 eq	5.95E-04	6.77E-06	1.52E-06	9.44E-06	4.54E-06	9.89E-07	1.53E-07
Ecotoxicity	CTUe	1.35E+01	1.43E-01	2.21E-01	6.51E-02	9.58E-02	8.52E-03	1.10E-03
Fossil fuel depletion	MJ surplus	1.43E+00	2.12E-02	1.92E-03	5.24E-03	1.43E-02	3.68E-03	4.19E-05

Table 17: Additional environmental impact indicators per kg of product (EN15804 + A2)

Impact Category	Unit	A1-A3	A4	A5	C1	C2	C4	D
Particulate Matter emissions	Disease Incidence	4.53E-08	1.11E-09	1.28E-10	3.14E-10	7.44E-10	1.77E-10	3.56E-11
Ionizing radiation, human health	kBq U235	3.51E-02	1.49E-04	7.59E-05	9.85E-04	9.99E-05	1.72E-05	2.25E-07
Eco-toxicity (freshwater)	CTUe	1.34E+01	7.55E-02	4.02E-01	1.83E-02	5.07E-02	3.68E-03	9.59E-05
Human toxicity, cancer	CTUh	6.79E-09	6.02E-11	1.55E-11	7.77E-12	4.04E-11	4.96E-12	3.75E-14

Human toxicity, non-cancer effects	CTUh	1.35E-08	1.14E-10	9.53E-11	3.99E-11	7.66E-11	4.60E-12	9.61E-14
Land use related impacts/ Soil quality	dimensionless	9.47E+00	1.27E-01	1.58E-02	1.39E-02	8.50E-02	5.30E-02	-4.94E-04

Table 18: Resource Category Indicators per kg of product

Resource Category Indicators	Unit	A1-A3	A4	A5	C1	C2	C4	D
RPRE	MJ	2.94E+00	2.35E-03	1.24E-03	1.13E-02	1.58E-03	2.50E-04	4.60E-06
RPRM	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RPRT	MJ	2.94E+00	2.35E-03	1.24E-03	1.13E-02	1.58E-03	2.50E-04	4.60E-06
NRPRE	MJ	1.40E+01	1.72E-01	2.05E-02	9.92E-02	1.15E-01	2.87E-02	3.32E-04
NRPRM	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRPRT	MJ	1.40E+01	1.72E-01	2.05E-02	9.92E-02	1.15E-01	2.87E-02	3.32E-04
SM	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	m^3	3.15E-01	7.91E-04	2.10E-02	1.13E-03	5.31E-04	1.18E-03	-1.26E-04

Table 19: Output Flows and Waste Category Indicators per kg of product

Output Flows and Waste	Unit	A1-A3	A4	A5	C1	C2	C4	D
HWD	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NHWD	kg	1.11E-02	0.00E+00	1.95E-02	0.00E+00	0.00E+00	1.76E-01	0.00E+00
HLRW	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ILLRW	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MR	kg	4.81E-03	0.00E+00	3.57E-02	8.24E-01	0.00E+00	0.00E+00	0.00E+00
MER	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EE	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 20: Carbon Emissions and Removals Category Indicators per kg of product

Carbon Category Indicators	Unit	A1-A3	A4	A5	C1	C2	C4	D
BCRK	kg CO2-eq	-8.31E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCEK	kg CO2-eq	0.00E+00	0.00E+00	8.31E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

BCRP	kg CO2-eq	-3.63E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BCEP	kg CO2-eq	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-02	0.00E+00

5. Life Cycle Interpretation and Recommendations

For the C-2000 NF, Concrete Admixture analyzed all modules were analyzed in the study. Some modules had an impact equal to zero because concrete does not require inputs for the use phase and the cut-off approach was applied to waste scenarios. The product cannot be separated from concrete therefore the lifecycle includes no use phase impacts. For the product studied the global warming potential impacts were largely due to the raw material supply, about 89.21%. While this is expected, considering the low waste and low energy demand for the product, it also gives the largest opportunity of potential with the substitution of materials with less impact. Incorporating recycled materials like recycled aggregate, or crushed glass may help to reduce the product impact for global warming potential. There is also a small impact for global warming potential from disposal of product at the end of life, less than 6%. Potential impacts from transportation of products to installation and end-of-life transportation for all products were the least significant contributors.

Relative to the Use Phase of the C-2000 NF, Concrete Admixture products, Xypex claims that the product has the ability to double the typical lifetime of concrete through crystallization within the structure. This crystallization allows for more waterproofing and less degradation for the concrete along the lifecycle. With this benefit, concrete that implements C-2000 NF, Concrete Admixture can assume a longer lifetime compared to the competitor products. The product can assume a benefit equal to the impacts of A1-A5 of producing the product minus the impact from transforming recycled material for use (the products load).

LCA results are based on a relative approach and indicate potential environmental effects therefore do not predict actual impacts on category impacts. The estimated impact results are only relative statements which do not indicate the end points of the impact categories, exceeding threshold values, safety margins or risks.

5.1. Findings

The analysis of concrete admixture products provide useful insights regarding the cradle-to-gate with options environmental impacts. The LCA results also identify where substantial impacts are occurring to allow further process and materials improvements to be implemented by Xypex.

5.1.1. Completeness Check

Detailed information on the inputs and outputs of the C-2000 NF, Concrete Admixture product was gathered with every effort made to perform a comprehensive analysis. An attempt was made to include as much detail as possible, even for processes that were found to be largely negligible in the environmental impact assessment. Processes were mass-balanced before allocation to ensure all waste and emissions were captured. This was done to ensure completeness. Furthermore, all energy consumption that was understood as relevant for the comparison was included.

5.1.2. Consistency Check

The products were modeled in a consistent manner. System boundaries for all products were defined in a similar manner. Therefore, any differences in overall potential environmental impacts should not be due to inconsistent modeling or data.

Some of the data provided in this report is based on information supplied by the manufacturer. TrueNorth Collective is not responsible for the accuracy, completeness, or reliability of the data provided by the manufacturer.

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Appendix A: Description of impact categories

Global Warming Potential (GWP): Aligned with the purpose of low carbon energy sources and high priority environmental issues, this impact category is deemed to be of high interest and relevance. Biogenic and non-biogenic carbon are assessed and included in estimating GWP values. In this study short-lived renewable or biogenic carbon dioxide uptake and release is considered to be neutral with respect to global warming emissions.

Background:

Global warming occurs at both regional and global levels. When the short-wave radiation from the sun reaches the earth's surface, a portion of the radiation is absorbed, and the rest is reflected as infrared radiation. The reflected portion is absorbed by greenhouse gases, scattered in multiple direction, and contributes to the warming of the earth. Major greenhouse gases include carbon dioxide, carbon monoxide, methane and CFCs. The global warming potential is expressed in CO_2 equivalent meaning that contributing gases are measured and expressed in one harmonized unit. Common residence time of gases in the atmosphere is defined as 100 years.

Ozone depletion potential and Smog formation: To include potential environmental impacts associated with stratospheric ozone depletion and atmospheric ozone creation, mentioned categories are added to the study.

Background:

Ozone layer acts as a shield for life on earth. It traps ultraviolet radiations which can penetrate to organism protective layers and damage DNA. Release of certain chemicals can contribute to the depletion of ozone layer in stratosphere. Ozone depletion potential is defined as potential of a chemical in degrading ozone layer. Common contributors include Halons, Chlorofluorocarbons (CFCs) and Hydrofluorocarbons (HFCs). For this category, impacts are expressed based on kg CFC-11 equivalent.

Smog formation is a result of ozone creation in the troposphere. It can damage vegetation and materials, and in high concentrations, it can be toxic to humans as well. Nitrogen oxides, chlorin compounds and hydrocarbons can react at ground level and create ozone. High concentration of ozone arises in high temperature, low humidity and when air is static. Impacts of this category are measured and expressed in kg O_3 equivalent.

Acidification and Eutrophication: These two categories are considered relevant to the study due to potential release of chemicals to air and water through processing and fuel combustion.

Background:

Acidification of soil and water bodies is caused by transformation of air pollutants to acid molecules. In this situation, the PH-level of rainwater and fog, drops to the acidic range, and it can damage ecosystems, nutrient balance of the soil, and buildings. Ammonia, hydrogen sulfides and chlorides, NO_x and SO_x are common contributors to this impact category. Although, this effect can happen at global level, the regional impacts can vary significantly. The impacts of this category are measured and expressed in kg SO_2 equivalent.

Eutrophication refers to excess of nutrient in aquatic or terrestrial environments. It can cause algal growth which prevents sunlight from reaching the lower depth of water and depletes available oxygen needed for growth of aquatic organisms. Air pollutants, wastewater and fertilization in agriculture can contribute to this impact. Phosphorus, ammonia and nitrogen compounds are considered as important pollutants. Impacts of this category as measured and expressed in kg Nitrogen equivalent.

Human Toxicity (carcinogenic, non-carcinogenic and respiratory effects): To address potential concerns related to combustion emissions from plastic waste, this indicator is added to shine a light on human health perspective. It is known that current methodologies have high uncertainties. The intent is to represent best estimate for potential health effects.

Background:

Carcinogenic and non-carcinogenic categories are focused on chemicals that can potentially damage human health. This category uses USEtox model to evaluate health effects of over 300 different chemicals. It's developed in continental and global scales and takes into account toxicity related to ingestion exposure and inhalation exposure. The comparative toxic unit for human toxicity impacts (CTUh) expresses the estimated increase in morbidity (the number of disease cases) in the total human population per unit of mass of the chemical emitted.

Ecotoxicity: This category is added to the study to consider potential effects of chemical pollution in freshwater bodies.

Background:

With focus on health of ecosystems, this impact category evaluates potential toxicity in fresh water as a result of chemical emissions. The background model is USEtox and (CTUe) expresses the estimated potentially affected fraction of species (PAF) integrated over time and the volume of the freshwater compartment, per unit of mass of the chemical emitted. In practice: PAF × m^3 × day per kg emitted = CTUe per kg emitted.

Fossil fuel depletion: Since the studied solution can replace nonrenewable sources of power generation, this category is deemed relevant and therefore, is added to the assessment.

Background:

This impact category evaluates the reduction of the global amount of fossil fuels. The results are measured and expressed in MJ surplus, translating to the surplus energy needed for future mining and extraction of fossil fuels.

Appendix B: Background Datasets

Extraction and upstream production Datasets

All raw material datasets and proxies specified in the tables below represent 1 kg of material input.

Material	Library Process 1	Amount 1	Unit 1
Cement	Cement, Portland {RoW}| market for cement, Portland | Cut-off, U	1	kg
Lime	Lime {RoW}| market for lime | Cut-off, U	1	kg
Proprietary Ingredient 1	see SimaPro	1	kg
Proprietary Ingredient 2	see SimaPro	1	kg
Proprietary Ingredient 3	see SimaPro	1	kg
Tracer	Aniline {RoW}| market for aniline | Cut-off, U	1	kg

Manufacturing Datasets

All manufacturing input datasets and proxies specified in the tables below represent 1 kg of material input.

Process/Material	Library Process 1	Amount 1	Unit 1
Electricity	Electricity, medium voltage {CA-BC}| market for electricity, medium voltage | Cut-off, U	0.333	kWh
Propane - Super Save	Propane, burned in building machine {GLO}| market for propane, burned in building machine | Cut-off, U	14.969	BTU
City of Richmond Water	Tap water {RoW}| market for tap water | Cut-off, U	1.85E-03	kg

Installation Datasets

All installation input datasets and proxies specified in the tables below represent 1 kg of material input.

Material	Library Process 1	Amount 1	Unit 1
Installation Water	Tap water {RoW}| market for tap water | Cut-off, U	1	kg
Installation Power	Electricity, medium voltage {CA-BC}| market for electricity, medium voltage | Cut-off, U	1	MJ

Transportation Datasets

The transportation distances and modes are modeled using ecoinvent v3.10.1 datasets shown in the table below. These datasets cover the transport of supplied materials to production facilities, distribution of finished goods and transport of product to disposal at End-of-Life.

Transportation	Library Process 1	Amount 1	Unit 1
Ground Transportation (Truck)	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	1	kgkm
Freight Forwarder (International)	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	1	kgkm

Waste Datasets

The waste processes are modeled using ecoinvent v3.10.1 datasets shown in the table below. These datasets cover the wastes of materials during production at the facility and end-of-life. The demolition and deconstruction process uses the electricity source from a global grid as a conservative assumption for the end user location.

Waste Materials

Material	Library Process 1	Amount 1	Unit 1	Library Process 2	Amount 2	Unit 2	Library Process 2	Amount 2	Unit 2
Recycle	Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U	120.331	lb						
Organics Waste (food)	Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U	0.668	lb						
General Waste	Municipal solid waste {RoW}| market for municipal solid waste | Cut-off, U	180.497	lb						

Packaging Waste pallets	Waste wood, untreated {GLO}| treatment of waste wood, untreated, unsanitary landfill, wet infiltration class (500mm) | Cut-off, U	0.256	kg	Empty process for recycling	0.682	kg	Waste wood, untreated {GLO}| treatment of waste wood, untreated, municipal incineration | Cut-off, U	0.062	lb
Packaging waste plastic	Empty process for recycling	0.087	kg	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	0.755	kg	Waste plastic, mixture {GLO}| treatment of waste plastic, mixture, municipal incineration | Cut-off, U	0.158	kg
Packaging Waste pulp	Empty process for recycling	0.682	kg	Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill | Cut-off, U	0.256	kg	Waste paperboard {GLO}| treatment of waste paperboard, municipal incineration | Cut-off, U	0.062	kg
EoL waste	Empty process for recycling	0.824	kg	Inert waste, for final disposal {RoW}| treatment of inert waste, inert material landfill | Cut-off, U	0.176	kg			
Demolition_Deconstruction	Electricity, medium voltage {GLO}| market group for electricity, medium voltage | Cut-off, U	1	kwh						

Packaging Datasets

The packaging materials are modeled using ecoinvent v3.10.1 datasets shown in the table below. These datasets cover the production and transport of supplied materials to production facilities, distribution of finished goods and transport of product to disposal at End-of-Life.

Material	Library Process 1	Amount 1	Unit 1	Library Process 2	Amount 2	Unit 2

Pallets	Plywood {RoW}| market for plywood | Cut-off, U	1.27E-04	kg			
Cardboard	Corrugated board box {RoW}| market for corrugated board box | Cut-off, U	1	kg			
Plastic sheet	Polyethylene, linear low density, granulate {GLO}| market for polyethylene, linear low density, granulate | Cut-off, U	1	kg	Extrusion, plastic film {GLO}| market for extrusion, plastic film | Cut-off, U	1	kg
plastic wrap	Polyethylene, linear low density, granulate {GLO}| market for polyethylene, linear low density, granulate | Cut-off, U	1	kg	Extrusion, plastic film {GLO}| market for extrusion, plastic film | Cut-off, U	1	kg

D Datasets

The materials used in module D are modeled using ecoinvent v3.10.1 and IDEMAT datasets shown in the table below. These datasets cover the production and transport of supplied materials to production facilities, distribution of finished goods and transport of product to disposal at End-of-Life. These datasets are used to understand loads and benefits of materials

Material	Library Process 1	Amount 1	Unit 1	Library Process 2	Amount 2	Unit 2	Library Process 3	Amount 3	Unit 3	Library Process 4	Amount 4	Unit 4
Concrete Recycling/ Replacing Aggregate	Gravel, round {RoW}| market for gravel, round | Cut-off, U	-4.16E-01	kg	Sand {RoW}| market for sand | Cut-off, U	-4.11E-01	kg	Waste reinforced concrete {RoW}| treatment of waste reinforced concrete, recycling | Cut-off, U	1	kg	Waste reinforced concrete {RoW}| treatment of waste reinforced concrete, sorting plant | Cut-off, U	1	kg
Module D	Concrete Recycling/Replacing Aggregate	1	p									

Appendix C: Critical Review Statement and Record

To be added once available.

About TrueNorth Collective

TrueNorth Collective is a team of passionate professionals committed to helping others on their journeys toward true sustainability using best-in-class Design for Sustainability resources. To move towards true sustainability, it must be embedded, and we can help.

We combine data analysis with a human centered mindset to inform strategy to integrate robust process and accountability within organizations large and small. We do this through custom projects, tailored education and pilots using Design for Sustainability and Life Cycle Assessment methodologies that we have refined over the past 12 years.

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