trans-mu-ta-tion

Environmental Product Declaration

In accordance with ISO 14025:2006 and EN 15804:2012+A2: 2019/AC:2021

Transmutation Concrete Bar chair from

Transmutation Pty Ltd (Australia)

ECO PLATFORM EPD VERIFIED

Programme:	The International EPD® System, www.environdec.com
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AUSTRALASIA EPD® ENVIRONMENTAL PRODUCT DECLARATION

EPD® THE INTERNATIONAL EPD® SYSTEM

An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at https://epd-australasia.com/

General EPD Information

Declaration Owner	Transmutation Pty Ltd 14 Flint Street, Robe SA 5276 T: +61 414730106 W: www.transmutation.com.au
Geographical Scope	Australia
Reference Year for Data	1 October 2023 - 30 September 2024
EPD programme operator:	EPD Australasia Limited epd-australasia.com info@epd-australasia.com EPD Australasia Limited 315a Hardy Street Nelson 7010, New Zealand EPD International AB info@environdec.com EPD International AB Box 210 60, SE-100 31 Stockholm, Sweden
PRODUCT CATEGORY RULES (PCR)	
CEN standard EN 15804 served as the core Product Category Rules (PCR)	
Product Category Rules (PCR):	PCR 2019.14 Construction Products, version 1.3.4
PCR review was conducted by:	The Technical Committee of the International EPD® System. See www.environdec.com for a list of members
Review Chair:	Claudia A. Peña, University of Concepción, Chile. The review panel may be contacted via the Secretariat www.environdec.com/contact
LIFE CYCLE ASSESSMENT (LCA)	
EPD Prepared by:	Sazal Kundu, Lilia Caballero Edge Environment Pty Limited Greenhouse, Level 3, 180 George Street, Sydney NSW 2000 W: www.edgeimpact.global E: info@edgeimpact.global
THIRD-PARTY VERIFICATION	
Independent verification of the declaration and data, according to ISO 14025:2006	☒ EPD verification by individual verifier
Third Party Verifier [*verifier's signature*]	Jane Anderson ConstructionLCA Market Rasen, Lincolnshire LN7 6NS, United Kingdom w: constructionlca.co.uk e: jane@constructionlca.co.uk
Verifier approved by:	EPD Australasia Ltd
Procedure for follow-up of data during EPD validity involved third-party verifier	☐ Yes ☒ No

An Environmental Product Declaration, or EPD, is a standardised and verified way of quantifying the environmental impacts of a product based on a consistent set of rules known as a PCR (Product Category Rules).

Transmutation has sole ownership, liability, and responsibility for this EPD. To the best of Transmutation's knowledge, the information provided in this document is accurate and reliable. However, no warranty, guarantee or representation is made as to its accuracy, reliability or completeness.

EPDs within the same product category but registered in different EPD programmes, or not compliant with EN 15804, may not be comparable. For two EPDs to be comparable, they must be based on the same PCR (including the same version number) or be based on fully-aligned PCRs or versions of PCRs; cover products with identical functions, technical performances and use (e.g. identical declared/functional units); have equivalent system boundaries and descriptions of data; apply equivalent data quality requirements, methods of data collection, and allocation methods; apply identical cut-off rules and impact assessment methods (including the same version of characterisation factors); have equivalent content declarations; and be valid at the time of comparison. For further information about comparability, see EN 15804 and ISO 14025.

About Transmutation

Transmutation Pty Ltd is a 100% Australian-owned company based in South Australia's Limestone Coast. Established in 2001, Transmutation initially specialized in providing transport and project management services to large logistics firms. However, in 2018, the company underwent a significant transformation by redirecting its focus to embrace a more environmentally conscious approach.

Transmutation has since evolved into a sustainable, recycling and manufacturing business that has specialized in accepting hard to recycle plastics and transforming them into commercial products.

Transmutation Recomposition manufactures products from fully recycled materials into high quality homeware, industrial and construction products.

Transmutation Resources excels in crafting high-quality resin pellets and has their own Trade Marked, PostPrime Plastic® polymer that is used in a wide variety of applications.

Transmutation Retail actively advocates for a circular economy, curating and selling items made from recycled materials while collaborating with like-minded artisans across Australia. The company aims to foster a sustainable retail outlet that not only produces goods from recycled materials but also educates customers on the principles of reduce, reuse, and recycle.

Our Commitment to Sustainability

At Transmutation, our commitment to sustainability drives us to innovate and find new ways to reduce waste and promote a circular economy. By partnering with Dulux, we have developed a groundbreaking solution that transforms powder waste into a valuable resource. This post-industrial plastic waste in combination with agricultural plastic wastes are converted into PostPrime Plastic® pellet feedstock, a material that displaces virgin plastic in manufacturing processes.

Our first product utilizing this innovative material is the Bar Chair, a durable and eco-friendly solution for concrete reinforcing applications. The Transmutation Bar chair is Good Environmental Choice Australia (GECA) certified[1], ensuring it meets the highest environmental, social, and governance (ESG) standards. The Bar Chair not only reduces energy usage and carbon emissions but also contributes to a circular economy by being fully manufactured from pellets that are produced from plastic wastes.

[1] The certification followed the Good Environmental Choice Australia (GECA) standard: Recycled Products RP v1.0ii-2015.

Product Covered by this EPD

Product description:

Developed through a Patent Pending method, this innovative product marks a significant advancement in polymer technology. Crafted entirely from recycled materials and proudly Australian-made, ensures transparency and accountability throughout its lifecycle.

This 50/65mm Bar Chair, GECA accredited for its environmental credentials, serves as a cornerstone in concrete construction projects. Manufactured at their facility in Robe, South Australia, this product not only elevates the standards of sustainability in the industry but also exemplifies a commitment to quality, innovation, and eco-conscious manufacturing practices. As a GECA accredited product, it meets stringent environmental criteria, providing assurance to customers seeking both high-performance and environmentally responsible solutions for their projects.

Applications/Uses

PostPrime Plastic® Bar Chairs are routinely used for supporting reinforcing bar / mesh when placing concrete. Additionally, bar chairs help to ensure the correct concrete cover is provided as per design specifications.

Reinforcing mesh is most effective in the top half of a slab, where it is used to increase its flexural strength and reduce the chance of shrinkage, heaving or settling cracking. To achieve this, bar chairs are utilised to suspend the mesh / reinforcing bar.

Typically, bar chairs which will allow 40-50mm of cover to the top of the finished pour height are selected. Using tie wire as part of the reinforcement placement process these chairs are tied to the layer of reinforcement to fix it and remove the chance of movement during the concrete pour.

Features and Benefits

- GECA Certified.
- Provides all ESG credentials: Full fact sheet and full product tracking.
- Ultra sturdy for supporting concrete reinforcing mesh.
- Quick to install with moulded seating preventing any unwanted movement.
- No metallic iron content to cause staining (pre concrete placement).
- Capable of supporting laser screed machines such as or similar to S-485 Laser Screed.
- AS/NZS 2425:2015 compliant to 200kg test rating*.
- The 50/65mm Bar Chair is available in cartons of 20 or 200.
- 100% Australian made and owned.

Plus, Transmutation is the first manufacturer of Bar Chairs from environmentally certified recycled plastic.

Life Cycle Assessment Methodology

Database(s) and LCA software used:

The specific data used is based on direct utility bills or feedstock quantities from Transmutation's procurement records. The application of generic and specific data follows the EN 15804+A2 requirements and approach, which are entered into the SimaPro (v9.6) LCA software program and linked to the pre-existing data for the upstream feedstocks and services selected in order of preference from:

- For Australia, the Australian Life Cycle Inventory (AusLCI) v1.42 compiled by the Australian Life Cycle Assessment Society ((ALCAS), 2023). The AusLCI database at the time of this report was less than a year old, while the Australasian Unit Process LCI was 9 years old.
- Other authoritative sources (e.g., ecoinvent v3.10, (Wernet, et al., 2024), where necessary adapted for relevance to Australian conditions (energy sources, transport distances and modes and so on, and documented to show how the data is adapted for national relevance). At the time of reporting, the ecoinvent v3.10 database was less than 1 year old.
- Other sources with sensitivity analysis reported to show the significance of this data for the results and conclusions drawn.

Allocation

In a process where more than one type of product is generated, it is necessary to allocate the environmental stressors (inputs and outputs) from the process to the different products (functional outputs) in order to get product-based inventory data instead of process-based data. An allocation problem also occurs for multi-input processes. In an allocation procedure, the sum of the allocated inputs and outputs to the products shall be equal to the unallocated inputs and outputs of the unit process.

The following stepwise allocation principles shall be applied for multi-input/output allocations:

- The initial allocation step includes dividing up the system sub-processes and collecting the input and output data related to these sub-processes.
- The first (preferably) allocation procedure step for each sub-process is to partition the inputs and outputs of the system into their different products in a way that reflects the underlying physical relationships between them.
- The second (worst case) allocation procedure step is needed when physical relationship alone cannot be established or used as the basis for allocation. In this case, the remaining environmental inputs and outputs from a sub-process must be allocated between the products in a way that reflects other relationships between them, such as the economic value of the products.

Cut-off rules and Exclusion of Small Amounts

It is common practice in LCA/LCI protocols to propose exclusion limits for inputs and outputs that fall below a threshold % of the total, but with the exception that where the input/output has a "significant" impact it should be included. According to the PCR 2019:14, Life cycle inventory data shall according to EN 15804 + A2 include a minimum of 95% of total inflows (mass and energy) per module. Data gaps in included stages in the downstream modules shall be reported in the EPD, including an evaluation of their significance. In accordance with the PCR 2019:14 Construction Products (v1.3.4), the following system boundaries are applied to manufacturing equipment and employees:

- Environmental impact from infrastructure, construction, production equipment, and tools that are not directly consumed in the production process are not accounted for. Capital equipment and buildings typically account for less than a few percent of nearly all life cycle inventories and this is usually smaller than the error in the inventory data itself. For this project, it is assumed that capital equipment makes a negligible contribution to the impacts as per Frischknecht et al. (Frischknecht, 2007) with no further investigation.

- Personnel-related impacts, such as transportation to and from work, are also not accounted for. The impacts of employees are also excluded from inventory impacts on the basis that if they were not employed for this production or service function, they would be employed for another. It is very hard to decide what proportion of the impacts from their whole lives should count towards their employment. For this project, the impacts of employees are excluded.
- The transport of the excavator, bobcat, grater, and roller are excluded.

Data Quality and Validation

The primary data used for the study (core module) is based on direct utility bills or feedstock quantities from the Transmutation's procurement records. Primary data was carefully reviewed in order to ensure completeness, accuracy and representativeness of the data supplied. Contribution analysis was used to focus on the key pieces of data contributing to the environmental impact categories. The data was benchmarked against relevant benchmark data in ecoinvent. Overall, the data was deemed to be of high quality for the core module. The data quality ranking is as follows: geographical representativeness – very good; technical representativeness – very good and time representativeness – very good.

Compliance with Standards

The methodology and report format has been modified to comply with:

- ISO 14040:2006 and ISO14044:2006+A1:2018 which describe the principles, framework, requirements and provides guidelines for life cycle assessment (LCA).
- ISO 14025:2006 Environmental labels and declarations – Type III environmental declarations -- Principles and procedures, which establishes the principles and specifies the procedures for developing Type III environmental declaration programmes and Type III environmental declarations.
- EN 15804:2012+A1:2013; Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.
- EN 15804:2012+A2:2019; Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.
- Product Category Rules (PCR) 2019:14, v1.3.4 – Construction products – Hereafter referred to as PCR 2019:14.
- General Programme Instructions (GPI) for the International EPD System v5.0 – containing instructions regarding methodology and the content that must be included in EPDs registered under the International EPD System.
- Instructions of EPD Australasia V4.2 – a regional annex to the general programme instructions of the International EPD System.

Assumptions, Choices, and Limitations

Table 1: Key assumptions, choices and limitation for this EPD

Assumption or limitation	Impact on LCA results	Discussion
Raw material data for panel production.	Minor	The Transmutation team provided the composition of the products and other manufacturing inputs. No proxy data was used. Energy and utility used as well as waste generated during the production of products were allocated to the different products using mass allocation method.
Exclusion of employees, capital good and infrastructure	Minor	Personnel-related impacts, such as transportation to and from work, are also not accounted for in the LCI. The impacts of employees are also excluded from inventory impacts on the basis that if they were not employed for this production or service function, they would be employed for another. It is very hard to decide what proportion of the impacts from their whole lives should count towards their employment. For this project, the impacts of employees are excluded.
Products distribution	Minor	Information obtained from Transmutation Team. The Transmutation team gave the destinations and associated average distance for each type of product.
Installation Energy	Minor	It's assumed that the installation of the Transmutation Bar chairs is done manually.
Deconstruction Energy	Minor	It is assumed that products could be removed manually without tools, so no activity is associated with C1 module.
Average distance for transport from deconstruction site to waste plant.	Minor	The distance from the installation site to the landfill is assumed to be 25 km based on the average distance travelled from deconstruction to waste plant, used in similar EPDs.
Pallet and Bulka bags disposal	Minor	Pallet and Bulka bags are encouraged to be returned to Transmutation for reuse. The % of pallet return rate is 80%, based on Transmutation estimation. It is assumed that they have been used 10 times, Bulka bags go back to SPS to be recycled and turned into pellets and the pallets are landfilled.
Recycling of concrete bar chairs, after use.	Minor	It is assumed that 100% of the products at End-of-Life are disposed in landfill. In consequence, the recycling rate has no impact on Module D avoided production calculations.

LCA Information

Declared unit: 1 Transmutation Concrete Bar Chair (65 g), manufactured in Robe, South Australia, Australia

The UN CPC code for the Transmutation concrete bar chair is 36499: Other articles of plastics, not elsewhere classified, and its ANZSIC Business industry code is 19120 (Rigid and Semi-Rigid Polymer Product Manufacturing).

Technical service life: 50 years

Time representativeness: The LCA study was conducted on the September 2023 to September 2024 production data.

System Boundaries

The scope of the LCA was cradle to gate with options, modules A4-A5, modules C1–C4 and module D. The geographical scope of this EPD is Australia.

This EPD has been produced in conformance with the requirements of PCR2019:14, General Program Instructions (GPI) and EN 15804.
It is discouraged to use the results of modules A1-A3 without considering the results of module C.

Table 2: Life Cycle of building products: stages and modules included in this EPD

	Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
	Raw material supply	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
Module	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Modules declared	x	x	x	x	x	ND	ND	ND	ND	ND	ND	ND	x	x	x	x	x
Geography	AU	AU	AU	AU	AU	-	-	-	-	-	-	-	AU	AU	AU	AU	AU
Specific data used	86%			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Variation – products	N/A			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Variation – sites	Not applicable			-	-	-	-	-	-	-	-	-	-	-	-	-	-

ND = not declared (such a declaration shall not be regarded as an indicator of zero result).

The following life cycle stages have not been declared, as they are deemed not applicable for Transmutation Concrete Bar Chair: Material emissions from usage (B1); Maintenance (B2); Repair (B3); Replacement (B4); Refurbishment (B5); Operational energy use (B6), and Operational water use (B7).

System Diagram:

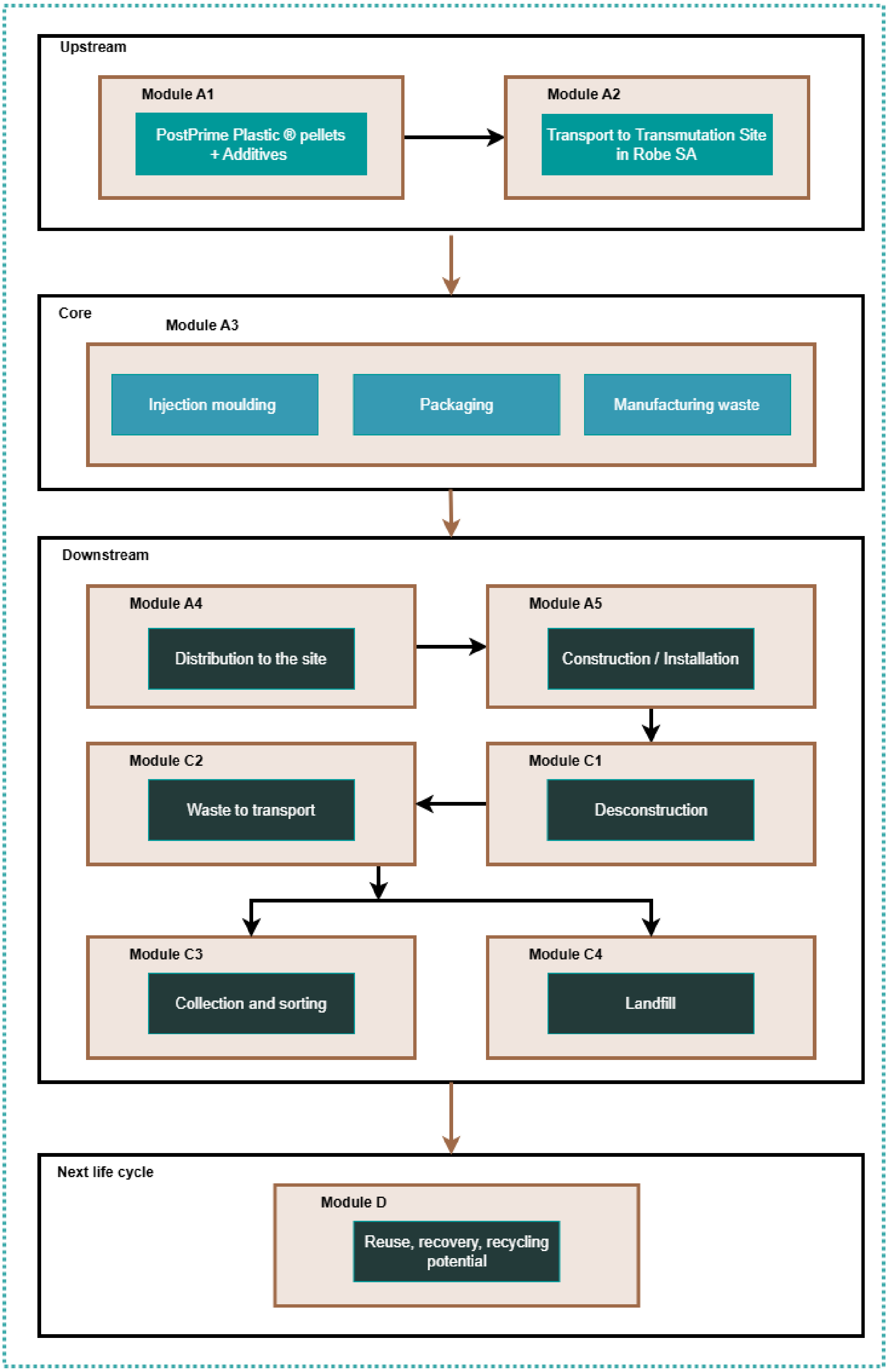

Figure 1 I System diagram of Transmutation Concrete Bar chair.

Upstream processes

The upstream processes include those involved in Module A1 - Raw material supply. This module includes:

- Manufacturing of Transmutation Pellets.

Core Processes

The core processes include those involved in Module A2 and Module A3, including:

- External transportation of materials to the core processes and internal transport. The transport of Transmutation Pellets from Sustainable Plastic Solutions (SPS) in Hamilton to the Transmutation factory in Robe is already considered in the Downstream processes for the LC of Transmutation Pellets, thus not considered in Module A2 for Transmutation Bar Chairs.
- Manufacturing of Transmutation Bar Chairs.
- Packaging materials

Downstream Processes

The downstream processes include those involved in Module A4 to C4, including:

- Transportation from the production gate to the construction site.
- Installation of the product on the site.
- Transport of equipment and use of materials for deconstruction at the end of life.
- Transport of waste generated at the end of life.
- Treatment of waste generated at the end of life.

Content Information

Product Stage (Modules A1 – A3)

The Transmutation Bar chairs are moulded using 100% PostPrime Plastic® pellets.

The Transmutation pellets are delivered in bulka bags and timber pallets. It's assumed that they are used 10 times before their final disposal, 80% of the bulka bags are sent back to the Hamilton plant where they get recycled, and the pallets are sent to landfill.

An inventory for manufacturing energy, utility and waste is given below.

Transport of Raw materials (A2)

The PostPrime Plastic® pellets are transported from Sustainable Plastic Solutions (SPS) in Hamilton VIC to the Transmutation factory, in Robe SA 5276. Where the PostPrime Plastic® is used to make the Concrete Bar chair products.

Manufacturing process (A3)

The manufacturing process for Transmutation Bar Chairs involves feeding PostPrime Plastic® pellets, into an injection moulding machine. The pellets are melted and injected into a precisely engineered mould. After cooling and solidifying, the Bar Chairs undergo quality checks to ensure they meet AS/NZS 2425:2015 standards. The final product is then packaged for distribution, offering a sustainable, reliable, and eco-friendly solution for the construction industry.

Energy Mix

The electricity used in the manufacturing of Transmutation Bar chairs comes from grid electricity (78%) and solar panels (22%).

The electricity consumption model was sourced from AusLCI database for grid electricity of South Australia consisting of wind power (60.6%), natural gas (33.9%), photovoltaic (3.7%), heat pump (1.2%) biogas (0.4%), and oil (0.2%) with a GWP-GHG impact of 1.17 kg CO_2 eq/kWh.

Packaging materials and waste

Certain wastes are generated during manufacture, these include packaging waste, and sandpaper. Based on the type of waste, they are routed to municipal landfill, or municipal recycling. Timber pallets are assumed to be reused between SPS and Transmutation manufacturing site up to 10 times before being discarded. While the pallets used to transport Bar chairs are assumed to be discarded at the installation site and sent to landfill.

All materials destined for the landfill do not have a specific use at end of life. All materials destined for recycling can be used for a specific purpose, there is a market for it, and all national and local laws and regulations are fulfilled.

Table 3 shows the materials used in manufacturing and packaging related data.

Table 3: Content declaration for 1 Transmutation Concrete Bar chair.

Product components	Weight, kg	Post-consumer recycled material (%)	Biogenic material, weight-% of product	Biogenic material, kg C/product or declared unit
PostPrime Plastic® (pellets)	0.065	0	0	0

The A1-A3 results includes the "balancing-out reporting" of the biogenic CO_2 of packaging released in moulding phase of the pellets (module A5).

Table 4: Content declaration of packaging for 1 Transmutation Concrete Bar chair.

Packaging components	Weight, kg	Post-consumer recycled material (%)	Biogenic material, weight-% of product	Biogenic material, kg C/product or declared unit
Cardboard boxes	2.25E-03	0	3.46%	9.40E-04
Timber pallets	7.50E-04	0	1.15%	3.13E-04
Plastic film	7.44E-05	0	0.00%	0

Note: 1 kg biogenic carbon is equivalent to 44/12 kg CO_2

Additional information on release of dangerous substances to indoor air, soil and water

The products are highly inert and are used predominantly in outdoor applications. They do not release any dangerous substances to indoor air, soil, or water.

None of the products contain one or more substances that are listed in the "Candidate List of Substances of Very High Concern for authorisation". Based on available information and safety data sheet, PostPrime Plastic® products are not classified as Hazardous according to Safe Work Australia criteria.

Distribution Stage (Module A4)

Transmutation Concrete Bar chairs are distributed within Australia is by road. The transport distances from manufacturing gate to customers' location were calculated based on primary data from percentage of total products shipped to customers.

Table 5 I Distribution distances

Product Name	Vehicle Type	Yearly mass (tonne)	Weighted Average Road Distance (km)
Concrete Bar chair	Truck	9.3	35

Installation Stage (Module A5)

Transmutation Bar Chairs are delivered to the construction site in one of two ways: either on a pallet containing 16 cartons, with 200 chairs per carton, or by individual cartons with 200 chairs each.

Once on-site, each Bar Chair is manually placed at intervals of every 1 square meter to support the reinforcing mesh at the required height, which could be 50mm or 65mm, depending on the engineering specifications provided for the project. After the mesh is properly supported by the chairs, concrete is poured around the mesh and chairs, with the bar chairs becoming an integral part of the finished concrete element. There are no cut-offs produced during installation since all products are ready to be placed beneath the reinforcing mesh that will be covered with concrete.

Deconstruction and End of Life (Modules C1 – C4)

A 50-year reference service life is commonly used as a standard for the life cycle assessment (LCA) of buildings and construction products. Since Transmutation Concrete Bar chairs are typically embedded within the structural components of buildings, they are assumed to remain in place for the entire lifespan of the construction. Therefore, their lifespan is also considered to be 50 years.

The recommended cradle to grave environmental profile will be based on the most common scenario as construction products are deconstructed and transported to material recovery facilities.

The following assumptions have been used in this study to model product deconstruction and end of life scenarios:

All products could be removed manually without tools, so no activity is associated with C1 module.

100% of the products are assumed to be collected during deconstruction for further process.

100% of the products at End-of-Life are disposed of in landfill.

25 km delivery distance for waste material to waste processing plant.

Benefits and loads beyond the system boundary (Module D)

Module D starts at the "end of waste" state, when the material is no longer a product in the current life cycle and starts to be a potential input for the next life cycle. Module D gives benefits or creates loads to the next system from the net recycling of a product, as prescribed in EN 15804+A2.

It is assumed that 100% of the products at End-of-Life are disposed of in landfill. In consequence, the recycling rate has no impact on Module D avoided production calculations

Environmental Impact Indicators

The potential environmental impacts, use of resources and waste categories included in this EPD were calculated using the SimaPro v9.6 tool and are listed in Table 6. The characterisation factors applied to the calculation of potential environmental impacts (Table 6) are based on version 3.1 of the reference package for CFs used in the Product Environmental Footprint (PEF) framework (EF 3.1).

All tables from this point will contain abbreviations only. The estimated impact results are only relative statements, which do not indicate the endpoints of the impact categories, exceeding threshold values, safety margins and/or risks.

Table 6: Life Cycle Impact, Resource and Waste Assessment Categories, Measurements and Methods in accordance with EN15804+A2

Impact Category	Abbreviation	Measurement Unit	Assessment Method and Implementation
Potential Environmental Impacts			
Total global warming potential	GWP - Total	kg CO_2 equivalents (GWP100)	Baseline model of 100 years of the IPCC based on IPCC 2021
Global warming potential (fossil)	GWP - Fossil	kg CO_2 equivalents (GWP100)	Baseline model of 100 years of the IPCC based on IPCC 2021
Global warming potential (biogenic)	GWP - Biogenic	kg CO_2 equivalents (GWP100)	Baseline model of 100 years of the IPCC based on IPCC 2021
Land use/ land transformation	GWP - Luluc	kg CO_2 equivalents (GWP100)	Baseline model of 100 years of the IPCC based on IPCC 2021
Ozone depletion potential	ODP	kg CFC 11 equivalents	Steady-state ODPs, WMO 2014
Acidification potential	AP	mol H^+ eq.	Accumulated Exceedance, Seppälä et al. 2006, Posch et al., 2008
Eutrophication – aquatic freshwater	EP - freshwater	kg P equivalent	EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe
Eutrophication – aquatic marine	EP - marine	kg N equivalent	EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe
Eutrophication – terrestrial	EP – terrestrial	mol N equivalent	Accumulated Exceedance, Seppälä et al. 2006, Posch et al.
Photochemical ozone creation potential	POCP	kg NMVOC equivalents	LOTOS-EUROS, Van Zelm et al., 2008, as applied in ReCiPe
Abiotic depletion potential (elements)*	ADPE	kg Sb equivalents	CML 2002 (v4.8)
Abiotic depletion potential (fossil fuels)*	ADPF	MJ net calorific value	CML 2002 (v4.8)
Water Depletion Potential*	WDP	m^3 equivalent deprived	Available Water Remaining (AWARE) Boulay et al., 2016 (includes Australia flows calculated using 36 Australian catchments)
**Disclaimer – The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator.*			
Resource use			
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	PERE	MJ, net calorific value	Manual for direct inputs 2
Use of renewable primary energy resources used as raw materials	PERM	MJ, net calorific value	Manual for direct inputs3
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	PERT	MJ, net calorific value	ecoinvent version 3.8 and expanded by PRé Consultants4

2 PERE = PERT - PERM
3 Calculated based on the lower heating value of renewable raw materials. LHV is taken from https://phyllis.nl/, as recommended by SimaPro in compliance with EN15804+A2: https://support.simapro.com/s/article/How-to-calculate-EN-15804-A2-indicators-in-desktop-SimaPro
4 Calculated as sum of renewables, biomass; renewable, wind, solar and geothermal, and renewable, water.

Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	PENRE	MJ, net calorific value	Manual for direct inputs5
Use of non- renewable primary energy resources used as raw materials	PENRM	MJ, net calorific value	Manual for direct inputs6
Total use of non- renewable primary energy resources (primary energy and primary energy resources used as raw materials)	PENRT	MJ, net calorific value	ecoinvent version 3.108 and expanded by PRé Consultants7
Use of secondary material	SM	kg	Manual for direct inputs
Use of renewable secondary fuels	RSF	MJ, net calorific value	Manual for direct inputs
Use of non-renewable secondary fuels	NRSF	MJ, net calorific value	Manual for direct inputs
Use of net fresh water	FW	m^3	ReCiPe 2016
Waste categories			
Hazardous waste disposed	HWD	kg	EDIP 2003 (v1.05)
Non-hazardous waste disposed	NHWD	kg	EDIP 2003 (v1.05) 8
Radioactive waste disposed/stored	RWD	kg	EDIP 2003 (v1.05)
Output flow categories			
Components for re-use	CRU	kg	Manual for direct inputs
Material for recycling	MFR	kg	Manual for direct inputs
Materials for energy recovery	MERE	kg	Manual for direct inputs
Exported energy - electricity	EE - e	MJ per energy carrier	Manual for direct inputs
Exported energy – thermal	EE – t	MJ per energy carrier	Manual for direct inputs
Additional environmental impact indicators			
Global warming potential, excluding biogenic uptake, emissions and storage	GWP-GHG	kg CO_2 equivalents (GWP100)	Baseline model of 100 years of the IPCC based on IPCC 20219
Global warming potential, aligned with the IPCC 2013 Fifth Assessment Report	GWP-GHG (AR5)	kg CO_2 equivalents (GWP100)	Baseline model of 100 years of the IPCC based on IPCC 5th Assessment Report
Particulate matter	Potential incidence of disease due to PM emissions (PM)	Disease incidence	SETAC-UNEP, Fantke et al. 2016
Ionising radiation - human health**	Potential Human exposure efficiency relative to U235 (IRP)	kBq U-235 eq	Human Health Effect model

5 PENRE = PENRT - PENRM
6 Calculated based on the lower heating value (LHV) of non-renewable raw materials. LHV is taken from https://phyllis.nl/, as recommended by SimaPro in compliance with EN15804+A2: https://support.simapro.com/s/article/How-to-calculate-EN-15804-A2-indicators-in-desktop-SimaPro
7 Calculated as sum of non-renewables, fossil and non-renewable, nuclear.
8 Calculated as sum of Bulk waste and Slags/ash.
9 This indicator accounts for all greenhouse gases except biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. As such, the indicator is identical to GWP-total except that the CF for biogenic CO_2 is set to zero.

Eco-toxicity (freshwater)*	Potential Comparative Toxic Unit for ecosystems (ETP-fw)	CTUe	USEtox
Human toxicity potential - cancer effects*	Potential Comparative Toxic Unit for humans (HTP-c)	CTUh	USEtox
Human toxicity potential - non cancer effects*	Potential Comparative Toxic Unit for humans (HTP-nc)	CTUh	USEtox
Potential Environmental Impacts – Indicators According to EN 15804+A1			
Global warming (GWP100a)	GWP	kg CO_2 equivalents	CML (v4.02) based on IPCC AR4
Ozone layer depletion	ODP	kg CFC-11 equivalents	CML (v4.02) based on WMO 1999
Acidification	AP	kg SO_2 equivalents	CML (v4.02)
Eutrophication	EP	kg PO_4^{3-} equivalents	CML (v4.02)
Photochemical oxidation	POCP	kg C_2H_4 equivalents	CML (v4.02)
Abiotic depletion	ADPE	kg Sb equivalents	CML (v4.02)
Abiotic depletion (fossil fuels)	ADPF	MJ, net calorific value	CML (v4.02)
Environmental impact indicators in accordance with Green Star v1.3			
Human toxicity cancer	HTP-c	CTUh	USEtox – cancer effect
Human toxicity noncancer	HTP-nc	CTUh	USEtox – noncancer effect
Land use	LU	kg C deficit-eq.	Soil Organic Matter method
Resource depletion - water	RDW	m^3	Water Stress Indicator
Ionising radiation	IR	kBq U-235-eq.	Human Health Effect model
Particulate matter	PM	kg PM2.5-eq.	RiskPoll

**Disclaimer – The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator.*

***Disclaimer – This impact category deals mainly with the eventual impact of low dose ionizing radiation on human health of the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents, occupational exposure nor due to radioactive waste disposal in underground facilities. Potential ionizing radiation from the soil, from radon and from some construction materials is also not measured by this indicator.*

Environmental Performance

The interpretation of results is presented in the following sections. Note that the use of results of modules A1-A3 or A1-A5, without considering the results of module C may mislead the communication and decision-making. The estimated impact results are only relative statements, which do not indicate the endpoints of the impact categories, exceeding threshold values, safety margins and/or risks.

Recycling at the end-of-life scenario

Table 7 | Environmental impacts per tonne of Bar chairs (results are in accordance with EN15804+A2:2019)

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
GWP-total	kg CO_2 eq.	6.21E-02	2.36E-03	5.71E-03	0.00E+00	5.02E-04	0.00E+00	2.48E-04	0.00E+00
GWP-fossil	kg CO_2 eq.	6.59E-02	2.36E-03	3.62E-04	0.00E+00	5.02E-04	0.00E+00	2.48E-04	0.00E+00
GWP-biogenic	kg CO_2 eq.	-3.89E-03	1.06E-07	5.35E-03	0.00E+00	2.25E-08	0.00E+00	1.21E-07	0.00E+00
GWP-luluc	kg CO_2 eq.	2.63E-05	6.89E-08	1.89E-07	0.00E+00	1.47E-08	0.00E+00	1.03E-10	0.00E+00
ODP	kg CFC 11 eq.	3.25E-10	3.16E-11	3.30E-13	0.00E+00	6.73E-12	0.00E+00	3.40E-11	0.00E+00
AP	mol H^+ eq.	1.74E-04	6.40E-06	2.29E-06	0.00E+00	1.36E-06	0.00E+00	6.51E-07	0.00E+00
EP - F	kg P eq.	2.27E-06	4.79E-08	1.43E-08	0.00E+00	1.02E-08	0.00E+00	2.85E-10	0.00E+00
EP - M	kg N eq.	4.17E-05	2.33E-06	1.04E-06	0.00E+00	4.97E-07	0.00E+00	1.16E-07	0.00E+00
EP - T	mol N eq.	4.14E-04	2.55E-05	1.04E-05	0.00E+00	5.43E-06	0.00E+00	1.27E-06	0.00E+00
POCP	kg NMVOC eq.	1.52E-04	9.54E-06	2.40E-06	0.00E+00	2.03E-06	0.00E+00	3.38E-07	0.00E+00
ADP	kg Sb eq.	7.42E-08	1.40E-10	2.56E-10	0.00E+00	2.98E-11	0.00E+00	4.58E-14	0.00E+00
ADPF	MJ	3.59E+00	3.15E-02	3.97E-03	0.00E+00	6.70E-03	0.00E+00	3.41E-03	0.00E+00
WDP	m^3 eq. deprived	3.19E-01	2.92E-05	6.06E-04	0.00E+00	6.22E-06	0.00E+00	2.35E-05	0.00E+00
Acronyms	GWP-fossil = Global Warming Potential fossil fuels; GWP-biogenic = Global Warming Potential biogenic; GWP-luluc = Global Warming Potential land use and land use change; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential, Accumulated Exceedance; EP-freshwater = Eutrophication potential, fraction of nutrients reaching freshwater end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals&metals = Abiotic depletion potential for non-fossil resources; ADP-fossil = Abiotic depletion for fossil resources potential; WDP = Water (user) deprivation potential, deprivation-weighted water consumption;								

* Disclaimer: The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

Table 8 | Resource use per tonne of Bar chairs (results are in accordance with EN15804+A2:2019)

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
PERE	MJ	5.17E-01	5.13E-05	5.47E-02	0.00E+00	1.09E-05	0.00E+00	4.51E-05	0.00E+00
PERM	MJ	5.48E-02	0.00E+00	-5.48E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERT	MJ	5.72E-01	5.13E-05	-2.09E-05	0.00E+00	1.09E-05	0.00E+00	4.51E-05	0.00E+00
PENRE	MJ	8.53E-01	3.15E-02	7.10E-03	0.00E+00	6.70E-03	0.00E+00	2.73E+00	0.00E+00
PENRM	MJ	2.73E+00	0.00E+00	-3.12E-03	0.00E+00	0.00E+00	0.00E+00	-2.73E+00	0.00E+00
PENRT	MJ	3.59E+00	3.15E-02	3.97E-03	0.00E+00	6.70E-03	0.00E+00	3.41E-03	0.00E+00
SM	kg	0.00E+00	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	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	0.00E+00
FW	m^3	8.82E-04	1.06E-06	6.46E-05	0.00E+00	2.25E-07	0.00E+00	5.16E-07	0.00E+00
Acronyms	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy re-sources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water								

Table 9 | Waste generated per tonne of Bar chairs (results are in accordance with EN15804+A2:2019)

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Hazardous waste disposed	kg	1.20E-06	2.15E-07	2.96E-12	0.00E+00	4.58E-08	0.00E+00	7.09E-10	0.00E+00
Non-hazardous waste disposed	kg	4.41E-04	1.35E-06	6.74E-04	0.00E+00	2.87E-07	0.00E+00	1.26E-06	0.00E+00
Radioactive waste disposed/stored	kg	6.52E-08	1.13E-09	1.13E-15	0.00E+00	2.41E-10	0.00E+00	1.88E-13	0.00E+00

Table 10 | Output flows per tonne of Bar chairs (results are in accordance with EN15804+A2:2019)

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Components for reuse	kg	3.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for recycling	kg	0.00E+00	0.00E+00	2.25E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for energy recovery	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported energy - electricity	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported energy - thermal	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 51 | Additional environmental impacts per tonne of Bar chairs (results are in accordance with EN15804+A2:2019)

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
GWP-GHG	kg CO_2 eq	6.67E-02	2.36E-03	1.12E-03	0.00E+00	5.02E-04	0.00E+00	2.48E-04	0.00E+00
GWP-GHG (IPCC AR5)	kg CO_2 eq	6.66E-02	2.36E-03	1.07E-03	0.00E+00	5.02E-04	0.00E+00	2.48E-04	0.00E+00
Particulate matter	disease incidence	2.75E-09	1.57E-10	2.48E-11	0.00E+00	3.35E-11	0.00E+00	3.95E-12	0.00E+00
Ionising radiation - human health**	kBq U-235 eq	8.55E-04	4.79E-06	-1.19E-06	0.00E+00	1.02E-06	0.00E+00	5.22E-09	0.00E+00
Ecotoxicity – freshwater*	CTUe	1.79E-01	2.07E-03	1.70E-03	0.00E+00	4.41E-04	0.00E+00	6.57E-04	0.00E+00
Human toxicity potential - cancer effects*	CTUh	4.94E-11	1.98E-13	2.43E-13	0.00E+00	4.21E-14	0.00E+00	3.64E-15	0.00E+00
Human toxicity potential - non cancer effects*	CTUh	2.43E-10	1.55E-11	6.11E-12	0.00E+00	3.31E-12	0.00E+00	2.99E-14	0.00E+00
Soil quality*	Pt	1.86E+00	1.29E-04	1.57E-03	0.00E+00	2.74E-05	0.00E+00	1.24E-04	0.00E+00
Acronyms	GWP-GHG = Global warming potential, excluding biogenic uptake, emissions and storage								

**Disclaimer – The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator.*

***Disclaimer – This impact category deals mainly with the eventual impact of low dose ionizing radiation on human health of the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents, occupational exposure nor due to radioactive waste disposal in underground facilities. Potential ionizing radiation from the soil, from radon and from some construction materials is also not measured by this indicator.*

Table 12 | Environmental impacts per tonne of Bar chairs (results are in accordance with EN15804+A1:2013)

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Global warming potential (GWP100)	kg CO_2 eq	6.65E-02	2.36E-03	9.96E-04	0.00E+00	5.02E-04	0.00E+00	2.48E-04	0.00E+00
Ozone layer depletion	kg CFC-11 eq	2.65E-10	2.50E-11	2.55E-13	0.00E+00	5.32E-12	0.00E+00	2.68E-11	0.00E+00
Acidification potential	kg SO_2 eq	9.08E-05	4.79E-06	1.76E-06	0.00E+00	1.02E-06	0.00E+00	4.36E-07	0.00E+00
Eutrophication potential	kg PO_4^{3-} eq	2.20E-05	9.64E-07	4.28E-07	0.00E+00	2.05E-07	0.00E+00	6.16E-08	0.00E+00
Photochemical ozone creation potential	kg C_2H_4 eq	1.41E-05	2.83E-07	6.67E-09	0.00E+00	6.02E-08	0.00E+00	2.26E-08	0.00E+00
Abiotic depletion potential for non-fossil resources	kg Sb eq	7.45E-08	1.40E-10	2.56E-10	0.00E+00	2.98E-11	0.00E+00	2.83E-13	0.00E+00
Abiotic depletion potential for fossil resources	MJ	7.23E-01	1.19E-03	-7.33E-04	0.00E+00	2.52E-04	0.00E+00	3.45E-03	0.00E+00

Table 13 | Environmental impacts per tonne of Bar chairs (results are in accordance with Green Star v1.3)

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D
Human Toxicity cancer	CTUh	1.71E-11	9.03E-14	8.45E-15	0.00E+00	1.92E-14	0.00E+00	2.96E-15	0.00E+00
Human Toxicity non-cancer	CTUh	8.58E-13	2.03E-15	-9.45E-16	0.00E+00	4.33E-16	0.00E+00	1.29E-15	0.00E+00
Land use	kg C deficit eq.	1.34E-01	6.37E-05	1.25E-03	0.00E+00	1.35E-05	0.00E+00	-2.22E-07	0.00E+00
Ionising radiation	kBq U235 eq	8.56E-04	4.80E-06	-1.19E-06	0.00E+00	1.02E-06	0.00E+00	5.22E-09	0.00E+00
Particulate Matter	kg PM2,5-Equiv.	2.86E-05	1.44E-06	4.03E-07	0.00E+00	3.07E-07	0.00E+00	6.81E-08	0.00E+00
Resource depletion - water	m^3	1.04E-02	1.53E-06	-1.63E-04	0.00E+00	3.26E-07	0.00E+00	8.19E-07	0.00E+00

Interpretation of Results

The following insights were observed from the LCA results for Transmutation Concrete Bar chair:

- The GWP-Total emission from the product stage (A1-A3) is 76% of total lifecycle emissions.
- The downstream (module A4) accounts 3.3% of total lifecycle emissions.
- Installation (module A5) accounts for only 22.6% of total lifecycle emissions.
- Waste transport (C2 module) accounts 0.7% of total lifecycle.
- In the landfilling scenario, module C4 contribute up to 0.3% of total GWP.
- Across all modules, 100% of the waste disposed is non-hazardous (NHWD).
- There are not recycling benefits at the end of its service life (D).

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