NSF Product Category Rule
for Environmental Product Declarations

NSF 1125-25

Fiber Reinforced Polymer Composite Products - Rebar or Dowel Bars

CSI Master Format 03 21 21

Program Operator: NSF

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Valid through August 31, 2030

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Prepared by NSF staff with assistance from

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No participation fees were charged by NSF to interested parties. NSF ensured that reasonable representation among the members of the PCR committee was achieved and potential conflicts of interest were resolved prior to commencing this PCR development. Each member has signed a legal document stating that they have no conflicts of interest.

PCR revision history

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For inquiries regarding this PCR, please reference the designation: “NSF 1125-25.”

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Unit abbreviations

The following table is provided as a reference for unit abbreviations for common forms of measurement used within NSF documents.

Time	second	s
	minute	min
	hour	h
	day	d
	week	wk
	month	mo
	year	yr
Length	inch	in.
	foot	ft
	yard	yd
	micrometer	µm
	nanometer	nm
	millimeter	mm
	centimeter	cm
	meter	m
	kilometer	km
	miles	mi
Liquid measure	milliliter	mL
	liter	L
	liters per day	LPD
	liters per minute	LPM
	ounce	oz
	pint	pt
	quart	qt
	gallon	gal
	gallons per minute	GPM
	gallons per day	GPD
Weight	microgram	µg
	picogram	pg
	nanogram	ng
	milligram	mg
	centigram	cg
	gram	g
	kilogram	kg
	pound	lb
	ton	t
	metric ton	mt

Miscellaneous	megajoule	MJ
	short ton	st

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Foreword

This sub-category product category rules (PCR) addresses fiber-reinforced polymer composite products – rebar and dowel bars, and documents the goal, scope, and other requirements of LCAs for this product category in order to produce EPDs according to ISO 14025:2006 and ISO 21930:2017. Fiber-reinforced polymer composite rebar and dowel bars are discrete reinforcing bars intended for internal reinforcement in concrete structures and infrastructure.

The Fiber Reinforced Polymer (FRP) Composite Products – Rebar or Dowel Bars, specifically classified under CSI Master Format 03 21 21, can be utilized in a similar manner to steel rebar. This particular multi-attribute Product Category Rule (PCR) is scoped cradle-to-gate. Modules A1 to A3 are mandatory, and Module D, which covers benefits and loads beyond the system boundary, is optional.

This is the first edition of this Product Category Rule.

Suggestions for improvement of this guideline are welcome. Comments should be sent to ncss@nsf.org, or c/o NSF, National Center for Sustainability Standards, PO Box 130140, Ann Arbor, Michigan 48113-0140, USA.

About the NSF National Center for Sustainability Standards (NCSS)

Through the NCSS, NSF develops life cycle-based, multi-attribute sustainability standards, protocols, and PCRs for various industries including building products and materials, furniture, carpet and flooring, fabrics, wallcoverings, roofing membranes, green chemicals, electronics, and water and wastewater.

The NCSS will continue to add to its growing portfolio while providing education, outreach, and innovation support to private industry, trade associations, government and academia to foster a consensus-based approach toward conformity assessment in the sustainability field. Visit nsfsustainability.org or contact ncss@nsf.org.

About the American Composites Manufacturing Association (ACMA)

ACMA is the world's largest composites industry trade group. We are manufacturers, material and equipment suppliers, distributors, academia, and end users. The ACMA headquarters are Washington-based.

As a member driven association, ACMA helps members prosper through relevant and timely education and information; expertise and representation in legislation and regulatory affairs; and market growth and development.

ACMA strives to be the "voice of the composites industry" and provides a forum for all relevant industry issues, opportunities, and commerce. We seek to position composites as the material of preference relative to all competing material systems.

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NSF Product Category Rule
for Environmental Product Declarations –

Fiber Reinforced Polymer Composite Products – Rebar or Dowel Bars

CSI Master Format 03 21 21

1 Scope

Per ISO 21930:2017 [1] Clause 1, with the following additions:

While this PCR will be used primarily in North America, it may be used in other regions where program operators deem it appropriate.

This sub-category PCR addresses fiber-reinforced polymer composite products – rebar and dowel bars, and documents the goal, scope, and other requirements of LCAs for this product category in order to produce EPDs according to ISO 14025:2006 and ISO 21930:2017. Fiber-reinforced polymer composite rebar and dowel bars are discrete reinforcing bars intended for internal reinforcement in concrete structures and infrastructure. Table 1 lists the specific product types covered by this PCR and the applicable standards and specifications.

This PCR is valid through August 31, 2030.

Table 1

Fiber reinforced polymer composite products – Rebar or dowel bars

carbon and glass, straight and bent bar	ACI 440.6, *Specification for carbon fiber-reinforced polymer bar material for concrete reinforcement*
glass fiber reinforced polymer (GFRP) composite bar	ASTM D7957/D7957M, *Standard specification for solid round glass fiber reinforced polymer bars for concrete reinforcement*
dowel bars	ASTM D8444, *Standard Specification for Fiber Reinforced Polymer Dowel Bars for Load Transfer Between Concrete Slabs*
basalt and glass fiber, epoxy	ASTM D8505/D8505M, *Standard specification for basalt and glass fiber reinforced polymer (FRP) bars for concrete reinforcement*
vinyl ester, bent and straight bars, glass	CSA S807, *Specification for fibre-reinforced polymers*

FRP composite rebar and dowel bars may be utilized in a variety of applications which are beyond the scope of consideration in the PCR. This PCR also excludes ground fiber, loosely bundled fibers and particles that could be added to concrete.

[1] International Organization for Standardization. Chemin de Blandonnet 8, Case Postale 401, 1214 Vernier, Geneva, Switzerland. <iso.org>

2 Normative references

The following documents are referred to in the text. For undated references, the latest edition of the referenced document (including any amendments) applies.

AASHTO, *LRFD Bridge Design Guide Specifications for GFRP–Reinforced Concrete, 2nd Ed. 2018* [2]

ACI 440.6-08(17)(22), *Specification for carbon fiber-reinforced polymer bar material for concrete reinforcement* [3]

ACI 440.9R-15, *Guide to accelerated conditioning protocols for durability assessment of internal and external fiber-reinforced polymer (FRP) reinforcement* [3]

ASTM D3878-20b, *Terminology for composite materials* [4]

ASTM D7957/D7957M-22, *Standard specification for solid round glass fiber reinforced polymer bars for concrete reinforcement* [4]

ASTM D8505/D8505M-23, *Standard specification for basalt and glass fiber reinforced polymer (FRP) bars for concrete reinforcement* [4]

ASTM D8444-24, *Standard Specification for Fiber Reinforced Polymer Dowel Bars for Load Transfer Between Concrete Slabs* [4]

CSA S807:19, *Specification for fibre-reinforced polymers* [5]

FTC, *Green Guides* [6]

Greenhouse Gas Protocol, *Product Life Cycle Accounting and Reporting Standard* [7]

ISO 14025:2006, *Environmental Labels and Declarations – Type III Environmental Declarations – Principles and Procedures* [1]

ISO/TC 14027:2018, *Environmental Labels and Declarations – Development of Product Category Rules* [1]

ISO 14040:2006/AMD 1:2020, *Environmental Management – Life Cycle Assessment – Principles and Framework* [1]

ISO 14044:2006/AMD 1:2007/AMD 2:2020, *Environmental Management – Life Cycle Assessment – Requirements and Guidelines* [1]

ISO 21930:2017, *Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services* [1]

US EPA/600/R-16/096, *Guidance on Data Quality Assessment for Life Cycle Inventory Data, June 2016* [8]

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[2] American Association of State Highway and Transportation Officials. 555 12th Street NW, Suite 1000, Washington, DC 20004. <transporation.org>

[3] American Concrete Institute. 38800 Country Club Drive, Farmington Hills, MI 48331. <concrete.org>

[4] ASTM International. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428. <astm.org>

[5] CSA Group. 178 Rexdale Boulevard, Toronto, ON M9W 1R3, Canada. <csagroup.org>

[6] Federal Trade Commission. 600 Pennsylvania Avenue, NW, Washington, DC 20580. <ftc.gov>

[7] World Resources Institute (WRI) and WBCSD. <ghgprotocol.org>

[8] US Environmental Protection Agency. 1200 Pennsylvania Avenue NW, Washington, DC 20004. <epa.gov>

US EPA, *Criteria for Product Category Rules (PCRs) to Support the Label Program for Low Embodied Carbon Construction Materials (Version 1), 2024* [8]

US EPA, *Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI 2.2)* [8]

US NREL, *LCI Database Project Development Guidelines* [9]

3 Terms and definitions

While this PCR will likely be used primarily in North America, it may be used in other regions where program operators deem it appropriate. Per ISO 21930:2017 [1] Clause 3, with the following additions:

composite: Engineering materials made from two or more constituent materials that remain distinct but combine to form materials with properties not possessed by any of the constituent materials.

consumptive water use: Water removed from available supplies without return to a water resource system (e.g. water used in manufacturing that is not returned to a stream, river, or water treatment plant).

cutoff criteria: Specification of the amount of material or energy flow or the level of environmental significance associated with unit processes of a product system to be excluded from an LCA study (adapted from ISO 140441[1]).

dowel bars: A straight element with a solid, round cross-section, having a smooth as produced surface that extends into adjoining portions of a concrete construction, as an expansion or contraction joint in a pavement slab, so as to transfer shear loads.

fiber: A continuous, slender and elongated solid material, generally with a length at least 100 times its diameter. For classification of continuous fibers under this PCR, refer to ASTM D578/D578M, ASTM D8448/D8448M. [4]

fiber reinforced polymer (FRP): A composite material comprising a polymer matrix reinforced with continuous fibers.

FRP bar: Composite material formed into a long, slender structural shape suitable for the internal reinforcement of concrete and consisting primarily of longitudinal fibers bound and shaped by a rigid polymer resin material.

FRP bent bar: An FRP reinforcing bar formed to a prescribed bent shape.

hazardous waste: Waste identified as hazardous according to regulations applicable in the market for which the EPD is valid. For the US market, wastes are hazardous if they are regulated as hazardous waste under the RCRA, [10] (see also 40 CFR § 261.33 [11]). For the Canadian market, wastes are hazardous if they are regulated under the CEPA, 1999 Regulations. [12]

[9] National Renewable Energy Laboratory, US Department of Energy, Office of Energy Efficiency and Renewable Energy. 901 D Street SW, Suite 930, Washington, DC 20024. <nrel.gov>

[10] Resource Conservation and Recovery Act. <epa.gov/rcra>

[11] 40 CFR § 261.33, *Discarded commercial chemical products, off-specification species, container residues, and spill residues thereof.* <govinfo.gov/content/pkg/CFR-2011-title40-vol26/pdf/CFR-2011-title40-vol26-sec261-33.pdf>

[12] Canadian Environmental Protection Act, Environment and Climate Change Canada, Government of Canada. <canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/substances-list/toxic/schedule-1-substances-cepa-1988.html>

industry-average EPD: EPD results for a specific product or group of composite material products categorized by performance for a specified region, group of manufacturers or both.

metric tonne: 1,000 kg.

net consumables: Items used during manufacturing, such as lubricants, grease and oils.

non-hazardous waste: Any commercial/industrial waste that is not known to cause harm to human or environmental health.

product-specific EPD: EPD results for a specific product or group of composite material products, categorized by performance and developed by a manufacturer for a specific manufacturing facility location(s).

recovered material: Material that would have otherwise been disposed of as waste or used for energy recovery but has instead been collected and recovered as a material input, in lieu of new primary material, for a recycling or a manufacturing process (see ISO 14021[1]).

short ton: 2,000 lb.

4 Abbreviated terms

Per ISO 21930:2017 [1] Clause 4, with the following additions:

AASHTO American Association of State Highway and Transportation Officials
ACI American Concrete Institute
ACLCA American Center for Life Cycle Assessment
ACMA American Composites Manufacturers Association
AP acidification potential
ASTM ASTM International
CEPA Canadian Environmental Protection Act
CFR Code of Federal Regulations
CSA CSA Group
DQA data quality assessment
EN European Standards
EP eutrophication potential
EPA Environmental Protection Agency
EPD Environmental Product Declaration
FRP fiber reinforced polymer
FTC Federal Trade Commission
GFRP glass fiber reinforced polymer
GWP global warming potential
IPCC Intergovernmental Panel on Climate Change
ISO International Organization for Standardization
LCA life cycle assessment
LCI life cycle inventory
LCIA life cycle impact assessment
NERC North American Electric Reliability Corporation
NIST National Institute of Standards and Technology
NREL National Renewable Energy Laboratory
ODP ozone depletion potential
PCR Product Category Rule
POCP photochemical oxidant creation potential
PPA power purchase agreement
RC reinforced concrete
RCRA Resource Conservation and Recovery Act
REC renewable energy credit
RSL reference service life
SI International System of Units
TRACI Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
US United States
USGBC United States Green Building Council

5 General aspects

5.1 Objectives of this PCR

Per ISO 21930:2017 [1] Clause 5.1, with the following additions:

The primary objective of this sub-category PCR is to provide rules for the application of ISO 21930:2017 to create Type III EPDs for composite products identified in Table 1.

Additional objectives include to:

- describe which stages of a product's life cycle are considered in the EPD and which processes are to be included in the life cycle stages
- encourage composite materials manufacturers to quantify, report, better understand and reduce the environmental impacts of FRP rebar
- represent composite materials appropriately following international standards for building materials and products
- specify the data quality to be attained in composite materials EPDs
- support the use and guidance of EPDs in sustainable design construction programs and rating systems
- working with end users to develop full project EPDs, identify the important life cycle stages to be included in the EPD
- address requirements for creating an industry-wide average EPD
- enable consistent and comparable reporting of LCA results related to composite material production
- promote transparency and incentivize manufacturer specific upstream data.

5.2 Life cycle stages

Per ISO 21930:2017 [1] Clause 5.2, with the following clarifications:

This PCR establishes requirements for the assessment and reporting of life cycle impacts associated with the production of composite products identified in Section 1. The system boundary of EPDs produced under this PCR shall be cradle-to-gate (modules A1-A3), no additional life cycle stages or information modules shall be included in EPDs developed under this cradle-to-gate sub-category PCR. The scope of the underlying LCA of composite products shall also be cradle-to-gate, with the gate being defined as the point at which the composite rebar product is transferred to a vehicle for transport to the customer (the last point of the producer's control).

As stipulated by ISO 21930:2017 the system boundary shall follow both the modularity and polluter pays principles. These are discussed in greater detail in Clause 7.1.1 and Table 1 of ISO 21930:2017.

Figure 1

Common four life cycle stages and their information modules

Construction works assessment information

Construction works life cycle information within the system boundary																Optional supplementary information beyond the system boundary
PRODUCTION (A1-A3) (Mandatory)			CONSTRUCTION (A4-A5)		USE (B1-B7)							END OF LIFE (C1-C4)				D
A1	A2	A3	A4	A5	B1	B2	B3	B4 [a]	B5	B6	B7	C1	C2	C3	C4	
Extraction and upstream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction/ 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

Note. Source: ISO 21930:2017.

[a] Replacement information module (B4) not applicable at the product level.

5.3 Average EPDs for groups of similar products

Per ISO 21920[1] Clause 5.3, with the following additions:

5.3.1 Specificity of manufacturing data

Manufacturing data specificity concerns the determination and reporting of specifically what activities/unit processes are included in the manufacturing stage (Module A3) for a particular product and which instead fall within the upstream modules A1 and A2. Manufacturing data specificity requires that an EPD be classified as one (and only one) of the following:

- **industry-average EPD**: Where an EPD represents an average of data from multiple manufacturers in a defined product sector and/or geographical area.
- **manufacturer-average EPD**: Where an EPD covers a single product or group of products produced by a single manufacturer using an average of data from multiple facility locations
- **facility-specific EPD**: Where an EPD covers a single manufacturer and a single facility at which the final product is manufactured.

This EPD shall report modules A1-A3 separately, in addition, reporting of A1-A3 in a single module is allowed. See Figure 2 for a depiction of the unit processes that occur in A1 and A3. An Industry average EPD may be developed under this PCR. Requirements for industry average EPDs given in ISO 21930:2017 Clause 5.3 shall apply, with the following additions:

- Report the robustness of the study by reporting the percent of the industry that participated, by both percent of manufacturers and percent of annual production.
- Indicate the method used to calculate each information module (A1-A3, etc.). In the cases where plant grouping averages are reported, the EPD must include the geographic range of the production facilities.
- Report the process used to ensure the EPD represents a range of company sizes (by production volume), type of manufacturing technology employed, and geographic location, shall be documented. Include in the EPD a list of all manufacturers who provided primary data for the LCA.
- Require the submission of primary data for at least one production facility for a manufacturer to be listed as a participant to the industry average EPD.
- Manufacturers seeking to compare their individual Type III EPDs against a Type III industry-average EPD shall have participated in the production of that industry-average EPD.
- The development of an industry average EPD shall not be used to actively exclude specific companies. Actions taken to notify potential stakeholders of participation in the process shall be documented.

A manufacturer may apply to the program operator for retroactive participation in an already published industry-average EPD by providing the information and data required of original participants to the LCA practitioner. The program operator, the primary sponsor, and the LCA practitioner of the industry-average EPD shall confer together to reach a consensus on how to proceed. However, this shall not automatically trigger a recalculation of the industry-average impacts. The effect of the additional data on the industry-average EPD shall be estimated, and a decision made on the need to update the EPD when the impact is expected to be greater than 5%.

For manufacturer-average EPDs, instances will likely occur where products are made at multiple manufacturing locations or travel to different distribution or retail centers. For situations such as this, a weighted average of production volume at each facility, site, or both shall be utilized for calculation purposes.

For example, if Site A manufactures 80% of the product system covered by the EPD and each kilogram of product manufactured requires 5 MJ of energy, whereas Site B makes 20% of the product and each kilogram of product manufactured requires 10 MJ of energy, the average energy used per kilogram would be 6 MJ [(80%*5) + (20%*10)]. The same methodology would apply for transportation distances.

The products included in an average EPD shall not differ in their environmental impact indicators by more than ±10%. Similar products included in other average EPDs should not differ in their environmental impact indicators by more than ±10%. In these cases, the products shall not be included in the industry-average EPD and should be considered for a product-average or product-specific EPD.

5.3.2 Specificity of products

An EPD shall report its product-specificity consistent with the requirements of the ACLCA *Guidance for Determining EPD Types and Calculating and Communicating Data Specificity Through the Supply Chain (2022)*. [13] An EPD shall indicate its specificity using one of the following terms:

- product-average EPD
- product-specific EPD.

For greater transparency, product-specific EPDs are preferred.

All single-product EPDs are product-specific. This PCR also allows the grouping of products made from the same fiber and same resin types in the exact same proportion (i.e. same composition) within a product-specific EPD. Groupings may include products with different shapes, lengths or dimensions under the declared unit of 1 t. Any EPDs containing multiple products that do not meet the requirements given above are product-average EPDs. Rules specific to averaging are spelled out in ISO 21930:2017 Clause 5.3. In all cases, the average must be carried out using a weighted average based on the annual production.

If data is unavailable and default values are not already provided by this PCR, justification for any used values shall be documented and disclosed in both the project report and subsequent EPD.

5.4 Use of EPDs for construction products

Per ISO 21930:2017 [1] Clause 5.4.

5.5 Comparability of EPDs for construction products

Per ISO 21930:2017 [1] Clause 5.5, with the following clarifications and additions:

- Consistent with the requirements listed in ISO 21930, EPDs developed under this PCR shall not be used to directly compare products due to the cradle-to-gate scope and use of a declared unit.

5.6 Documentation

Per ISO 21930:2017 [1] Clause 5.6. See Sections 8 through 10 for guidance on additional environmental information, EPD content, and the project report.

[13] American Center for Life Cycle Assessment. 6900 Wisconsin Avenue, Unit 30953, Bethesda, MD 20824. <aclca.org>

6 PCR development and use

Per ISO 21930:2017 [1] Clause 6, with the following additions:

This PCR document is effective for five (5) years from the latest date of publication and shall be open for revision at that time. If at any time, relevant changes in the product category or other relevant factors occur (for example, the evolution of LCA methodology in ISO 21930:2017), this document will be revised.

This PCR was formally developed by a panel of representatives of composite products industry members and manufacturers, raw material suppliers, standards development groups, regulators, and other interested parties and conforms to ISO 21930:20171 requirements. This panel interacted with NSF and members of the ACMA [14] and its member companies; The list of participating companies and representatives is included in the front material of this document.

7 PCR for LCA

7.1 Methodological framework

7.1.1 LCA modeling and calculation

Per ISO 21930:2017 [1] Clause 7.1.1.

7.1.2 Functional unit

No functional unit is defined in this cradle-to-gate (A1-A3) PCR.

7.1.3 Declared unit

Per ISO 21930:2017 [1] Clause 7.1.3, with the following clarifications:

The declared unit shall be per 1 mt (1,000 kg) of composite products that is ready for shipment. Data may also be provided per short ton (2,000 lb) of composite products.

Note. A table providing linear mass g/m may be included covering the bar sizes in the EPD.

The following statement shall be included in the EPD:

"When evaluating different materials, the relative densities of the materials should be considered."

7.1.4 Reference service life

Declaration of an RSL is outside of the cradle-to-gate scope and is thus not permitted.

7.1.5 System boundary with nature

Per ISO 21930:2017 [1] Clause 7.1.5.

[14] American Composites Manufacturers Association. 2000 15th Street N, Suite 250, Arlington, VA 22202. <acmanet.org>

7.1.6 System boundary between products systems

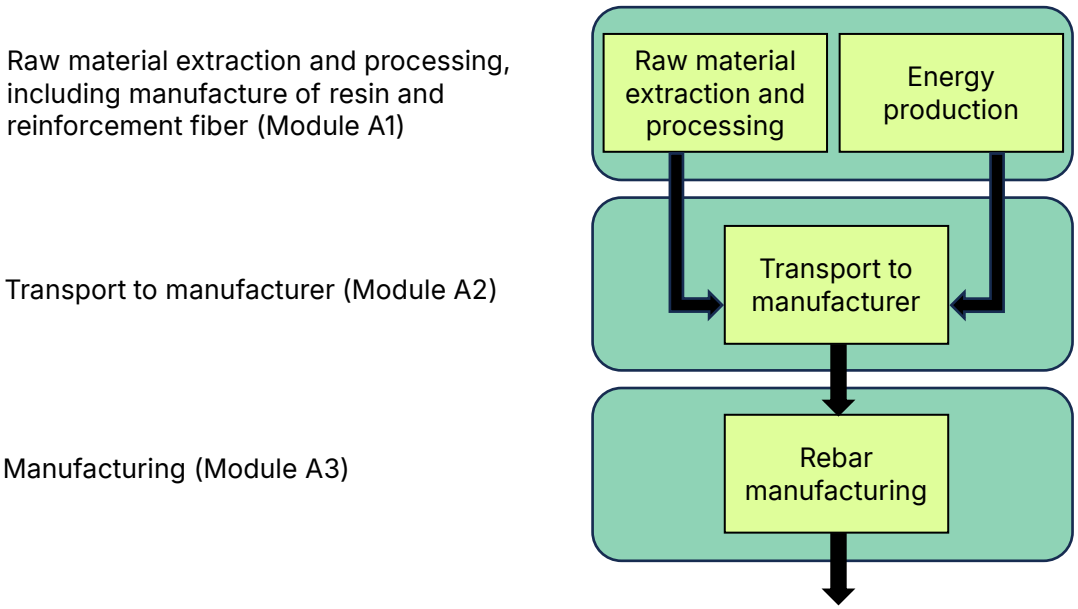
Per ISO 21930:2017 [1] Clause 7.1.6.

7.1.7 System boundaries and technical information for scenarios

Per ISO 21930:2017 [1] Clause 7.1.7, with the following additions:

Figure 2 of this PCR shows the life-cycle stages broken out by modules as defined by ISO 21930:2017. This PCR covers the production stage of composite products, which includes modules A1-A3, no additional life cycle stages or information modules shall be included in EPDs developed under this cradle-to-gate sub-category PCR.

Figure 2
Cradle-to-gate scope of fiber reinforced composite rebar



This section of the PCR details the processes and flows to be considered for each module. Specific items that shall be excluded from the system boundary include:

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

7.1.7.1 General

Per ISO 21930:2017 [1] Clause 7.1.7.1.

7.1.7.2 A1 to A3, production stage

Per ISO 21930:2017 [1] Clause 7.1.7.2.

7.1.7.2.1 General

Per ISO 21930:2017 [1] Clause 7.1.7.2.1.

7.1.7.2.2 A1, extraction and upstream production

Per ISO 21930:2017 [1] Clause 7.1.7.2.2.

All raw materials and feedstocks (e.g. glass fiber, resins) shall be evaluated in the A1 module, unless specific primary data for its inclusion in Module A3 is provided.

7.1.7.2.3 A2, transport to factory

Per ISO 21930:2017 [1] Clause 7.1.7.2.3, with the additional clarification:

Primary data for transport of raw materials, secondary materials, or both, shall be used. If primary data is not available, generic data may be used with documented justification. Transportation to the processing plant shall include empty backhauls and transportation to interim distribution centers or terminals.

7.1.7.2.4 A3, manufacturing

Per ISO 21930:2024 [1] Clause 7.1.7.2.4, with the additional clarification:

Module A3 calculations should rely on background/upstream data for the generation of electricity, steam and heat from primary energy resources used in manufacturing, including their extraction, refining and transport.

7.1.7.2.5 Input of secondary materials or recovered energy

This clause of ISO 21930:2017 [1] does not apply.

7.1.7.2.6 Co-products leaving the system

Per ISO 21930:2017 [1] Clause 7.1.7.2.6.

7.1.7.2.7 Output of waste

Per ISO 21930:2017 [1] Clause 7.1.7.2.7.

7.1.7.2.8 End-of-life scenarios for packaging

Per ISO 21930:2017 [1] Clause 7.1.7.2.8.

7.1.7.3 Use stage

ISO 21930:2017 [1] Clause 7.1.7.4 is not applicable due to cradle-to-gate scope.

7.1.7.4 End-of-life stage

ISO 21930:2017 [1] Clause 7.1.7.5 is not applicable due to cradle-to-gate scope.

7.1.7.5 Benefits and loads beyond the system boundary

Per ISO 21930:2017 [1] Clause 7.1.7.6 with the following additions:

Module D is optional. If provided, a description of the reference scenarios shall be documented in the EPD.

7.1.8 Criteria for the inclusion and exclusion of inputs and outputs

Per ISO 21930:2017 [1] Clause 7.1.8.

The procedure used shall be documented in Section 9.3.

7.1.9 Selection of data and data quality requirements

Per ISO 21930:2017 [1] Clause 7.1.9, with the following clarification:

The data used to create the inventory model shall be as precise, complete, consistent, and representative as possible with regards to the goal and scope of the study.

7.1.9.1 Foreground system

Processes under the operational control of the EPD owner (generally referred to as the foreground system) shall be modeled using primary data, i.e. data that is obtained (by direct measurement or a calculation based on a direct measurement) by the EPD owner/developer at its original source (i.e. the EPD owner's facility(ies) or other operations). Foreground system data are typically the quantities of material and energy flows into a system as well as outflows of products, co-products, emissions and wastes. While each of these data points are based on primary measured or calculated data, they are typically modeled in LCA software using background or generic datasets.

7.1.9.2 Background system

Background system processes including the production of input materials, energy sources, and transportation, shall be modeled with background LCI/LCA data following this hierarchy from most to least preferable:

1. Facility-specific LCA data (including supply chain-specific, if available)

If facility-specific data is unavailable:

2. ACMA's LCI database for common raw materials for the manufacture of composite products. For information on accessing this database, contact the ACMA [14] (sustainability@acmanet.org). Access to the database will be made available at no cost to anyone, upon request.

If the above sources are deemed not appropriate:

3. An alternative source or method for which the EPD shall provide justification. For a deviation where the input contributes at least 30% to the total A1-A3 result for any impact category, the justification shall include a description of the data source's representativeness and a data quality assessment following the ACLCA *Assessing Data Quality of Background Life Cycle Inventory Datasets*. [13] Acceptance of such deviation is at the discretion of the LCA and EPD verifier and Program Operator.

During the development of this PCR, some commonly used database publishers were making updates to oil and natural gas refining and other upstream material processing assumptions that might significantly increase or decrease impacts compared to previous versions of those data sets. To improve comparability between

EPDs that use the older-versus-newer versions of data sets with significant changes, the following additional disclosure is required:

- For secondary data sets that contribute 20% or more to impacts, the LCA background report must demonstrate that each data set used in the LCA has been compared to the previous version of the data set in the impact categories of global warming, ozone depletion potential, acidification, eutrophication, and photochemical oxidation (smog). If the data set used has greater than ±10% variance in the compared impacts, that information shall be disclosed in the EPD. The identity of databases used in the preparation of the EPD is provided in Section 9.

7.1.9.3 Energy data requirements

Additional data requirements related to energy apply, including:

- Purchased electrical energy data shall use NERC regions or similar data to represent electrical energy production for the US and Canada. Preference shall be given to datasets that include transmission and distribution losses.
- For regions other than the US and Canada, country or region-specific processes shall be used for the manufacturing stage provided they are representative. The sources for electricity and the calculation procedure shall be documented.
- Credit may not be applied to LCA baseline when RECs, PPAs, or other green power certificates are used, but certificates may be reported in the Additional Environmental Information section.

7.1.9.4 Data quality

Per ISO 21930[1] Clause 7.1.9, with the addition of the following table:

Indicator	Definition	←Highest data quality (lowest score)				Lowest data quality (highest score)→
		1	2	3	4	5 (default)
Temporal representativeness	Indicates the temporal difference between the date of data generation and the date the data are supposed to represent based on the PCR.	Less than 3 yr of difference	Less than 6 yr of difference	Less than 10 yr of difference	Less than 15 yr of difference	Age of data unknown or more than 15 yr
Geographical representativeness	Indicates how well the geographical area from which data for a unit process are collected satisfies the goal of the study. (ISO 14044:2006/ AMD 1:2017/ AMD 2:2022)	Data from same resolution [a] and same area of study	Within one level of resolution and a related area of study [b]	Within two levels of resolution and a related area of study	Outside two levels of resolution but a related area of study	From a different or unknown area of study
Technological representativeness	Indicates technical representativeness based on four categories: process design, operating conditions, material quality/type and process scale.	All technology categories [c] are equivalent	Three of the technology categories are equivalent	Two of the technology categories are equivalent	One of the technology categories is equivalent	None of the technology categories are equivalent
Data collection methods	Assessment of the robustness of the sampling methods and data collection period.	Representative data from > 80% of the relevant market, [d] over an adequate period [e]	Representative data from 60% to 79% of the relevant market, over an adequate period, or representative data from > 80% of the relevant market, over a shorter period	Representative data from 40% to 59% of the relevant market, over an adequate period, or representative data from 60% to 79% of the relevant market, over a shorter period	Representative data from < 40% of the relevant market, over an adequate period, or representative data from 40% to 59% of the relevant market, over a shorter period	Unknown data from a small number of sites and from shorter periods

Indicator	Definition	←Highest data quality (lowest score)				Lowest data quality (highest score)→
		1	2	3	4	5 (default)
Reliability	Indicates quality of data generation method and verification of data collection methods.	Verified [f] data based on measurements	Verified data based on a calculation or non-verified data based on measurements	Non-verified data based on a calculation	Documented estimate	Undocumented estimate

Note. Source: <cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=321834>

[a] Levels of resolution are defined as follows: global, continental, sub-region, national, state/province/region, county/city, site-specific. (The first four of these are from the UN geoscheme (United Nations, 2013.) The same approach applies for imports to the US.

[b] A related area of study is defined by the user and should be documented in the geographical metadata. By default, a related area of study is one within the same hierarchy of political boundaries (e.g. Denver is within Colorado, which is within the US, which is within North America).

[c] Technology categories are process design, operating conditions, material quality, and process scale.

[d] The relevant market should be documented in the DQA. The default relevant market is measured in production units; if the relevant market is determined using other units, this should be documented in the DQA. The relevant market established in the metadata should be consistently applied to all flows within the unit process.

[e] An adequate time period can be evaluated as long enough to even out normal fluctuations. The default period is 1 yr, except for emerging technologies (2 to 6 mo) or agricultural projects over 3 yr. Seasonality considerations shall be incorporated for construction materials where relevant.

[f] Verification may take place in several ways, e.g. by on-site checking, by recalculation, through mass balances or crosschecks with other sources. For values calculated from a mass balance or another verification method, an independent verification method must be used in order to qualify the value as verified.

7.1.10 Units

Per ISO 21930:2017 [1] Clause 7.1.10, with the following additions:

All EPD values shall be reported using SI (metric) units. Optionally, EPDs may provide both SI units and US imperial units using the following conversion factors from NIST. Conversion factors given in Table 2 shall be used, if applicable.

Table 2
Conversion factors

Convert from:	Convert to:	Multiply by:
cubic yard (yd^3)	cubic meter (m^3)	7.645 549 E-01
square foot (ft^2)	square meter (m^2)	9.290 304 E-02
foot (ft)	meter (m)	3.048 E-01
British Thermal Unit (BTU)	megajoule (MJ)	1.055 056 E-03
pound (lb)	kilogram (kg)	4.535 924 E-01
short ton (st)	metric tonne (mt)	9.071 848 E-01

Note. Source: NIST: <nist.gov/pml/special-publication-811>

7.2 Inventory analysis

Per ISO 21930:2017 [1] Clause 7.2.

7.2.1 Data collection

Per ISO 21930:2017 [1] Clause 7.2.1 (which references ISO 14044:2006).

7.2.2 Calculation procedures

Per ISO 21930:2017 [1] Clause 7.2.2.

7.2.3 Allocation situations

Per ISO 21930:2017 [1] Clause 7.2.3.

7.2.4 Principles for allocation both allocation situations

Per ISO 21930:2017 [1] Clause 7.2.4.

7.2.5 Allocation for co-products

Per ISO 21930:2017 [1] Clause 7.2.5.

7.2.5.1 General

Per ISO 21930:2017 [1] Clause 7.2.5.1.

7.2.5.2 Co-product allocation procedure

Per ISO 21930:2017 [1] Clause 7.2.5.2, with the following clarification.

Recycled and recovered materials shall be considered raw materials. Only the materials, water, energy, emissions, and other elemental flows associated with reprocessing, handling, sorting, and transportation from the generating industrial process to their use in the production process shall be considered (i.e. the cut-off method).

7.2.5.3 Avoiding allocation generally

Per ISO 21930:2017 [1] Clause 7.2.5.3.

7.2.5.4 Allocation by subdivision

Per ISO 21930:2017 [1] Clause 7.2.5.4.

7.2.6 Allocation between product systems (across the system boundary)

Per ISO 21930:2017 [1] Clause 7.2.6.

7.2.7 Accounting of biogenic carbon update and emissions during the life cycle

ISO 21930:2017 [1] Clause 7.2.7.

7.2.8 Carbonation

ISO 21930:2017 [1] Clause 7.2.8 is not applicable to this PCR.

7.2.9 Accounting of delayed emissions

ISO 21930:2017 [1] Clause 7.2.9 is not applicable to this PCR.

7.2.10 Inventory indicators describing resource use

ISO 21930:2017 [1] Clause 7.2.10.

7.2.11 Greenhouse gas emissions from land use change

Per ISO 21930:2017 [1] Clause 7.2.11 .

The manufacture of glass fiber composite rebar does not involve processes that impact land use, therefore this metric does not apply to an EPD created in conformance to this PCR.

7.2.12 Additional inventory indicators describing emissions and removal of carbon

Per ISO 21930:2017 [1] Clause 7.2.12.

7.2.13 Inventory indicator describing consumption of freshwater

Per ISO 21930:2017 [1] Clause 7.2.13.

7.2.14 Environmental information describing waste categories and output flows

Per ISO 21930:2017 [1] Clause 7.2.14.

7.3 Impact assessment indicators describing main environmental impacts derived from LCA

Per ISO 21930:2017 [1] Clause 7.3. The indicators shown in Table 3 shall be reported using the indicated methods.

Table 3
Mandatory impact categories and methods

Impact category and abbreviation	Default international characterization method	Default North American market characterization method	Default European market characterization method as provided in:
global warming potential (GWP 100)	IPCC	TRACI	EN 15804
ozone depletion potential (ODP)	WMO	TRACI	EN 15804
eutrophication potential (EP)	Heijungs et al.	TRACI	EN 15804
acidification potential (AP)	Hauschild and Wenzel	TRACI	EN 15804
photochemical oxidant creation potential (POCP)	Goedkoop et al.	TRACI	EN 15804

Note 1. Source: ISO 21930:2017 Clause 7.3, Table 5, pg 54

Note 2. TRACI 2.2 or later should be used.

The LCIA category indicator results shall be reported separately as cradle-to-gate scope by individual modules A1 through A3 and total life cycle (A1-A3).

8 Additional environmental information

Per ISO 21930:2017 [1] Clause 8 with the following modifications:

Information related to the durability of composite rebar is from published sources. The committee believes that while the information is not relevant to a cradle-to-gate EPD, it is important additional environmental information for fiber reinforced composite rebar products. EPDs published under this PCR may include the statement found in Section 9.6, clearly labeled as additional environmental information. If included, the statement must be provided unaltered in its entirety and include all citations.

9 Content of an EPD

9.1 General

Per ISO 21930:2017 [1] Clause 9.1.

9.2 Declaration of general information

Per ISO 21930:2017[1] Clause 9.2, with the following clarification and additions:

The manufacturer is responsible for the provision of all information in the following sections. An EPD developed under this PCR shall include the following information:

9.2.1 Owner and verification information

- Table 4 along with the required information shall be provided in the EPD on the inside front cover:

Table 4
Declaration of general EPD information and verification

Product Name	
Manufacturer Name and Address	
Program Operator	
General Program Instructions and Version Number	
Declaration Number	
Reference PCR and Version Number	
EPD Type and Scope	
Defined functional or declared unit	
Product intended Application and Use	
Markets of Applicability	
Date of Issue	
Period of Validity	
Year of reported manufacturer primary data	
LCA Software and Version Number	
LCI Database and Version Number	
LCIA Methodology and Version Number	
Overall Data Quality Assessment Score	
The sub-category PCR review was conducted by:	
This declaration was independently verified in accordance with ISO 14025: 2006. ISO 21930:2017 serves as the core PCR. Sub-category PCR: **Fiber Reinforced Polymer Composite Rebar Products** Product Category Rule ☐ Internal ☐ External	**Thomas P. Gloria, PhD**
This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by:	
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	
Explanatory Material may be obtained from the following:	

9.2.2 Required statements

- The statement:

  "EPDs are only comparable if they comply with ISO 21930:2017, this sub-category PCR, include all relevant information modules and are based on equivalent scenarios with respect to the construction works context."

- The statement:

  "Environmental declarations from different programs may not be comparable. Comparison of the environmental performance of products using EPD information shall be based on the product's use and impacts at the building or construction works level, and therefore EPDs may not be used for comparability purposes when not considering the whole building life cycle. EPD comparability is only possible when all stages of the life cycle have been considered. However, variations and deviations are possible. Example of variations: Different LCA software and background datasets may lead to differences in the results upstream or downstream of the life cycle stages declared."

- If the EPD is based on a declared unit, include the statement:

  "The environmental impact results of products in this document are based on a declared unit and therefore do not provide sufficient information to establish comparisons. The results shall not be used for comparisons without knowledge of how the physical properties of the product impact the precise function at the construction level. The environmental impact shall be converted to a functional unit basis before any comparison is attempted."

- The statement:

  "The EPD Owner has sole ownership, responsibility, and liability for the content of this EPD."

9.2.3 Material content

- Identification of the product name, composite product category, product size, and the relevant ASTM specification according to Table 1. A depiction of the item shall be included.
- A description of the main product components or materials that make up the product shall be given both in mass and percent of total. Alternatively, the list of materials may be reported in order of greatest mass, or aggregated by type, or both, to protect confidential information.
- EPDs shall list, at a minimum, all substances contained in the construction product that are identified as hazardous according to standards or regulations of the applicable market(s). For products where no such substances are present, the EPD shall include the statement:

  "No substances required to be reported as hazardous are associated with the production of this product."

9.2.4 Environmental information

- Any environmental certification program applied to the product and a statement on where an interested party may find details of the certification.
- Environmental activities of the organization, such as participation in recycling or recovery programs. The EPD shall provide contact information on where details of the activities or programs may be accessed by the purchaser or user of the product.

9.3 Declaration of methodological framework

Per ISO 21930:2017 [1] Clause 9.3, with the following additions and clarifications:

- The EPD shall specify the following:
    - Declared Unit of 1 mt of composite products as sold, and optionally 1 st
    - Data collection period for foreground data (12-mo consecutive)
    - Type of EPD with respect to life-cycle stages covered
    - Life cycle stages covered and not covered, using Table 5. The table shall indicate by module whether that module is declared or not declared in the EPD. Modules A1-A3 are required.

Table 5
Description of EPD system boundary

Production stage			Construction stage		Use stage							End of life stage				Benefits and loads beyond the system boundary
Raw material extraction	Transport	Manufacturing	Transportation to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operation energy use	Operation water use	De-construction	Transport	Waste processing	Disposal	Reuse/recycle
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	optional

Note. MND = module not declared, X = module declared, O = optional declaration

- A table outlining the primary sources of data used to complete the upstream material LCI background data including the date or version number of the dataset or database
- For industry-wide average EPDs including a list of all companies who participated in the EPD data.

Note. For cradle-to-gate EPDs, scenarios are not required to be reported.

9.4 Declaration of technical information and scenarios

ISO 21930:2017 [1] Clause 9.4 does not apply for cradle-to-gate EPDs.

9.5 Declaration of environmental indicators derived from LCA

9.5.1 Per ISO 21930:2017 [1] Clause 9.5, with the following additions:

- environmental impacts for each of the core indicators identified in Section 7.3 shall be reported individually by module for A1, A2 and A3, as well as in total (A1-A3).
- LCI parameters to be declared in the EPD (see Sections 7.2.10 through 7.2.14), include the following:
  - depletion of non-renewable energy resources (MJ)
  - depletion non-renewable material resources (kg)
  - use of renewable material resources (kg)
  - use of renewable primary energy (MJ)
  - secondary materials (kg)
  - renewable secondary fuels (MJ)
  - non-renewable secondary fuels (MJ)
  - recovered energy (MJ)
  - abiotic depletion, fossil fuels (MJ
  - consumption of freshwater (m^3)
  - hazardous waste (kg)
  - non-hazardous waste (kg)
  - high-level radioactive waste (kg)
  - intermediate and low-level radioactive waste (kg)
  - components for reuse (kg)
  - materials for recycling (kg)
  - materials for energy recovery (kg)
  - recovered energy exported from the product system (MJ).

9.5.2 Per ISO 21930, [1] Clause 7.2.12, the following indicators shall also be reported, where relevant and available, if included in the quantification of the GWP:

- biogenic CO_2, reporting the removals and emissions associated with biogenic carbon content contained within biobased products, occurring in each module

- biogenic CO_2, reporting the removals and emissions associated with biogenic carbon content contained within the biobased packaging, occurring in each module
- CO_2 from calcination and carbonation, reporting the emissions and uptake of CO_2 from calcination and carbonation occurring in the relevant modules
- biogenic CO_2, reporting the emissions from combustion of waste from renewable sources used in product processes
- CO_2 emissions from combustion of waste from non-renewable sources used in product processes.

9.6 Declaration of additional environmental information

Per ISO 21930:2017 [1] Clause 9.6, with the following additions:

9.6.1 EPDs published under this PCR may include the following statement [15] clearly labeled as additional environmental information. If included, the statement must be provided unaltered in its entirety and include all citations:

> *"The long-term material properties and interaction mechanisms influencing the service life of glass fiber reinforced polymer (GFRP) reinforced concrete (RC) elements has been evaluated for several decades (Nkurunziza et al. 2005, [16] Ceroni et al. 2006, [17] Manalo et al. 2020 [18]). As a result, alkaline-based accelerated conditioning protocols, as those specified within ASTM D7957 and D8505, have been established to provide acceptable threshold values for the rate of degradation of GFRP bars. Furthermore, numerous laboratory investigations have been conducted by immersing bare GFRP bars in concentrated alkaline solutions at elevated temperatures and assessing their strength retention (Robert et al. 2009 [19]). These studies have utilized well-established prediction models to extrapolate the results for a projected service life of 100-200 years. Based on these findings, design codes incorporate a conservative knockout reduction factor to ensure a service life of 100 years (Benmokrane et al. 2020 [20]). Additionally, field durability studies have been conducted by retrieving GFRP bar samples from RC elements in use for up to 20 years (Gooranorimi and Nanni 2017, [21] Ramanathan et al. 2021, [22] Al-Khafaji et al. 2021 [23]). These investigations have demonstrated that laboratory experiments tend to be more severe on GFRP bars than real-world environmental conditions (Benmokrane et al. 2018 [24]). It was concluded that the extracted GFRP bar samples exhibited a reduction in tensile strength of 2.5% after 17 years of service. Extrapolating this result to a 100-year service life, the predicted tensile strength would be reduced by 12.5%, which remains within*

[15] White paper is available here: <acmanet.org/reinforced-concrete-service-life/>

[16] Nkurunziza, G., Debaiky, A., Cousin, P., and Benmokrane, B., 2005. Durability of GFRP bars: A critical review of the literature. *Progress in structural engineering and materials, 7(4), pp.194-209.*

[17] Ceroni, F., Cosenza, E., Gaetano, M., and Pecce, M., 2006. Durability issues of FRP rebars in reinforced concrete members. Cement and concrete composites, 28(10), pp.857-868.

[18] Manalo, A., Maranan, G., Benmokrane, B., Cousin, P., Alajarmeh, O., Ferdous, W., Liang, R. and Hota, G., 2020. Comparative durability of GFRP composite reinforcing bars in concrete and in simulated concrete environments. *Cement and Concrete Composites*, *109, p.103564.*

[19] Robert, M., Cousin, P., and Benmokrane, B. (2009). "*Durability of GFRP Reinforcing Bars Embedded in Moist Concrete.*" ASCE Journal of Composites for Construction, Vol. 13, No. 2, pp. 66-73.

[20] Benmokrane, B., V. Brown, A. H. Ali, K. Mohamed, and C. Shield. 2020. Reconsideration of the Environmental Reduction Factor CE for GFRP Reinforcing Bars in Concrete Structures. J. Compos. Constr., 24(4): 06020001.

[21] Gooranorimi, O. and Nanni, A., 2017. GFRP reinforcement in concrete after 15 years of service. *Journal of composites for construction*, *21*(5), p.04017024.

[22] Ramanathan, S., Benzecry, V., Suraneni, P., and Nanni, A., 2021. Condition assessment of concrete and glass fiber reinforced polymer (GFRP) rebar after 18 years of service life. *Case Studies in Construction Materials, 14, p.e00494.*

[23] Al-Khafaji, A.F., Haluza, R.T., Benzecry, V., Myers, J.J., Bakis, C.E., and Nanni, A., 2021. Durability assessment of 15-to 20-year-old GFRP bars extracted from bridges in the US. II: GFRP bar assessment. *Journal of composites for construction*, *25(2), p.04021008.*

[24] Benmokrane, B., C. Nazair, M.-A. Loranger, and A. Manalo. 2018. Field durability study of vinyl-ester-based GFRP rebars in concrete bridge barriers. J. Bridge Eng. 23 (12): 04018094.

the threshold values specified by the design codes for the rate of degradation of GFRP bars in RC. Hence, it is evident that GFRP bars can be used for a cradle-to-grave timeline equivalent to 100 years of service life."

9.6.2 The following references shall be provided at a minimum in the EPD:

- ISO 21930:2017, *Sustainability in Building Construction – Environmental Declaration of Building Products* [1]
- NSF 1125-25, *PCR for Fiber Reinforced Polymer Composite Rebar Products*.

10 Project report

Per ISO 21930:2017 [1] Clause 10.

EPDs for Composite Products that are developed using a verified software tool do not need an individual project report for each EPD. Instead, the underlying project report for the software tool may serve as the project report for the EPD. In addition, the report shall address the steps taken to ensure the security and integrity of the tool over time and describe the specific conditions under which a re-review of the software tool would be triggered (e.g. change in scope). If a verified software tool is used to create the EPD, then the underlying project report shall be available to the tool user and to the EPD verifier.

11 Verification and validity of an EPD

Per ISO 21930:2017 [1] Clause 11, with the following additions:

EPD calculations completed by software systems are permitted provided the software has been verified in a process similar to that of the verification of an EPD. When a product-specific EPD is aligned with an industry-wide average EPD, the following additional item is required.

In order to evaluate the consistency of results between product-specific EPDs and industry-wide average EPDs the same LCA background data set and characterization model shall be used to create the EPD.

EPDs shall be recalculated when any of the following conditions apply:

- changes to manufacturing practices are reasonably expected to result in a significant change to the EPD results
- the EPD period of validity is complete or when updates to the PCR result in significant changes to the EPD results
- a manufacturer requests inclusion of their product in the industry-average EPD, and the estimated impact is greater than 5%

  Note. Significant changes are defined here as an increase or decrease of GWP 100, AP, EP or POCP by > 5% of previously reported result.

12 References

The development of this PCR included consideration and reference to the following:

12.1 ISO standards

ISO 6707-1:2014, *Buildings and Civil Engineering Works – Vocabulary – Part 1: General Terms* [1]

ISO 14021:1999, *Environmental Labels and Declarations – Self-declared Environmental Claims (Type II Environmental Labeling)* [1]

ISO 14067:2018, *Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification* [1]

ISO 14050:2009, *Environmental Management – Vocabulary* [1]

12.2 Other references

ACLCA, *Guidance for Assessing Data Quality of Background Life Cycle Inventory (LCI) Datasets*

EN 15804:2012+A1:2013, *Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products*, January 2012

US EPA, *Waste Reduction Model (WARM)* [8, 25]

USGBC, *LEED v4 for Building Design and Construction*, 11 Jan 2019 [26, 27]

[25] <epa.gov/warm/versions-waste-reduction-model-warm#15>

[26] US Green Building Council. 2101 L Street, NW, Suite 500, Washington, DC 20037. <usgbc.org>

[27] <usgbc.org/resources/leed-v4-building-design-and-construction-current-version>

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