LIFE CYCLE ASSESSMENT (LCA) OF TOTO NEOREST® NX DUAL FLUSH TOILET & TOTO NEOREST® WX DUAL FLUSH WALL-HUNG TOILET WITH IN-WALL TANK SYSTEM

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EXECUTIVE SUMMARY

TOTO is a leading manufacturer of bathroom products, renowned for its innovation and quality. The company's product range includes toilets, bidets, faucets, showers, and bathroom accessories. Environmental sustainability is at the core of TOTO's philosophy, as they strive to develop eco-friendly products and practices, such as water-saving technologies, energy-efficient systems, and sustainable manufacturing processes. By combining innovation with environmental stewardship, TOTO aims to contribute to a healthier planet while enhancing the everyday lives of its customers. The company commissioned this study to evaluate the potential environmental impacts of its NEOREST® NX and WX toilet products, using a cradle-to-grave approach.

This study covers two models within the NEOREST® NX series: the NEOREST® NX1 Dual Flush Toilet (MS902CUMFG) and NEOREST® NX2 Dual Flush Toilet (MS903CUMFX), both with 1.0 gpf / 0.8 gpf. The NEOREST® WX series toilets come with an in-wall tank system. Two models are covered within the NEOREST® WX series: the NEOREST® WX1 Wall-Hung Toilet (CWT9538CEMFG with WT175MA) and NEOREST® WX2 Wall-Hung Toilet (CWT9538CEMFX with WT175MA). The evaluated models within each product family have the same material composition and differ only in the features they offer. The NEOREST® NX washlet unit is assembled in Toki, Japan and shipped to Kokura, Japan where it is assembled with the bowl, manufactured in-house in Kokura. The NEOREST® WX washlet unit is assembled in Shanghai, China and also shipped to Kokura, Japan for assembly with the bowl. The WT175MA tank support system is manufactured in China and shipped separately to the US.

A functional unit of one unit of product over the estimated service of the building was used for the assessment. The estimated service life of the building (ESL) is 75 years, and the reference service life (RSL) for both products is 20 years. This life cycle assessment (LCA) was conducted conforming to the relevant PCRs and applicable ISO standards using a cradle-to-grave approach, including all life cycle stages from raw material extraction through final assembly, transportation of materials between supplier facilities and manufacturing facilities, manufacturing operations, distribution to end users, resource consumption during product use, and end-of-life disposal.

A high-level summary of the findings of this study is illustrated in the table below, which shows impacts per functional unit. The table presents the potential CO_2-equivalent emissions and SM single score results for NEOREST® toilets. For other impact categories and a breakdown by each life cycle stage, refer to section 5.2 in the full report. Overall, the study found that environmental performance is driven primarily by product usage. The impacts within the use phase are dominated by the product replacements and electricity consumption for bidet operations. All evaluated NEOREST® toilets must be replaced 2.75 times to meet the prescribed ESL of 75 years. The cumulative impact of manufacturing, distributing, and disposing of multiple units over the desired service period makes product replacement resource and energy intensive. Washlets consume a considerable amount of electricity per use, which adds up significantly for the ESL period and leads to significant potential environmental impacts. Raw material extraction and the ceramic manufacturing operations also represent a considerable share, but it is small when compared to the impacts generated in the use phase.

Product	**Impact categories**	**Unit**	**Production**	**Construction/ Installation**	**Use**	**End of life**	**Total**
			A1-A3	**A4-A5**	**B1-B7**	**C1-C4**	
NEOREST® NX Dual Flush Toilet	*Global warming potential*	kg CO_2 eq	4.23E+02	6.16E+01	3.86E+03	1.25E+01	**4.36E+03**
		%	9.71%	1.41%	88.59%	0.29%	**100%**
	SM single figure score	mPts	5.20E+01	3.54E+00	6.68E+02	5.06E-01	**7.24E+02**
		%	7.19%	0.49%	92.25%	0.07%	**100%**
NEOREST® WX Wall-Hung Toilet with In-Wall Tank System	*Global warming potential*	kg CO_2 eq	3.45E+02	5.37E+01	3.80E+03	1.87E+01	**4.21E+03**
		%	8.19%	1.28%	90.09%	0.44%	**100%**
	SM single figure score	mPts	9.53E+01	3.07E+00	8.13E+02	7.13E-01	**9.12E+02**
		%	10.45%	0.34%	89.14%	0.08%	**100%**

Contents

1. BACKGROUND

1.1. Opportunity

TOTO is a leading manufacturer of bathroom products, renowned for its innovation and quality. The company's product range includes toilets, bidets, faucets, showers, and bathroom accessories. TOTO's NEOREST® Collection offers the most innovative, design-forward array of products available with elegant designs drawn from nature, cutting-edge technology, flawless performance, and extraordinary comfort. TOTO believes that the bath space should be a relaxing, restorative place where people escape the stresses of daily life, and their everyday bathroom rituals are transformed into enriching experiences. With its NEOREST® Collection, TOTO has brought this design philosophy to its most beautiful and welcoming expression.

TOTO is committed to creating high-performance, technologically advanced, and environmentally sustainable products. Their goals in product innovation focus on improving hygiene, comfort, and convenience for users, while also reducing water and energy consumption. Environmental sustainability is at the core of TOTO's philosophy, as they strive to develop eco-friendly products and practices, such as water-saving technologies, energy-efficient systems, and sustainable manufacturing processes. By combining innovation with environmental stewardship, TOTO aims to contribute to a healthier planet while enhancing the everyday lives of its customers.

As part of the ongoing commitments to environmental sustainability, TOTO is embarking on this project to transparently communicate the potential environmental impacts and performance associated with the NEOREST® NX and WX toilets. As a result, it is important to conduct life cycle assessments (LCAs) to evaluate the potential environmental impacts from raw materials acquisition through the end of life. The goal is to explore the potential environmental impacts that the product has and to identify ways to improve processes and reduce impacts. This project is critical to TOTO's PeoplePlanetWater mission of innovating products for the benefit of people, planet, and water supply.

To understand the true impacts of its NEOREST® NX Dual Flush Toilet (referred to as NEROEST® NX hereafter) and NEOREST® WX Wall-Hung Toilet with In-Wall Tank System (referred to as NEROEST® WX hereafter), TOTO commissioned Sustainable Minds to help develop an LCA using a cradle-to-grave approach. TOTO is looking forward to having guidance for future product improvements that can be informed by the results of this study. TOTO is interested in having LCA data available for its NEOREST® NX and WX toilets to be able to obtain Sustainable Minds Transparency Reports [EPDs]™ (TRs), which are ISO 14025 Type III environmental declarations that can be used for communication with and amongst other companies, architects, and consumers, and that can also be utilized in whole building LCA tools in conjunction with the LCA background report and life cycle inventory (LCI). This study aims to conform to the requirements of ISO 14040/14044 [1] [2], ISO 21930:2017 [3], and Sustainable Minds Part A [4]. In addition, this study also aims to comply with the Sustainable Minds Part B for residential toilets [5].

1.2. Life cycle assessment (LCA)

LCA is performed to comprehensively explore, quantify, and interpret the potential environmental impacts associated with a product or service over the entire life cycle. A product's life cycle consists of various stages, starting from raw material acquisition and manufacturing to product use and maintenance, plus final product disposal. Depending on the inclusion and exclusion of life cycle stages, an LCA could be cradle to gate (from raw material acquisition to the manufactured product ready to be shipped), cradle to gate with options (which also optionally includes other modules such as shipment and installation), or cradle to grave (which includes all other stages including product usage and disposal once the useful life is over).

Any LCA conducted with the intention of publishing EPDs needs to conform to the internationally accepted ISO 14040 and ISO 14044 standards. ISO 14040 provides principles and frameworks for conducting a LCA [1], while ISO14044 specifies requirements and provides guidelines for an LCA [2]. ISO 14040 sets out a four-phase methodology framework for completing a LCA, as depicted in **Figure 1**.

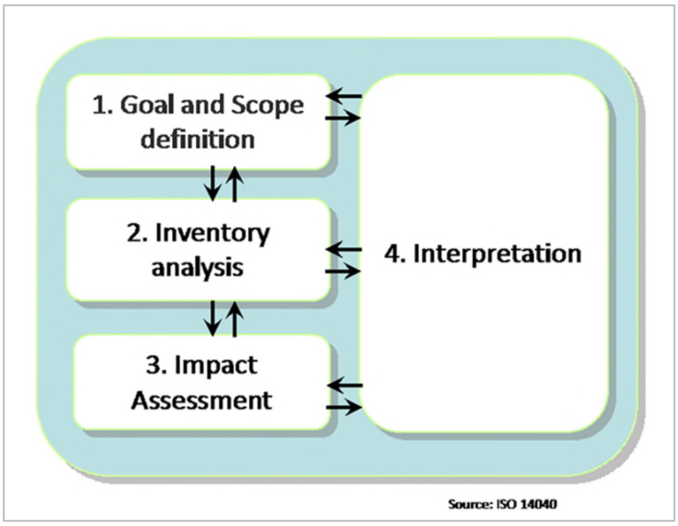

Figure 1. Phases of an LCA

- **Goal and scope definition:** Goals refer to establishing the purpose of the LCA, and they define the environmental aspects to be studied and the intended audience. Scope outlines the system boundaries, the functional unit of analysis, and the life cycle stages to be included. System boundaries set up inclusions and exclusions in an LCA. PCRs usually specify whether the boundary must be cradle-to-gate, cradle-to-installation, or cradle-to-grave.

- **Life cycle inventory analysis:** In this step, a detailed inventory of all the environmental inputs and outputs associated with each stage of the product's life cycle is compiled. Primary data about materials, energy, and emissions assessing the upstream supply chain, company's manufacturing operations, and downstream processes (after product leaves the factory gate) are collected via LCI data collection templates or tools. Annual data is suggested in most cases to be representative of the manufacturing operations. In the case of multi outputs, resources can be allocated to the product of interest via mass or volume, or as relevant. The inventory is then scaled to meet the functional unit of the LCA.

- **Life cycle impact assessment:** The compiled LCI is then modeled using an LCA software like SimaPro, GaBi, openLCA, or others using suitable background data sets available on their databases. Each is assigned to categories according to different impact methodologies, and the software provides final impact values for those different environmental impact categories. Several LCIA methodologies exist in the market including ReCiPe, TRACI, CML, and ILCD, which differ in terms of their approaches, characterization factors, evaluated impact categories, and modeling assumptions. Practitioners can choose a combination of LCIA methodologies to provide a holistic view of the environmental performance of a product.

- **Interpretation of results:** In this step, the LCIA results are analyzed and presented via an LCA report. This stage helps draw conclusions about the environmental performance of the product, identify any environmental hotspots, make recommendations, and assess the significance of the findings. Sensitivity analysis, scenario studies, and uncertainty assessment are often included as a part of the interpretation to ensure the reliability and robustness of the results. LCA, if well interpreted and evaluated, presents a number of opportunities for the manufacturer in developing sustainability goals and initiatives.

This LCA study follows an attributional approach and uses a cradle-to-grave system boundary. This report incorporates LCA terminology. To assist the readers in understanding LCA, special attention has been given to list definitions of important terms used at the end of this report.

A critical review of the LCA and an independent verification of the TRs are required for ISO 14025 Type III environmental declarations. Both are included in this project.

1.3. Team

This LCA report is the outcome of the efforts of the project team led by Gary Soe, Engineering Manager on behalf of TOTO, with support from TOTO personnel during the data collection, reporting, and interpretation phases. Sustainable Minds led the development of the LCA results, LCA report, and TRs.

1.4. Status

All information in this report reflects the best possible data inventory by TOTO at the time it was collected, and Sustainable Minds and TOTO adhered to best practices in transforming the inventory into this report.

The data covers annual manufacturing data for January 2023 – December 2023 from TOTO's relevant manufacturing facilities. Where data was missing, assumptions were made for the facilities based on expertise from TOTO and its upstream suppliers.

This study includes primary data from processes at the upstream manufacturing facilities and background data to complete the inventory and fill gaps where necessary.

This is a supporting LCA report for the TOTO Transparency Reports [EPDs]™ and was evaluated for conformance to the PCR according to the ISO 14025 [6] and ISO 14040/14044 [1][2] standards. The LCA review and verification of the Sustainable Minds Transparency Reports [EPDs]™ was carried out by Jack Geibig, President, Ecoform on behalf of NSF and found to be conformant to ISO 14040/14044 and the relevant PCR.

2. Goal and Scope

This chapter explains the goal and scope of the study. The aim of the goal and scope is to define the product and the depth and breadth of the study.

2.1. Intended application and audience

This report intends to define the specific application of the LCA methodology to the life cycle of the NEOREST® NX and WX toilets manufactured and distributed by TOTO. The report serves both internal and external purposes and is intended for a diverse audience. The intended audience includes the program operator (Sustainable Minds) and reviewers who will be assessing the LCA for conformance to the PCR, as well as TOTO's internal stakeholders involved in marketing and communications, operations, and design.

The results presented in this document are not meant to support comparative claims. The outcomes will be made available to the public in Sustainable Minds' Transparency Reports [EPDs]™ (Type III environmental declarations per ISO 14025), intended for communication between businesses and consumers (B2C).

2.2. Product description

TOTO's product range includes toilets, bidets, faucets, showers, and bathroom accessories. The two products covered in this study are the NEOREST® NX Dual Flush Toilet and NEOREST® WX Wall-Hung Toilet with In-Wall Support System. TOTO's NEOREST® Smart Bidet Toilets offer a seamless blend of luxury, innovation, and sustainability. They are equipped with following features making the bath space relaxing and restorative:

- Auto Flush: Touchless TORNADO flushing technology
- PREMIST®: The bowl's interior is sprayed with a fine water mist to reduce waste's ability to stick to its surface, resulting in a better clean
- CEFIONTECT®: a nano-tech glaze that creates a super-slippery, non-porous surface on porcelain, preventing waste from clinging
- EWATER+®: Electrolyzed water sprays bowl and wand, ensuring cleanliness without harsh chemicals; reverts to tap water over time
- TORNADO FLUSH®: Quiet, powerful dual flush with rimless bowl and trapway effectively removes waste and cleans bowl

The NEOREST® NX is comprised of a washlet unit and a ceramic bowl. The NEOREST® WX is comprised of a washlet unit, ceramic bowl, and a tank support system. For each product family, two models are covered in this study as shown in **Table 1**. Evaluated models within each family have the same material composition and differ only in a single feature offered. The NX2 and WX2 have ACTILIGHT® clean light technology built into the lid, while the NX1 and WX1 do not. The NEOREST® NX's washlet unit is assembled in Toki, Japan and shipped to Kokura, Japan where it is assembled with the bowl, manufactured in-house in Kokura, and later shipped to TOTO's distribution center in GA, USA. The NEOREST® WX's washlet unit is assembled in Shanghai, China and also shipped to Kokura, Japan for assembly with the bowl. The WT175MA tank support system is manufactured in China and shipped separately to TOTO's distribution center in GA, USA.

Table 1. Evaluated NEOREST® NX and WX models

Product family	Product model	Model description
TOTO NEOREST® NX Dual Flush Toilet	MS902CUMFG	NEOREST® NX1 Dual Flush Toilet, 1.0 GPF / 0.8 GPF
	MS903CUMFX	NEOREST® NX2 Dual Flush Toilet, 1.0 GPF / 0.8 GPF
TOTO NEOREST® WX Wall-Hung Toilet with In-Wall Tank System	CWT9538CEMFG with WT175MA	NEOREST® WX1 Wall-Hung Dual Flush Toilet - 1.2 GPF / 0.8 GPF
	CWT9548CEMFX with WT175MA	NEOREST® WX2 Wall-Hung Dual Flush Toilet - 1.2 GPF / 0.8 GPF

Figure 2 provides representative images for the products evaluated in this study.

NEOREST® NX toilet   NEOREST® WX toilet

Figure 2. Visual representation of products

Table 2 lists the product information in accordance with PCR, including declaration name, CSI MasterFormat® classification, manufacturing location, compliant standards, and the type of declaration. As shown in the table, two Transparency Reports [EPDs]™ will be developed from this study to represent TOTO's NEOREST® NX and NEOREST® WX toilets.

Table 2. Declared product information and type of declaration

Transparency Report [EPD]™ name	CSI MasterFormat® classification	Manufacturing location	Standards/Certifications	Type of declaration
TOTO NEOREST® NX Dual Flush Toilet	22 41 13	Kokura, Japan	Meets and exceeds: ASME A112.19.2/CSA B45.1 ASME A112.4.2, UL 1431, CSA C22.2 #68	Product-specific, plant-specific declaration
TOTO NEOREST® WX Wall-Hung Toilet with In-Wall Tank System	22 41 13	Kokura, Japan *(top unit)* Shanghai, China *(tank support system)*	Code compliance with UPC, IPC, NSPC, NPC Canada, and others Certified with IAPMO, EPA WaterSense	Product-specific, plant-specific declaration

For more information about the products and models covered, visit the TOTO website.

2.3. Functional unit

This LCA covers the cradle-to-grave stages for TOTO's NEOREST® NX and WX toilets. A functional unit of one dual flush toilet in an average residential environment, with electronic bidet seat, over the estimated service life of the building was used.

The estimated service life of the building (ESL) is 75 years per the PCR. The reference service life (RSL) of the toilet is 20 years.

2.4. System boundary

This section describes the system boundary for the analysis. The system boundary defines which life cycle stages are included and which are excluded.

This LCA's system boundary is from cradle to grave. Therefore, the life cycle activities and related processes shall include all life cycle stage modules from A1-C4 as illustrated in **Figure 3**. This includes raw materials extraction and preprocessing, transportation, manufacturing, distribution, installation, use stages, and end of life stages. This study follows the modularity principle, where all environmental impacts and potential impacts are declared in the life cycle stage where they can be attributed. This study follows the modularity principle, where all environmental impacts and potential impacts are declared in the life cycle stage where they can be attributed. **Table 3** lists specific inclusions and exclusions for the system boundary.

Scope	PRODUCTION STAGE			CONSTRUCTION STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
	Extraction and upstream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/Demolition	Transport to waste processing or disposal	Waste processing	Disposal of waste	Reuse, Recovery, Recycling Potential
Cradle to grave	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	MND

Figure 3. Applied system boundary

Table 3. System boundary inclusions and exclusions

Included	Excluded
• Raw material extraction for components • Transport of raw materials/ purchased components to the manufacturing/assembly facility • Interfacility transport of assemblies • Processing of raw materials into components (for externally purchased and in-house manufactured) • Energy production • Manufacturing scrap and its disposal • Outbound transportation of product to users • Packaging for the final product and its disposal • Installation of the product • Use phase activities (maintenance, repair, replacement, operational energy & water use) • Product disposal after use	• Construction of major capital equipment • Maintenance and operation of support equipment • Human labor and employee transport • Manufacture, transport, and disposal of packaging materials not associated with final product • Energy consumption in the warehouses, distribution centers, and retail facilities during the course of transport to the final customer • Construction of water and wastewater infrastructure

2.4.1. Product flow - NEOREST® NX Dual Flush Toilet

The NEOREST® NX toilet is comprised of a washlet unit and a ceramic bowl. The washlet unit is assembled in TOTO's plant in Toki, Japan and then shipped to TOTO's plant in Kokura, Japan where it is assembled with the ceramic bowl. The bowl is manufactured in-house in the Kokura plant. The complete NX unit is later shipped to TOTO's distribution center in GA, USA after final product testing and packaging. From there, the product is transported to the end user site and installed. Once the product is installed, it requires periodic cleaning and replacement (at the end of the RSL). Various parts need to be replaced within the RSL. Energy and water are consumed throughout the ESL for continuous operation of the product during the use phase. Per the PCR, the product is assumed to be landfilled at the end of life. **Figure 4** provides an overview of the product flow during its life cycle.

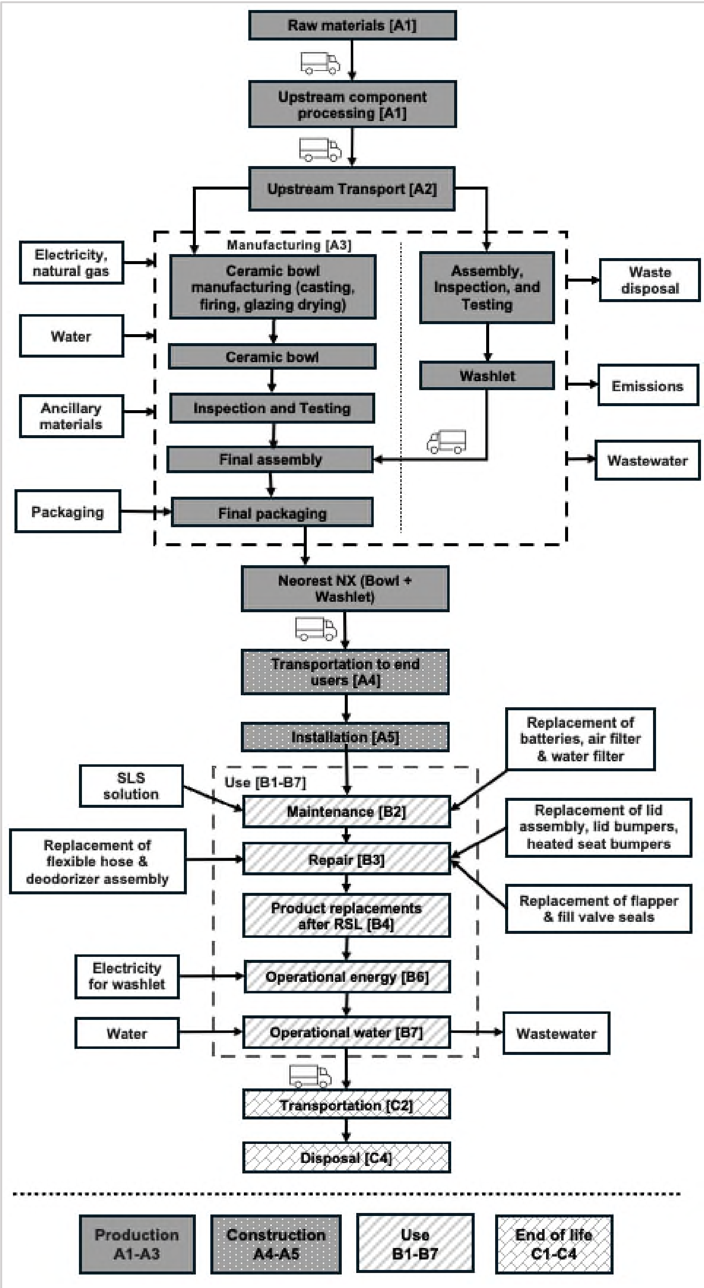

Figure 4. System boundary and product flow diagram of TOTO NEOREST® NX toilet

2.4.2. Product flow - NEOREST® WX Wall-Hung Toilet with In-Wall Tank System

The NEOREST® WX toilet is comprised of a washlet unit, a ceramic bowl, and a tank support system. The washlet unit is assembled in TOTO's plant in Shanghai, China and then shipped to TOTO's plant in Kokura, Japan where it is assembled with the ceramic bowl. The bowl is manufactured in-house in the Kokura plant. This is later shipped to TOTO's distribution center in GA, USA after final product testing and packaging. From there, the complete WX product (bowl unit and tank support system) is transported to the end user site and installed. The tank support system is manufactured in China and shipped directly to GA, USA after inspection and later to end users. Once installed, it requires periodic cleaning and replacement (at the end of the RSL). Various parts need to be replaced within the RSL. Energy and water are consumed throughout the ESL for continuous operation of the product during the use phase. Per the PCR, the product is assumed to be landfilled at the end of life. **Figure 5** provides an overview of the product flow during its life cycle.

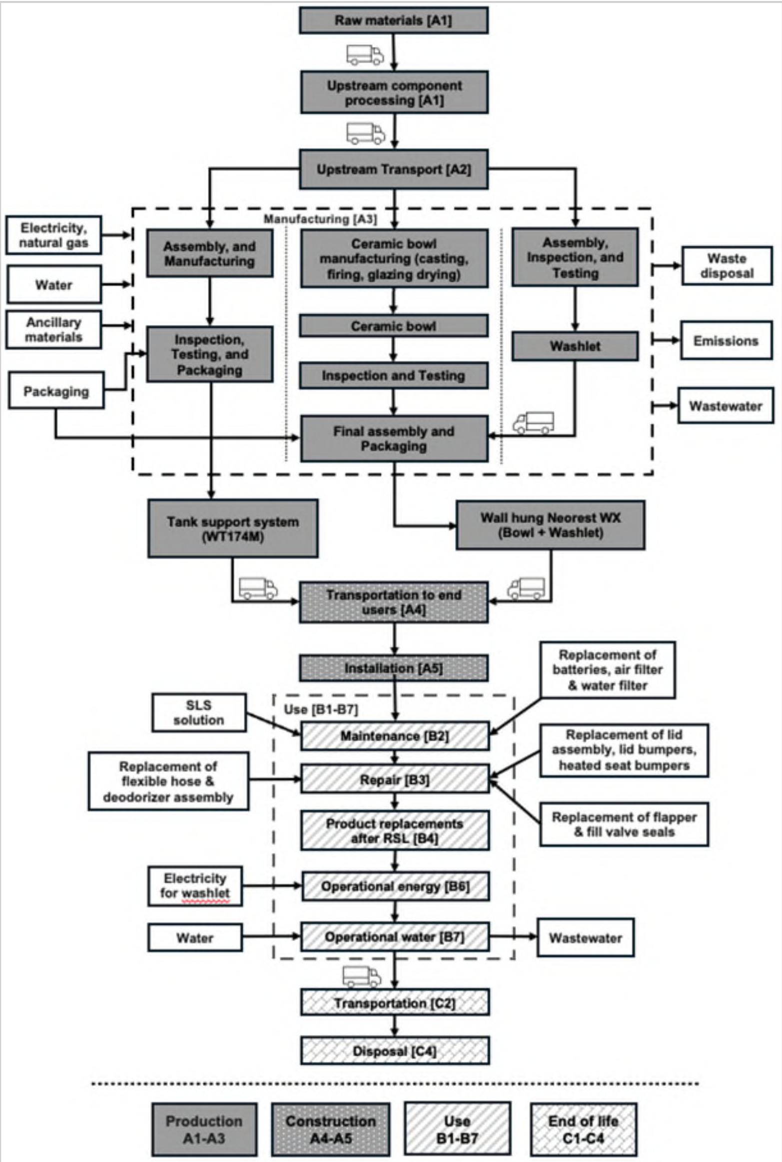

Figure 5. System boundary and product flow diagram of TOTO NEOREST® WX toilet

3. LIFE CYCLE INVENTORY ANALYSIS

This chapter includes an overview of the obtained data and data quality that has been used in this study. A complete life cycle inventory calculation workbook, which catalogs the flows crossing the system boundary and provides the starting point for life cycle impact assessment, can be found in the appendix.

3.1. Data collection procedures

Primary data was provided by TOTO representing the supply chain (A1-A2), manufacturing processes (A3), and distribution (A4) of the NEOREST® NX and WX toilets. Data was collected in a consistent manner and level of detail to ensure high-quality data. All submitted data were checked for quality multiple times on the plausibility of inputs and outputs using mass balance and benchmarking. All questions regarding data, including gaps, outliers, and any inconsistencies, were resolved with TOTO and their suppliers. Assumptions for upstream processing operations regarding each purchased component were developed via suggestions from TOTO personnel and suppliers. Annual data for the year 2023 (January 2023 to December 2023) was collected at the manufacturing facilities for the assembly and manufacturing of the associated product assemblies and final products. The resulting inventory calculations were developed by an analyst at Sustainable Minds and subsequently checked internally.

While the inventory for the production and construction/installation stage (A1-A5) was developed using primary data, the inventory for the use stage (B1-B7) and end-of-life stage (C1-C4) were developed using the assumptions prescribed by the PCRs and TOTO's product specifications.

Expert judgment was used in selecting appropriate data sets to model the associated activities in this study, including raw materials, upstream component processing, and energy, which have been noted in the subsequent sections. Databases adopted in the model include ecoinvent v3.10, US-EI 2.2, and Industry data 2.0 databases. Overall, the quality of the data used in this study is considered to be good and representative of the described systems. All appropriate means were employed to guarantee the data quality and representativeness.

3.2. Primary data and PCR guidelines

Besides upstream component processing, primary data was collected for the A1-A4 modules. Appropriate upstream component processing was identified together with the TOTO team to best represent the manufacturing of each individual component being shipped to the TOTO facility for product assembly. Primary data were collected using either direct measurement or the manufacturing facility personnel's best engineering estimates based on actual production if measurements were not available. PCR guidelines were used for the remaining product life cycle stages.

3.2.1. Raw materials acquisition and transportation (A1-A2)

These modules represent raw materials extraction, preprocessing/upstream processing, and transportation to the manufacturing facility. Full bills of materials (BOMs) were provided for the NEOREST® NX washlet unit, NEOREST® WX washlet unit, and WT175MA unit with a detailed breakdown of parts/components and raw materials for each component. Raw materials are extracted and manufactured by material suppliers and transported to the component manufacturing plants. Components are then transported to the TOTO facility where the individual components are assembled into the final product and/or product assemblies. Supply chain primary data, including information on component supplier locations, shipping distances, and transportation modes to the final manufacturing plants, were all provided. A single supplier is used for a specific component. It must be noted that the packaging materials used for the shipment of components to the final TOTO plants were not included in this study.

For the ceramic bowls, the Kokura plant provided an annual quantity of raw materials being shipped into the facility, which was normalized to input materials per kg of ceramic output and later scaled up to meet the mass of the specific ceramic bowl used in NEOREST® NX and WX toilets. Only the base ingredients and glazing materials are included in the analysis since the resin molds are reused 10,000+ times, making the impacts per unit of product negligible. Neither toilet contains hazardous substances according to the standards or regulations of the Resource Conservation and Recovery Act (RCRA), Subtitle C.

The NEOREST® NX toilet is comprised of a ceramic bowl and washlet unit. All components used in the washlet are purchased directly from suppliers. Shipment distances vary. the upstream road transport distance is ~371 km on average (on a per component basis), and components from overseas travel an average of ~2,637 km by sea. Upstream manufacturing activities have been modeled separately in addition to the raw material extraction. The washlet unit is later shipped to the Kokura plant for assembly with the in-house manufactured ceramic bowl. The material composition and total reference flow is same for both NEOREST® NX toilets (NX1 and NX2) and is reported below in **Table 4**. While the final corrugated packaging is included in the table below, it is included as a resource input to the manufacturing (A3) stage during analysis and results generation.

Table 4. NEOREST® NX assemblies and raw material mass per functional unit
Submitted to the verifier

The NEOREST® WX toilet is comprised of a ceramic bowl, washlet unit, and in-wall tank support system. All components used in the washlet are purchased directly from suppliers. The upstream road transport distance is ~447 km on average (on aper component basis), and components from overseas travel an average of ~1,852 km by sea. Some components for the tank support system are purchased from suppliers with an average upstream road distance of ~39 km, whereas the ceramic bowl is manufactured in-house with base materials coming from suppliers. Upstream manufacturing activities have been modeled separately in addition to the raw material extraction. The material composition and total reference flow is the same for both NEOREST® WX toilets (WX1 and WX2) and is reported below in **Table 5**. While the final corrugated packaging is included in the table below, it is included as a resource input to the manufacturing (A3) stage.

Table 5. NEOREST® WX assemblies and raw material mass per functional unit
Submitted to the verifier

For both NEOREST® toilets, upstream processing operations for purchased components were identified with help from the TOTO team and depending on the material type, manufacturing method, and manufacturing country, components were categorized. Existing ecoinvent data sets were modified manually, and embedded unit processes (mainly electricity and water) were appropriately substituted to represent component production in a particular country. As the transportation data sets represent load factors as an average of empty and fully loaded (i.e., average load factor), empty backhauls are accounted for in the model.

3.2.2. Manufacturing (A3)

This module incorporates the manufacturing operations in the product manufacturing facilities. The manufacturing stage for the NEOREST® NX toilets includes the assembly of the washlet in Toki, Japan and the production of the ceramic bowl in Kokura, Japan. The manufacturing stage for the NEOREST® WX toilets includes the assembly of the washlet in Shanghai, China, production of the ceramic bowl in Kokura, Japan, and the production of the tank support system in China.

For the washlets, all components are purchased from suppliers and shipped directly to the TOTO manufacturing facilities. All TOTO sister companies are under the same efficiency guidance by TOTO Japan, and it was assumed that the same manufacturing resources are consumed for the assembly of washlets (for all models) in all TOTO facilities. Resources (energy, water, and ancillary materials) consumed for the assembly of a unit washlet were calculated using the annual production units. Annual resources, covering the entire year for 2023, consumed for the washlet assembly lines were provided.

$$Resource\ per\ unit\ product\ = \frac{\text{Annual facility resource consumption for assembly}}{\text{Annual production units}}$$

Wastes generated during the assembly process of the washlet were assumed to be 100% landfilled. Manufacturing inputs and outputs per washlet are listed in **Table 6**.

Table 6. Manufacturing resources per washlet unit

Resource category	Flow	Amount	Unit
Energy	Electricity	*Submitted to the verifier*	kWh
Ancillary materials	Lubricants	*Submitted to the verifier*	kg
	Motor oil[1]	*Submitted to the verifier*	L
	Grease[2]	*Submitted to the verifier*	kg
	Plastic wrap	*Submitted to the verifier*	kg
	Polypropylene plastic container	*Submitted to the verifier*	kg
	Stainless steel jig	*Submitted to the verifier*	kg
Waste generation	Non-hazardous waste, landfilled	*Submitted to the verifier*	kg
	Hazardous waste, landfilled	*Submitted to the verifier*	kg
Waste transport	Transport for waste disposal	100	km

[1] Motor oil was clarified to be WD-40, and a density of 875 kg/m^3 was used.
[2] Silicone grease was used, assumed to have a mass composition of 90% silicone oil and 10% fumed silica.

Annual manufacturing data for the year 2023 was provided by the Kokura facility for ceramic manufacturing. **Figure 6** Illustrates all manufacturing activities involved in the production of ceramic bowls.

Submitted to the verifier

Figure 6. Bowl production in the TOTO Kokura plant

The reported annual data was normalized based on the total annual ceramic output mass to develop the inventory per kg of ceramic output. The normalized manufacturing resource per kg ceramic mass output is tabulated in **Table 7**.

$$Resource\ per\ kg\ ceramic\ output\ = \frac{\text{Annual facility resource consumption}}{\text{Annual ceramic production mass}}$$

All waste, including hazardous waste, is reported to be recycled. The plant has on-site wastewater treatment plants, and the major chemicals used for wastewater treatment have been reported as shown in **Table 7**. The recovered water is sent back to the ceramic production processes. The Kokura facility also reported waterborne emissions in its sewage, also included in the analysis.

Table 7. Manufacturing resources per kg ceramic bowl

Resource category	Flow	Amount	Unit
Energy	Electricity (grid)	*Submitted to the verifier*	kWh
	Electricity (diesel generator)	*Submitted to the verifier*	kWh
	Heat, natural gas	*Submitted to the verifier*	m^3
	Heat, heavy oil	*Submitted to the verifier*	L
Water	Municipal supply	*Submitted to the verifier*	m^3
	River water	*Submitted to the verifier*	m^3
Ancillary materials (for wastewater treatment)	Aluminum sulfate	*Submitted to the verifier*	kg
	Aluminum chloride	*Submitted to the verifier*	kg
	Sodium hypochlorite	*Submitted to the verifier*	kg
	Calcium chloride	*Submitted to the verifier*	kg
	Soda ash	*Submitted to the verifier*	kg
	Hydrochloric acid	*Submitted to the verifier*	kg
Waste generation	Non-hazardous waste, recycled	*Submitted to the verifier*	kg
	Hazardous waste, recycled	*Submitted to the verifier*	kg
	Sewage	*Submitted to the verifier*	m^3
Waste transport	Transport for waste disposal sites (weighted average)	*Submitted to the verifier*	km

For the tank support system used in the NEOREST® WX toilet, annual facility resources were provided and normalized using annual production units. Manufacturing resources per unit tank support system are listed in
Table 8.

Table 8. Manufacturing resources per tank support system unit

Resource category	Flow	Amount	Unit
Energy	Electricity (for arc welding)	*Submitted to the verifier*	kWh
Ancillary materials	Grease[3]	*Submitted to the verifier*	kg
	Steel welding rods[4]	*Submitted to the verifier*	kg
Waste generation	Hazardous waste, landfilled	*Submitted to the verifier*	kg
Waste transport	Transport for waste disposal	100	km

3.2.3. Product distribution (A4)

This module refers to the transport and delivery of products from the manufacturing facility to the sites where the products are installed and used.

The NEOREST® NX manufactured in Kokura, Japan is first shipped to TOTO's distribution center in Georgia, USA and then transported to end users and building sites. Shipments to end users can occur via trucks or rail with trucks contributing to 83% of the shipments in 2023. As the transportation data sets represent load factors as an average of empty and fully loaded (i.e., average load factor), empty backhauls are accounted for in the model. Average transportation distances are shown in **Table 9**.

Table 9. NEOREST® NX distribution distances and methods per functional unit

Resource category	Flow	Value	Unit
Manufacturing facility (Japan) to GA, US	Road transport in Japan	689	km
	Sea transport	36,608	km
	Rail transport from port to GA, US	2,191	km
Transport to final users	Road transport (83% share)	1,421	km
	Rail transport (17% share)	2,042	km

The NEOREST® WX bowl manufactured in Kokura, Japan is first shipped to TOTO's distribution center in Georgia, USA and then transported to end users and building sites. Similarly, the WT175MA in-wall tank support system is shipped separately to GA, USA from China. Average transportation distances are shown below in **Table 10**.

[3] Silicone grease was used, assumed to have a mass composition of 90% silicone oil and 10% fumed silica.
[4] Steel welding rods have a >95% share of steel by mass.

Table 10. NEOREST® WX distribution distances and methods per functional unit

Resource category	Flow	Value	Unit
Manufacturing facility (Japan) to GA, USA	Road transport in Japan	689	km
	Sea transport	36,608	km
	Rail transport from port to GA, US	2,191	km
Manufacturing facility (China) to GA, USA	Road transport in China	34.6	km
	Sea transport	11,234	km
	Rail transport from port to GA, US	2,191	km
Transport to final users	Road transport (83% share)	1,421	km
	Rail transport (17% share)	2,042	km

3.2.4. Product installation (A5)

This module represents the installation of the product, making it ready for use.

Installation of the product is manual but assumed to use a 0.15 kg wax ring for both NEOREST® NX and WX toilets. Upstream processing for the wax ring is also included in the study as an injection molding process. The inputs in this module include the disposal of packaging waste (plastic bags and corrugated board) with a waste transportation distance of 100 km. The disposal scenario for corrugated board packaging is assumed to be 80.88% recycled, 15.37% landfilled, and the remaining incinerated, in alignment with US EPA's 2018 end of life data for paperboard containers and packaging[5]. Likewise, the disposal scenario for plastic packaging is assumed to be 13.63% recycled, 69.44% landfilled, and the remaining incinerated, in alignment with US EPA's 2018 end of life data for plastic containers and packaging[6].

3.2.5. Product use (B1)

This module covers any activity related to product use which is not already included in other use modules (B2-B7). There are no activities in this module for NEOREST® NX and WX toilets.

3.2.6. Maintenance (B2)

This module covers all planned technical services and associated operations during the reference service life to maintain the product in a state where it can continue provide its required functional and technical services. A building estimated service life (ESL) of 75 years and reference service life (RSL) of 20 years were used.

Maintenance activities as recommended by the PCR are taken into consideration. Sodium lauryl sulfate (SLS) solution is used for the periodic cleaning of product parts. Each liter of 1% SLS solution is comprised of 10 grams of SLS and 0.99 liters of water. The following maintenance activities have been included in this study for both products:

- Toilet basin, bowl, seat, and lid cleaning – twice per month
- Cleaning of electric plug and gap between toilet tank & seat – monthly

[5] Product specific data for paper and paperboard containers and packaging, EPA 2018. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/containers-and-packaging-product-specific#PaperandPaperboardC&P%20

[6] Product specific data for plastic containers and packaging, EPA 2018.

- Deodorizing filter cleaning – monthly
- Nozzle/wand cleaning – weekly
- Water filter parts cleaning – twice a year
- Replacement of deodorizer/air filter every 10 years – once per RSL
- Replacement of water filter every 10 years – once per RSL
- Replacement of battery every 6 years – thrice during RSL

For the replaced components, the total material inputs, upstream component processing, waste transport of replaced parts (100km), and end of life disposal (100% sanitary landfilled) are included in the analysis. Since replacement components can be purchased separately by the user, an upstream transport distance of 2,000 km was included. All maintenance activity inputs have been quantified in **Table 11**.

Table 11. NEOREST® NX and WX maintenance inputs per functional unit

Name	NEOREST® NX toilet	NEOREST® WX toilet	Unit
Reference service life (RSL)	20		years
Estimated service life (ESL)	75		years
Number of uses over ESL	109,500		uses
Maintenance cycles			
Toilet basin, bowl, seat, and lid cleaning	1,800		per ESL
Electric plug and gaps cleaning	900		per ESL
Deodorizer filter cleaning	900		per ESL
Nozzle/wand cleaning	3,900		per ESL
Water filter parts cleaning	150		per ESL
Air filter replacement	3.75		per ESL
Water filter replacement	3.75		per ESL
Battery replacement	11.25		per ESL
Water consumption	147		L
Auxiliary material (cleaning agent)	1.485		kg
Other resources	-		kg
Electricity	-		kWh
Other energy carriers	-		MJ
Maintenance waste	0.291	0.281	kg per ESL
Disposal sent for landfill	100		%

All maintenance parameters are the same except for the amount of waste generated during this stage, because of the mass differences in the filters being replaced.

3.2.7. Repair (B3)

This module includes all technical services and associated operations during the product service life in the form of corrective, responsive, or reactive actions to return the product into an acceptable condition to continue to provide its services.

Repair activities for the NEOREST® NX and WX toilets can be broken down into the repair of the washlet portion and repair of the toilet. Repair components were identified in the respective product BOMs of NEOREST® NX and WX toilets with assistance from the TOTO team. NEOREST® toilets have an automatic flush, so the trip lever handle is not applicable, and only the flapper seal and fill valve seal require replacements per the PCR.

For the washlet units, the lid assembly, lid bumpers, seat bumpers, deodorizer assembly, air filter, and flexible hose assembly are fully replaced once during the RSL. Material inputs, upstream component processing (grouped by material type and processing operations), component transportation to users, and disposal are all included. Since replacement components can be purchased separately by the user, an upstream transportation distance of 2,000 km was assumed. The components are assumed to be sourced from within the US using road transport. The old components are assumed to be 100% sanitary landfilled with a waste transportation distance of 100 km. The repair activity inputs are listed in **Table 12**.

Table 12. NEOREST® NX and WX repair inputs

Name	NEOREST® NX toilet	NEOREST® WX toilet	Unit
Information on the repair process	Toilets: Replacement of flapper seal and fill valve seal once during the RSL. Washlets: Replacement of lid assembly, lid & seat bumpers, deodorizer assembly, deodorizer air filter, and flexible hose assembly once during the RSL.		
Repair cycle	1		cycle/RSL
	3.75		cycles/ESL
Repair waste	5.82	10.4	kg per ESL
Waste sent for landfill	100		%

3.2.8. Replacement (B4)

Replacement covers all technical services and associated operations during the ESL associated with replacing the whole product once its RSL is over. Per the PCR, replacements must be counted proportionally to the nearest hundredth of a product and must include the sum of the impacts from stages A1-A5 and C1-C4 multiplied by the number of replacements.

Since the RSL is 20 years, 2.75 product replacements are needed to fulfill the ESL. The replacement activity inputs have been listed in **Table 13**.

Table 13. NEOREST® NX and WX replacement inputs per functional unit

Name	Value	Unit
Replacement cycles over ESL	2.75	toilets
Electricity consumption	-	kWh
Liters of fuel	-	l/100 km
Replacement of worn parts	-	kg

3.2.9. Refurbishment (B5)

This module covers any applicable restoration activities. Refurbishment is not expected to occur during the normal operation of the NEOREST® NX and WX; therefore, there is no activity in this stage.

3.2.10. Operational energy use (B6)

This module covers energy usage during the operation of the product and its associated environmental aspects and potential impacts. Washlet units incorporated in the toilets consume electricity during operation. Two operation modes are reported. The startup mode lasts for 30 seconds and uses a peak wattage for seat heating, nozzle spraying, and water heating. The peak wattages for the NEOREST® NX and WX toilets are 1,290 W and 1,452 W, respectively. The second mode uses a nominal energy of 75.6 W, for both the NEOREST® NX and WX toilets, and lasts for the remainder of 12 minutes. Since water heating is included within the washlet operations, no separate calculation is needed. The operational energy use inputs have been listed in **Table 14**.

Table 14. NEOREST® NX and WX operational energy use

Name	NEOREST® NX toilet	NEOREST® WX toilet	Unit
Number of washlet uses over ESL	109,500		uses
Electricity consumption	2,764	2,912	kWh/ESL
Natural gas consumption	-		MJ
Other energy carriers	-		MJ

3.2.11. Operational water use (B7)

This module covers water usage during the operation of the product and its associated environmental aspects and potential impacts. There are two sources of water consumption: water used directly by the electronic bidet seat functions, and water consumed during each toilet flush. It is assumed that incoming water is municipal tap water, and no filtration is required.

For the electronic bidet seat portion of water use, as reported in the product specifications[7], the water spray for rear cleansing, rear soft cleansing, front cleansing, and wide front cleansing uses an average of 0.095gpm for both NEOREST® NX and WX. Per the PCR, the duration of water flow per use is assumed to be 0.58 minutes, and the number of uses per day is assumed to be 4 uses per day. The NEOREST® NX and WX toilets also feature pre-misting and post-misting, which consume 28 mL and 94 mL of water per use, respectively. Periodical misting also occurs automatically, consuming 47 mL of water every 8 hours.

For the toilet flush portion of water use, both toilets are dual flush toilets with solid/liquid flush capacities of 1.0gpf/0.8gpf and 1.2gpf/0.8gpf for the NEOREST® NX and WX toilets, respectively. Per the PCR, the total flushes per day is assumed to be 13, with 3 solid and 10 liquid flushes.

An electricity factor of 0.000961 kWh per liter of water as prescribed by the PCR is used to represent energy for upstream municipal water collection, treatment, supply, and downstream sewage management. The operational water use inputs have been listed in **Table 15**.

[7] TOTO NEOREST® NX & WX product specifications
https://www.totousa.com/filemanager_uploads/product_assets/SpecSheet/SS-02221_MS902CUMFG.pdf
https://www.totousa.com/filemanager_uploads/product_assets/SpecSheet/SS-02254_CWT9538CEMFG.pdf

Table 15. NEOREST® NX and WX operational water use

Name	NEOREST® NX toilet	NEOREST® WX toilet	Unit
Number of bidet uses over ESL	109,500		uses
Bidet water flow rate			
Spray cleansing	0.095		gpm
Premisting	28		mL/use
Postmisting	94		mL/use
Periodical misting	141		mL/day
Flushes over ESL			
Solid flush	82,125		flushes
Liquid flush	273,750		flushes
Flush water rate			
Solid flush	1.0	1.2	gpf
Liquid flush	0.8	0.8	gpf
Water consumption	311,787	328,212	gallons/ESL
Electricity consumption	1,135	1,195	kWh/ESL
Wastewater generation	311,787	328,212	gallons/ESL

3.2.12. Deconstruction/demolition (C1)

This module includes the dismantling of the product from the building and associated energy. NEOREST® toilets are assumed to be manually removed using common hand tools at the end of life; therefore, there is no activity in this module.

3.2.13. Transport to waste processing or disposal (C2)

This module refers to the transportation of the discarded product to the waste processing sites, either to a recycling site or for final product disposal. Per the PCR, the waste transportation distance is assumed to be 100 km.

3.2.14. Waste processing (C3)

This module represents the processing of waste generated resulting in materials for reuse, secondary materials, and secondary fuels. There is no activity considered in this module for the studied products.

3.2.15. Waste disposal (C4)

This module represents the final waste disposal including the physical treatment and management of the disposal site. Per the PCR, 100% of the discarded product is sent to sanitary landfills. End of life activity inputs have been reported in **Table 16**. Processes specific to each material type were selected.

Table 16. NEOREST® NX and WX end of life inputs per functional unit

Name	NEOREST® NX toilet	NEOREST® WX toilet	Unit
Transport from building site to landfill	100		km
Mixed construction waste	62.7	64.9	kg
Landfilling total	62.7	64.9	kg

3.3. Background data

This section details the background data sets used for modeling all relevant activities associated with the cradle to grave life cycle of the NEOREST® NX and WX toilets. Each table lists the data set name, database, year of last update, and geography. The LCA model was created using the SimaPro Developer 9.6 software. The ecoinvent v3.10, US-EI 2.2, and Industry data 2.0 databases provided the life cycle inventory data for the raw materials and processes for modeling the products.

3.3.1. Materials

Data representing upstream and downstream raw materials were obtained from the ecoinvent v3.10 and Industry 2.0 database. Data sets matching each raw material were looked up in the available databases, and if not found, manual data sets were developed. Where country-specific data were unavailable, global or rest-of-world averages were used to represent production in those locations.

Table 17 lists the most relevant LCI data sets used in modeling the raw materials.

Table 17. Key material data sets used in inventory analysis

Raw material	Data set	Database	Technology	Year of last update	Geography[1]
Polypropylene (PP), Polyphenylene ether (PPE)	Polypropylene, granulate {GLO}| market for polypropylene, granulate | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Rubber, EPDM, Silicone foam	Synthetic rubber {GLO}| market for synthetic rubber | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Copper	Copper, cathode {GLO}| market for copper, cathode | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Nylon	Nylon 6 {RoW}| market for nylon 6 | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	RoW
Acrylonitrile butadiene styrene (ABS)	Acrylonitrile-butadiene-styrene copolymer {GLO}| market for acrylonitrile-butadiene-styrene copolymer | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Silicone	Silicone product {RoW}| market for silicone product | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Polyethylene terephthalate (PER)	Polyethylene terephthalate, granulate, amorphous {GLO}| market for polyethylene terephthalate, granulate, amorphous | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Aluminum	Aluminium, primary, ingot {RoW}| market for aluminium, primary, ingot | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Aluminum alloys	Aluminium alloy, AlLi {GLO}| market for aluminium alloy, AlLi | Cut-off, U	ecoinvent v3.10	Appropriate technology	2019	GLO
Polyol resin	Polyether polyols, short chain {RoW}| market for polyether polyols, short chain | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Glass	Glass tube, borosilicate {GLO}| market for glass tube, borosilicate | Cut-off, U[2]	ecoinvent v3.10	Appropriate technology	2011	GLO
Magnet	Permanent magnet, for electric motor {GLO}| market for permanent magnet, for electric motor | Cut-off, U[2]	ecoinvent v3.10	Appropriate technology	2012	GLO
Instruction manuals	Printed paper, offset {RoW}| offset printing, per kg printed paper | Cut-off, U[2]	ecoinvent v3.10	Appropriate technology	2012	GLO
Polyphenylene sulfide (PPS)	Polyphenylene sulfide {GLO}| market for polyphenylene sulfide | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO

Polyurethane (PU)	Polyurethane, flexible foam {RoW}| market for polyurethane, flexible foam | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	RoW
Polyethylene (PE)	Polyethylene, high density, granulate {GLO}| market for polyethylene, high density, granulate | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Polyoxymethylene (POM)	Polyoxymethylene (POM)/EU-27	Industry data 2.0	Appropriate technology	2024	EUR
Polyethylene terephthalate (PET)	Polyethylene terephthalate, granulate, amorphous {GLO}| market for polyethylene terephthalate, granulate, amorphous | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Tetrafluoroethylene	Tetrafluoroethylene {GLO}| market for tetrafluoroethylene | Cut-off, U	ecoinvent v3.10	Appropriate technology	2018	GLO
Polyvinyl chloride (PVC)	Polyvinylchloride, suspension polymerised {GLO}| market for polyvinylchloride, suspension polymerised | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Nitrile butadiene rubber (NBR)	30% Acrylonitrile: *Acrylonitrile {GLO}| market for acrylonitrile | Cut-off, U* & 70% Butadiene*: Butadiene {RoW}| market for butadiene | Cut-off, U*	Manually developed	Appropriate technology	-	GLO
Styrene butadiene rubber (SBR)	57.75% Polybutadiene: Polybutadiene {GLO}| market for polybutadiene | Cut-off, U 17.25% Styrene: Styrene {GLO}| market for styrene | Cut-off, U & 25% Carbon black: Carbon black {GLO}| market for carbon black | Cut-off, U	Manually developed	Appropriate technology	-	GLO
Low density polyethylene (LDPE)	Polyethylene, low density, granulate {GLO}| market for polyethylene, low density, granulate | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Corrugated board	Corrugated board box {RoW}| market for corrugated board box | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Charcoal	Charcoal {GLO}| market for charcoal | Cut-off, U[2]	ecoinvent v3.10	Appropriate technology	2011	GLO
Printed wiring board	**Printed wiring board, surface mounted, unspecified, Pb free {GLO}| printed wiring board production, surface mounted, unspecified, Pb free | Cut-off, U[2]**	**ecoinvent v3.10**	**Appropriate technology**	**2011**	**GLO**
Stainless steel	**Steel, chromium steel 18/8 {GLO}| market for steel, chromium steel 18/8 | Cut-off, U**	**ecoinvent v3.10**	**Appropriate technology**	**2020**	**GLO**
Lubricating oil	Lubricating oil {RoW}| market for lubricating oil | Cut-off, U[2]	ecoinvent v3.10	Appropriate technology	2011	GLO
Silicone grease	90% silicone oil: Polydimethylsiloxane {GLO}| market for polydimethylsiloxane | Cut-off, U and 10% fumed silica: Silica fume, densified {GLO}| market for silica fume, densified | Cut-off, U	Manually developed	Appropriate technology	-	GLO
Battery (Alkaline AA)	LCI based on an external research paper, with DOI 10.1007/s11367-016-1134-5	Manually developed	Appropriate technology	-	GLO
Brass	Brass {RoW}| market for brass | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	RoW
Carbon	Carbon black {GLO}| market for carbon black | Cut-off, U[2]	ecoinvent v3.10	Appropriate technology	2011	GLO
Cellulose	Cellulose fibre {RoW}| market for cellulose fibre | Cut-off, U	ecoinvent v3.10	Appropriate technology	2020	RoW
Iron	Cast iron {GLO}| market for cast iron | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Electroplated iron	Steel Electrogalvanized {GLO} | blast furnace route | production mix, at plant | 1kg, typical thickness between 0.3 - 3 mm. typical width between 600 - 2100 mm | LCI result	Industry data 2.0	Appropriate technology	2022	GLO

Sericite & Dolomite	Dolomite {RoW}| dolomite production | Cut-off, U; *manually updated for production in Japan*	ecoinvent v3.10	Appropriate technology	2022	Japan
Kaolin	Kaolin {RoW}| kaolin production | Cut-off, U; *manually updated for production in different countries*	ecoinvent v3.10	Appropriate technology	2023	RoW
Clay	Clay {RoW}| clay pit operation | Cut-off, U	ecoinvent v3.10	Appropriate technology	2016	RoW
Feldspar	Feldspar {RoW}| feldspar production | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	RoW
Alumina	Aluminium oxide, non-metallurgical {CN}| aluminium oxide production | Cut-off, U	ecoinvent v3.10	Appropriate technology	2019	China
Sodium silicate	Sodium silicate, without water, in 37% solution state {RoW}| sodium silicate production, furnace liquor, product in 37% solution state | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	RoW
Silica	Silica sand {RoW}| silica sand production | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	RoW
Lime	Lime {RoW}| lime production, milled, loose | Cut-off, U; *manually updated for production in Japan*	ecoinvent v3.10	Appropriate technology	2014	Japan
Zinc oxide	Zinc oxide {RoW}| zinc oxide production | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	RoW
Zircon	Zircon {RoW}| heavy mineral sand quarry operation | Cut-off, U	ecoinvent v3.10	Appropriate technology	2022	RoW
Frits	Frit, for ceramic tile {GLO}| frit production, for ceramic tile | Cut-off, U	ecoinvent v3.10	Appropriate technology	2014	RoW

[1] 'GLO' stands for global geography; 'EUR' stands for Europe, and 'RoW' stands for Rest of World (non-Europe) geography.

[2] Data sets older than 10 years were chosen because they closest represent the technology used to manufacture the material and are assumed to be more accurate than other potential proxies with more precise geography and temporal representativeness.

3.3.2. Upstream processing

For the components purchased directly from external suppliers, component processing was added separately. Manufacturing operations were identified for each component, and depending on the material type, manufacturing method, and manufacturing country, components were categorized. A similar approach was taken for ceramic materials. Existing ecoinvent data sets were modified manually, and embedded unit processes (mainly electricity and water) were appropriately substituted, as applicable, to represent the component/material production in a particular country. **Table 18** below shows the component categories developed and associated data set updates for representing the component processing.

Table 18. Upstream processing data sets, with manual modifications, used in inventory analysis

Component category	Base data set & manual updates applied	Database	Technology	Geography[1]
Copper extrusion (in Japan and China)	Base dataset: Sheet rolling, copper {RoW}| sheet rolling, copper | Cut-off, U *Updates made: Electricity datasets, water related inputs & outputs updated to specific country (JP & CN). Municipal solid waste also updated to JP for Japan.*	Ecoinvent v3.10	Appropriate technology	Japan (JP) China (CN)
Steel/ Brass casting (in China)	Base dataset Casting, brass {RoW}| casting, brass | Cut-off, U *Does not include the metal input for casting so same can be used for brass or steel casting.* *Updates made: Electricity datasets updated with China electricity to represent casting in China.*	Ecoinvent v3.10	Appropriate technology	China (CN)

Plastic extrusion (in China and Japan)	Base dataset: Extrusion, plastic pipes {CA-QC}| extrusion, plastic pipes | Cut-off, U *Updates made: Electricity datasets, water related inputs & outputs updated to CN/JP.*	Ecoinvent v3.10	Appropriate technology	China (CN) Japan (JP)
Steel extrusion (in Japan and China)	Impact extrusion of steel, warm, 2 strokes {RoW}| impact extrusion of steel, warm, 2 strokes | Cut-off, U *Updates made: NO*	Ecoinvent v3.10	Appropriate technology	RoW
Plastic injection molding (in China, Japan, Thailand, and Vietnam)	Base dataset: Extrusion, plastic pipes {CA-QC}| extrusion, plastic pipes | Cut-off, U *Updates made: Electricity datasets, water related inputs & outputs updated to CN/JP /TH/VN. Municipal solid waste dataset also updated to JP for Japan.*	Ecoinvent v3.10	Appropriate technology	China (CN) Japan (JP) Thailand (TH) Vietnam (VN)
Average aluminum metalworks (in China and Japan)	Metal working, average for aluminium product manufacturing {RoW}| metal working, average for aluminium product manufacturing | Cut-off, U *Updates made: NO*	Ecoinvent v3.10	Appropriate technology	RoW
Average copper metalworks (in China)	Metal working, average for copper product manufacturing {RoW}| metal working, average for copper product manufacturing | Cut-off, U *Updates made: NO*	Ecoinvent v3.10	Appropriate technology	RoW
Average steel metalworks ((in China, Japan, and Vietnam)	Metal working, average for steel product manufacturing {RoW}| metal working, average for steel product manufacturing | Cut-off, U *Updates made: NO*	Ecoinvent v3.10	Appropriate technology	RoW
Average metalworks ((in China, Japan, and Vietnam)	Metal working, average for metal product manufacturing {RoW}| metal working, average for metal product manufacturing | Cut-off, U *Updates made: NO*	Ecoinvent v3.10	Appropriate technology	RoW
Kaolin production (in Vietnam, France, UK, Korea, and Japan)	Base dataset: Kaolin {RoW}| kaolin production | Cut-off, U *Updates made: Electricity datasets, water related inputs & outputs updated to VN/FR /GB/KR/JP.*	Ecoinvent v3.10	Appropriate technology	Vietnam (VN) France (FR) United Kingdom (GB) Korea (KR) Japan (JP)
Dolomite production (in Japan)	Base dataset: Dolomite {RoW}| dolomite production | Cut-off, U *Updates made: Electricity datasets, water related inputs & outputs updated to JP.*	Ecoinvent v3.10	Appropriate technology	Japan (JP)

[1] 'RoW' stands for Rest of World (non-Europe) geography.

3.3.3. Transportation

Raw materials and components are transported to the product manufacturing facility from the suppliers via different transportation modes. Final products are first shipped using container ships to the TOTO distribution center in GA, USA and then transported to end users via either road or rails. Transportation distances from the production facility to the adjacent ports and from the destination port to the TOTO distribution center are included. As the transportation data sets represent load factors as an average of empty and fully loaded (i.e., average load factor), empty backhauls are accounted for in the model. Data sets matching each transportation mode were found in the available databases. Where country-specific data were unavailable, global or rest-of-world averages were used to represent transportation in those locations. **Table 19** shows the most relevant LCI data sets used in modeling transportation.

Table 19. Transportation data sets used in inventory analysis

Transport mode and legs	Data set	Database	Technology	Last updated	Geography[1]
Upstream road transport in Japan & China	Transport, freight, lorry, unspecified {RoW}| transport, freight, lorry, all sizes, EURO6 to generic market for transport, freight, lorry, unspecified | Cut-off, U	ecoinvent v3.10	Appropriate technology	2021	RoW
Sea transport	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	ecoinvent v3.10	Appropriate technology	2018	GLO
Road transport from TOTO facilities to seaport	Transport, freight, lorry 16-32 metric ton, EURO6 {RoW}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U	ecoinvent v3.10	Appropriate technology	2014	RoW
Rail transport (from US port to GA and to building sites)	Transport, freight, rail, diesel/US US-EI U	US-EI 2.2	Appropriate technology	2021	United States
Final road transport to building sites	Transport, lorry 3.5-16t, fleet average/US- US-EI U	US-EI 2.2	Appropriate technology	2021	United States
Overseas waste transport	Municipal waste collection service by 21 metric ton lorry {GLO}| market for municipal waste collection service by 21 metric ton lorry | Cut-off, U[2]	ecoinvent v3.10	Appropriate technology	2011	GLO
US waste transport	Transport, municipal waste collection, lorry 21t/US* US-EI U[2]	US-EI 2.2	Appropriate technology	2021	United States

[1] 'GLO' stands for global geography; 'RoW' stands for Rest of World (non-Europe) geography.

[2] Data sets older than 10 years (light commercial vehicle, EURO5 16-32t lorry, EURO6 >32t lorry, and waste collection lorry) were chosen because they closest represent the technology used for transportation of the materials and are assumed to be more accurate than other potential proxies with more precise geography and temporal representativeness.

3.3.4. Fuels and energy

The fuel inputs and electricity grid mixes were obtained using the databases available in SimaPro. The final assembly occurs in Malaysia, so the electricity data set for Malaysia was used. For upstream processing of purchased components, relevant processing data sets from ecoinvent v3.10 were selected, and the embedded electricity unit process was modified to represent the supplier country. For example, for injection molded plastic components in Japan, the base RoW injection molding data set available in the ecoinvent database was manually updated using the electricity data set for Japan.

For electricity consumed during the use phase, the most recent eGRID average data set was used. **Table 20** shows the most relevant LCI data sets used in fuels and energy.

Table 20. Key energy data sets used in inventory analysis

Energy source	Data set	Database	Technology	Last updated	Geography[1]
Japan electricity	Electricity, medium voltage {JP}| market for electricity, medium voltage | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Japan
China electricity	Electricity, medium voltage {CN}| market for electricity, medium voltage | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	China
Vietnam electricity	Electricity, medium voltage {VN}| market for electricity, medium voltage | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Vietnam
France electricity	Electricity, medium voltage {FR}| market for electricity, medium voltage | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	France
Korea electricity	Electricity, medium voltage {KR}| market for electricity, medium voltage | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Korea
UK electricity	Electricity, medium voltage {GB}| market for electricity, medium voltage | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	Great Britain
Natural gas	Heat, district or industrial, natural gas {RoW}| market for heat, district or industrial, natural gas | Cut-off, U[2]	ecoinvent v3.10	Appropriate technology	2011	RoW
Heavy fuel oil	Heat, district or industrial, other than natural gas {RoW}| heat production, heavy fuel oil, at industrial furnace 1MW | Cut-off, U	ecoinvent v3.10	Appropriate technology	2015	RoW
Diesel	Diesel, burned in diesel-electric generating set, 10MW {GLO}| diesel, burned in diesel-electric generating set, 10MW | Cut-off, U	ecoinvent v3.10	Appropriate technology	2023	GLO
Use phase electricity	**Electricity mix 2021/US US-EI U**	**US-EI 2.2**	**Appropriate technology**	**2023**	**United States**

[1] 'RoW' stands for Rest of World (non-Europe) geography

[2] Data set older than 10 years (natural gas) was chosen because it closest represents the technology used to manufacture the material and are assumed to be more accurate than other potential proxies with more precise geography and temporal representativeness.

3.3.5. Disposal

Disposal processes were obtained from the ecoinvent v3.10 and US-EI 2.2 databases. Processes specific to waste types, if available, were selected to correspond to the disposal of facility waste streams, packaging waste during installation, product replacement waste, and end-of-life waste streams. Rest of world or global data sets were selected to represent disposal outside of the US, since country-specific data sets were not available. **Table 21** lists the relevant disposal data sets used in the model.

Table 21. Key disposal data sets used in inventory analysis

Material disposal	Data set	Database	Technology	Last updated	Geography[1]
Municipal waste, landfilled	Municipal solid waste {RoW}| treatment of municipal solid waste, sanitary landfill | Cut-off, U	ecoinvent v3.10	Appropriate technology	2024	RoW
Landfilled, hazardous waste	Municipal solid waste {GLO}| treatment of municipal solid waste, unsanitary landfill, moist infiltration class (300mm) | Cut-off, U	ecoinvent v3.10	Appropriate technology	2024	GLO
Household sewage	**Treatment, sewage, from residence, to wastewater treatment, class 2/US* US-EI U** ***Energy consumption removed manually.***	**US-EI 2.2**	**Appropriate technology**	**2024**	**United States**
Landfilled, cardboard packaging	Disposal, packaging cardboard, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2023	United States
Incinerated, cardboard packaging	Disposal, packaging cardboard, 0% water, to municipal incineration/US* US-EI U	US-EI 2.2	Appropriate technology	2023	United States
Ceramics, landfilled	Disposal, inert material, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2024	United States
Landfilled, aluminum	Disposal, aluminium, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2023	United States
Landfilled, battery	Disposal, NiMH batteries/GLO US-EI U	US-EI 2.2	Appropriate technology	2023	United States
Landfilled, polyethylene	Disposal, polyethylene, to US sanitary landfill/US US-EI U	US-EI 2.2	Appropriate technology	2024	United States
Landfilled, polyethylene terephthalate	Disposal, polyethylene terephthalate, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2024	United States
Landfilled, polypropylene	Disposal, polypropylene, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2024	United States
Landfilled, polyurethane	Disposal, polyurethane, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2024	United States
Landfilled, polyvinyl chloride	Disposal, polyvinylchloride, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2024	United States
Landfilled, plastics	Disposal, plastics, mixture, to US sanitary landfill/US US-EI U	US-EI 2.2	Appropriate technology	2024	United States
Landfilled, paper	Disposal, paper, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2024	United States
Landfilled, other waste streams	Disposal, municipal solid waste, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	Appropriate technology	2024	United States

[1] 'GLO' stands for global geography; 'RoW' stands for Rest of World (non-Europe) geography

3.4. Cut-off criteria

The time period over which inputs to and outputs from the system shall be accounted for is 100 years from the year for which the data set is deemed representative.

The cut-off criteria on a unit process level can be summarized as follows:

- All inputs and outputs to a (unit) process shall be included in the calculation of the pre-set parameters results, for which data are available. Data gaps shall be filled by conservative assumptions with average, generic or proxy data. Any assumptions for such choices shall be documented. Assumptions and proxies, whenever used, have been explained in this report.
- Mass – If a flow is less than 1% of the cumulative mass of the model it may be excluded, providing its environmental relevance is not a concern. Small quantities of chemicals, with annual consumption <+1 kg, used in the

wastewater treatment plants in ceramic production facility have been omitted in this study. Resin molds which are reused 10,000+ times have also been excluded. However, the overall omitted mass is much less than 1% and no other known mass flows have been omitted in this study.
- Energy – If a flow is less than 1% of the cumulative energy of the model it may be excluded, providing its environmental relevance is not a concern. No known energy flow has been omitted in this study.
- Environmental relevance – If a flow meets the above criteria for exclusion, yet it is thought to potentially have a significant environmental impact, it is included. No known mass or energy flow has been omitted in this study.
- Hazardous and toxic materials – The study shall include all hazardous and toxic materials in the inventory therefore the cutoff rules shall not apply to such substances. All known hazardous waste released from the manufacturing facility have been included in this study.
- The sum of the neglected material flows does not exceed 5% of mass, energy or environmental relevance for flows indirectly related to the process (e.g., operating materials). No major mass flow has been omitted in this study.

In this report, barring insignificant quantities of wastewater treatment chemicals and reused resin molds, no known flows are deliberately excluded; therefore, these criteria have been met. The completeness of the bill of materials defined in this report satisfies the above-defined cut-off criteria.

3.5. Allocation

Whenever a system boundary is crossed, environmental inputs and outputs must be assigned to the different products. Where multi-inputs or multi-outputs are considered, the same applies. The PCR prescribes where and how allocation occurs in the modeling of the LCA.

All washlets being manufactured in TOTO facilities follow the same assembly process and consume the same quantity of resources, and annual resources provided for the assembly were evenly distributed based on the annual production quantity. Similar allocation was used for the tank support systems being manufactured in the China plant; annual resources were evenly distributed based on the annual production quantities. The washlet assembly and tank support system assembly have dedicated assembly lines, and since annual resources were reported for each, there are no other co-products being manufactured in each case. No co-product allocation or allocation of multi-input processes are required.

For ceramic production in the Kokura plant, multiple products (ceramic bowls and tanks) are manufactured. Mass allocation of the resources was sufficient, since all products go through the same set of operations. No allocation situation occurred requiring the allocation of product inputs and outputs into each co-product. Annual resources used for ceramic processing were normalized using the annual ceramic output mass to develop the inventory for resources per kg of ceramic output.

The model used in this report ensures that the sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation. This means that no double counting or omissions of inputs or outputs through allocation is occurring.

Allocation of reuse, recycling, and energy recovery is not applicable for this study.

3.6. Discussion of data quality

Inventory data quality is judged by its precision (measured, calculated, or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied on a study serving as a data source), and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the ecoinvent v3.10, US-EI 2.2, and Industry data 2.0 databases were used.

Precision and completeness

- *Precision*: As the relevant foreground data is primary data or modeled based on primary information sources of the owner of the technology, precision is considered to be high. Background data are from the ecoinvent v3.10 and US-EI 2.2 databases with documented precision to the extent available.

- *Completeness*: Sustainable Minds worked with TOTO and its manufacturing partners to obtain a comprehensive set of primary data associated with the manufacturing processes. The product system was checked for mass balance and completeness of the inventory. The data set was considered complete based on our understanding of the manufacturing site and a review with key stakeholders on the TOTO team, and cut-off criteria were observed consistent with those prescribed in the PCR. Besides capital equipment, no data was knowingly omitted.

Consistency and reproducibility

- *Consistency*: Primary data were collected with a similar level of detail, while background data were sourced primarily from the ecoinvent database. Other databases were used if data were not available in ecoinvent, or the data set was judged to be more representative. Other methodological choices were made consistently throughout the model.

- *Reproducibility*: Reproducibility is warranted as much as possible through the disclosure of input-output data, data set choices, and modeling approaches in this report. Based on this information, a knowledgeable third party should be able to approximate the results of this study using the same data and modeling approaches.

Representativeness

- *Temporal:* All primary data were collected for January 2023 – December 2023, ensuring the representativeness of the manufacturing process. Secondary data obtained from external databases are typically representative of recent years.

- *Geographical*: Primary data are representative of production in Malaysia. The upstream manufacturing processes of purchased components have been represented with the country of production. In general, secondary data were collected specific to the country under study. Where country-specific data were unavailable, global or rest-of-world averages were used to represent production in those locations. Geographical representativeness is therefore considered to be high.

- *Technological*: All primary and secondary data were modeled to be specific to the technologies under study. Technological representativeness is considered to be high.

3.7. Comparability

ISO 21930:2017 section 5.5 highlights the following limitations and clarifications in EPD comparability: EPDs are comparable only if they use the same PCR (or sub-category PCR where applicable), include all relevant information modules, and are based on equivalent scenarios with respect to the context of construction works [3]. Per Sustainable Minds Part A, EPDs are not comparative assertions; that is, no claim of environmental superiority can be inferred or implied [4].

EPDs can only be compared when the same functional requirements between products are ensured and the requirements of ISO 21930:2017 section 5.5 are met. However, variations and deviations are possible. For example, different LCA software and background LCI data sets may lead to different results for the life cycle stages declared.

One cannot compare 75 years of use of a toilet in an average US environment to another unless the following conditions are met, including but not limited to the materials being functionally equivalent (same strength, durability, thermal properties, etc.), the environment it is installed in being the same (same usage, maintenance cleaning schedule, etc.), and an equivalent installation method being used with the same structural integrity of the wall. While it is theoretically possible to compare functionally equivalent assemblies, it is difficult in practice to design two truly functionally equivalent systems using the multiple criteria by which performance can be analyzed. Therefore, the report is not intended for comparative assertions.

3.8. Assumptions and limitations

A life cycle assessment of a product system is broad and complex, and it inherently requires assumptions and simplifications. The following assumptions and limitations of the study should be recognized:

- Assumptions for upstream processing operations regarding each purchased component were developed via suggestions from TOTO personnel and suppliers.
- It was assumed that the same manufacturing resources were consumed for the assembly of washlets (for all models) in all TOTO facilities.
- It is assumed that incoming water is municipal tap water, and no filtration is required.
- Data sets older than 10 years were chosen because they closest represent the technology used to manufacture the material and are assumed to be more accurate than other potential proxies with more precise geography and temporal representativeness.
- Available ecoinvent data sets were manually updated to represent the upstream component production in the supplier country. However, actual manufacturing operations and resources consumed for each component might vary.
- Manufacturing yield has been considered for each upstream component production based on TOTO’s internal discussions and outreach with suppliers, but actual material losses during production of components vary.

- Each product was torn down manually to develop/verify the BOM. Discrepancies are possible in the identification of materials and upstream processing technologies.
- Generic data sets used for material inputs, transportation, and waste processing are considered good quality, but actual impacts from material suppliers, transport carriers, and local waste processing may vary.
- The impacts of resin molds, expected to be minimal, in ceramic production is excluded from the study.
- Some chemicals used in wastewater treatment in ceramic production plant with minimal share (annual facility consumption <= 1 kg) has been excluded.
- For materials with unknown suppliers and transport distances, a generic value of 2,000 km was used as suggested by PCR. However, actual transport distances might vary.
- The impact assessment methodology categories do not represent all possible environmental impact categories.
- Characterization factors used within the impact assessment methodology may contain varying levels of uncertainty.
- LCA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.

4. IMPACT ASSESSMENT METHODS

4.1. Impact assessment characterization

The environmental indicators as required by the PCR are included as well as other indicators required to use the SM2013 Methodology [7] (see **Table 22**). The impact indicators are derived using the 100-year time horizon[8] factors, where relevant, as defined by TRACI 2.1 classification and characterization [8]. Long-term emissions (>100 years) are not taken into consideration in the impact estimate. USEtox indicators[9] are used to evaluate toxicity. Emissions from waste disposal are considered part of the product system under study, according to the "polluter pays principle".

Table 22. Selected impact categories and units

Impact category	Unit	Description
Acidification	kg SO_2 eq (sulphur dioxide)	Acidification processes increase the acidity of water and soil systems and causes damage to lakes, streams, rivers and various plants and animals as well as building materials, paints, and other human-built structures.
Ecotoxicity	CTUe	Ecotoxicity causes negative impacts to ecological receptors and, indirectly, to human receptors through the impacts to the ecosystem.
Eutrophication	kg N eq (nitrogen)	Eutrophication is the enrichment of an aquatic ecosystem with nutrients (nitrates and phosphates) that accelerate biological productivity (growth of algae and weeds) and an undesirable accumulation of algal biomass.
Global warming	kg CO_2 eq (carbon dioxide)	Global warming is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere.
Ozone depletion	kg CFC-11 eq	Ozone depletion is the reduction of ozone in the stratosphere caused by the release of ozone depleting chemicals.
Carcinogenics	CTUh	Carcinogens have the potential to form cancers in humans.
Non-carcinogenics	CTUh	Non-Carcinogens have the potential to causes non-cancerous adverse impacts to human health.
Respiratory effects	kg $PM_{2.5}$ eq (fine particulates)	Particulate matter concentrations have a strong influence on chronic and acute respiratory symptoms and mortality rates.
Smog	kg O_3 eq (ozone)	Smog formation (photochemical oxidant formation) is the formation of ozone molecules in the troposphere by complex chemical reactions.
Fossil fuel depletion	MJ surplus	Fossil fuel depletion is the surplus energy to extract minerals and fossil fuels.

This LCA study follows the cut-off method. All environmental impacts associated with the production, use, and disposal of a product are allocated to the original product's life cycle. Secondary products (like recycled materials) enter the system with no burdens attached, as they do not carry over the environmental burdens from the original product. No credits are given for flows exiting the product system. With respect to global warming potential, biogenic carbon is included in impact

[8] The 100-year period relates to the period in which the environmental impacts are modeled. This is different from the time period of the declared unit. The two periods are related as follows: all environmental impacts that are created in the period of the declared unit are modeled through life cycle impact assessment using a 100-year time horizon to understand the impacts that take place.

[9] USEtox is available in TRACI and at http://www.usetox.org/

category calculations. The biogenic carbon measured in this study originates from packaging materials and instruction manuals, and no raw materials in the NEOREST® NX and WX toilets are expected to contain biogenic carbon. Greenhouse gas emissions from land-use change are expected to be insignificant and were not reported. Carbon emissions during carbonation and calcination are also considered in this study, and no carbonation or calcination are expected to occur during the production and manufacture of the NEOREST® NX and WX toilets.

It shall be noted that the above impact categories represent impact potentials. They are approximations of environmental impacts that could occur if the emitted molecules follow the underlying impact pathway and meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach).

The results from the impact assessment indicate potential environmental effects and do not predict actual impacts on category endpoints, the exceedance of thresholds, or safety margins or risks.

4.2. Normalization and weighting

To arrive at a single score indicator, normalization [9] and weighting [10] as shown in **Table 23** conforming to the SM 2013 Methodology were applied. The SM 2013 Methodology uses TRACI 2.1 impact categories developed by U.S. EPA, and North American normalization and weighting values developed by EPA and NIST respectively, to calculate single figure LCA results. Sustainable Minds recognizes that weighting is socially defined based on the importance that society attaches to the different environmental impact categories. However, these single score indicators serve as an easy starting point to get to know the product under consideration across all impact categories, rather than focusing all efforts on just one impact category (like global warming potential). The interpretation of the results starts with the Sustainable Minds single score results and then allows users to further explore the underlying impact categories individually. Details including the characterization models, factors, and methods used, including all assumptions and limitations, can be found in the SM 2013 Methodology Report [7].

Table 23. Normalization and weighting factors

Impact category	Normalization	Weighting (%)
Acidification	90.9	3.6
Ecotoxicity	11000	8.4
Eutrophication	21.6	7.2
Global warming	24200	34.9
Ozone depletion	0.161	2.4
Carcinogenics	5.07E-05	9.6
Non-carcinogenics	1.05E-03	6.0
Respiratory effects	24.3	10.8
Smog	1390	4.8
Fossil fuel depletion	17300	12.1

5. Assessment and Interpretation

This chapter includes the results from the LCA for the product studied. It details the results per functional unit, outlines the sensitivity analyses, and concludes with recommendations.

5.1. Resource use and waste flows

Resource use indicators, output flows and waste category indicators, and carbon emissions and removals are presented in this section. These life cycle inventory (LCI) indicators reflect the flows from and to nature for the product system, prior to characterization using an impact assessment methodology to calculate life cycle impact assessment (LCIA) results (as shown in section 5.2).

LCI flows were calculated with the help of American Center for Life Cycle Assessment's (ACLCA) guidance for calculating the ISO 21930:2017 metrics [11]. The consumption of freshwater indicator, which was calculated in accordance with this guidance, is reported in compliance with ISO 14046. Use of renewable and non-renewable energy resources with energy content were calculated using the Cumulative Energy Demand (LHV) impact assessment methodology [12]. Abiotic depletion potential was calculated using the CML impact assessment methodology [13]. LCI flows were reported in conformance to ISO 21930:2017 [3].

Resource use indicators represent the quantity of materials consumed to produce not only the product itself but also the raw materials, electricity, natural gas, etc. that go into the product's life cycle.

Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process and is expressed in energy demand from renewable and non-renewable resources. Efficiencies in energy conversion are considered when calculating primary energy demand from process energy consumption. Water use represents the total water used over the entire life cycle. No renewable energy was used in production beyond that accounted for in the electricity grid mix used.

Hazardous and non-hazardous wastes are calculated based on the amount of waste generated during the life cycle of each product studied, mainly during the manufacturing of the products. All waste treatments in models were considered based on the local waste management code and the assumptions mentioned in the PCR. Waste treatments included within the system boundary are reported. Unrecyclable wastes either are disposed of in landfills or incinerated.

When transforming the inputs and outputs of combustible material into inputs and outputs of energy, the net caloric value specific to the material was applied based on scientifically accepted values. There is no biogenic carbon associated with the product, but biogenic carbon relevant to packaging materials has been reported per life cycle stage. CO_2 from calcination and carbonation does not apply to these studied products. **Table 24** represents all the resource use and waste flow indicators evaluated in this study, along with the acronyms used.

Table 24. Resource use and waste flow indicators

Indicator	Acronym used
Resource use indicators	
Renewable primary energy used as energy carrier (fuel)	**RPR_E**
Renewable primary resources with energy content used as material	**RPR_M**
Total use of renewable primary resources with energy content	**RPR_{total}**
Non-renewable primary resources used as an energy carrier (fuel)	**$NRPR_E$**
Non-renewable primary resources with energy content used as material	**$NRPR_M$**
Total use of non-renewable primary resources with energy content	**$NRPR_{total}$**
Secondary materials	**SM**
Renewable secondary fuels	**RSF**
Non-renewable secondary fuels	**NRSF**
Recovered energy	**RE**
Use of net fresh water resources	**FW**
Abiotic depletion potential (fossil)	**ADPf**
Output flows and waste category indicators	
Hazardous waste disposed	**HWD**
Non-hazardous waste disposed	**NHWD**
High-level radioactive waste, conditioned, to final repository	**HLRW**
Intermediate- and low-level radioactive waste, conditioned, to final repository	**ILLRW**
Components for re-use	**CRU**
Materials for recycling	**MR**
Materials for energy recovery	**MER**
Exported energy	**EE**
Carbon emissions and removals	
Biogenic Carbon Removal from Product	**BCRP**
Biogenic Carbon Emission from Product	**BCEP**
Biogenic Carbon Removal from Packaging	**BCRK**
Biogenic Carbon Emission from Packaging	**BCEK**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	**CBCEW**
Calcination Carbon Emissions	**CCE**
Carbonation Carbon Removals	**CCR**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	**CWNR**

Resource use, output flows, waste categories, and carbon emissions & removals for each product type have been tabulated in the sections below.

5.1.1. NEOREST® NX Dual Flush Toilet

Table 25 shows resource use, output and waste flows, and carbon emissions and removals respectively for the NEOREST® NX toilet per functional unit.

Table 25. Resource use, output and waste flows, and carbon emissions and removals for NEOREST® NX per functional unit

Parameters	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Resource use indicators																
RPR_E	MJ, NCV	5.49E+02	1.30E+00	4.14E-01	0	1.33E+02	2.91E+01	1.51E+03	0	2.28E+03	1.51E+03	0	1.71E-01	0	1.57E-01	**6.02E+03**
RPR_M	MJ, NCV	3.25E+00	0	0	0	0	0	7.61E+00	0	0	0	0	0	0	0	**1.22E+01**
RPR_{total}	MJ, NCV	5.52E+02	1.30E+00	4.14E-01	0	1.33E+02	2.91E+01	1.52E+03	0	2.28E+03	1.51E+03	0	1.71E-01	0	1.57E-01	**6.03E+03**
$NRPR_E$	MJ, NCV	5.75E+03	7.46E+02	3.04E+01	0	4.54E+01	5.26E+02	1.84E+04	0	2.72E+04	1.49E+04	0	1.06E+02	0	5.94E+00	**6.76E+04**
$NRPR_M$	MJ, NCV	4.67E+02	0	0	0	6.44E-01	2.03E+02	1.10E+03	0	0	0	0	0	0	0	**1.96E+03**
$NRPR_{total}$	MJ, NCV	6.21E+03	7.46E+02	3.04E+01	0	4.61E+01	7.29E+02	1.95E+04	0	2.72E+04	1.49E+04	0	1.06E+02	0	5.94E+00	**6.95E+04**
SM	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
NRSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RE	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FW	m^3	2.25E+03	3.51E+00	1.35E+00	0	2.08E+01	1.38E+02	6.21E+03	0	3.26E+01	1.35E+03	0	1.79E-02	0	2.95E-03	**1.00E+04**
ADPf	MJ, NCV	5.73E+03	7.43E+02	2.99E+01	0	4.24E+01	7.00E+02	1.82E+04	0	1.88E+04	1.03E+04	0	1.06E+02	0	5.38E+00	**5.47E+04**
Output flows and waste category indicators																
HWD	kg	7.87E-04	0	0	0	0	0	2.16E-03	0	0	0	0	0	0	0	**2.95E-03**
NHWD	kg	8.78E-05	0	1.76E+00	0	2.91E-01	5.82E+00	1.77E+02	0	0	0	0	0	0	6.27E+01	**2.48E+02**
HLRW	kg	2.01E-03	1.13E-05	2.10E-06	0	1.59E-05	1.34E-04	5.58E-03	0	2.47E-02	1.34E-02	0	1.85E-06	0	1.65E-06	**4.58E-02**
ILLRW	kg	7.55E-03	2.49E-05	4.55E-06	0	3.49E-05	3.12E-04	2.09E-02	0	5.50E-02	2.98E-02	0	4.12E-06	0	3.69E-06	**1.14E-01**
CRU	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MR	kg	2.47E+01	0	8.37E+00	0	0	0	9.08E+01	0	0	0	0	0	0	0	**1.24E+02**
MER	kg	0	0	4.30E-01	0	0	0	1.18E+00	0	0	0	0	0	0	0	**1.61E+00**
EE	MJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
BCRP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCEP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCRK	kg CO_2	1.92E+01	0	0	0	0	0	5.29E+01	0	0	0	0	0	0	0	**7.22E+01**
BCEK	kg CO_2	0	0	1.60+01	0	0	0	4.43E+01	0	0	0	0	0	0	9.00E-02	**6.04E+01**
CBCEW	kg CO_2	0	0	7.08E-01	0	0	0	1.95E+00	0	0	0	0	0	0	0	**2.66E+00**
CCE	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CCR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CWNR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

5.1.2. NEOREST® WX Wall-Hung Toilet with In-Wall Tank System

Table 26 shows resource use, output and waste flows, and carbon emissions and removals respectively for the NEOREST® WX toilet per functional unit.

Table 26. Resource use, output and waste flows, and carbon emissions and removals for NEOREST® WX per functional unit

Parameters	**Unit**	**Produc-tion**	**Construction/ Installation**		**Use**							**End of life**				**Total**
		A1-A3	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	
Resource use indicators																
RPR$_E$	MJ, NCV	4.86E+02	1.14E+00	3.99E-01	0	1.33E+02	4.47E+01	1.34E+03	0	2.40E+03	1.59E+03	0	1.77E-01	0	2.52E-01	**6.00E+03**
RPR$_M$	MJ, NCV	1.82E+00	0	0	0	0	0	5.00E+00	0	0	0	0	0	0	0	**6.82E+00**
RPR$_{total}$	MJ, NCV	4.88E+02	1.14E+00	3.99E-01	0	1.33E+02	4.47E+01	1.35E+03	0	2.40E+03	1.59E+03	0	1.77E-01	0	2.52E-01	**6.01E+03**
NRPR$_E$	MJ, NCV	4.54E+03	6.58E+02	2.58E+01	0	4.40E+01	8.84E+02	1.47E+04	0	2.87E+04	1.57E+04	0	1.10E+02	0	7.28E+00	**6.54E+04**
NRPR$_M$	MJ, NCV	4.54E+02	0	0	0	4.95E-01	3.74E+02	1.25E+03	0	0	0	0	0	0	0	**2.08E+03**
NRPR$_{total}$	MJ, NCV	5.00E+03	6.58E+02	2.58E+01	0	4.45E+01	1.26E+03	1.59E+04	0	2.87E+04	1.57E+04	0	1.10E+02	0	7.28E+00	**6.74E+04**
SM	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
NRSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RE	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FW	m^3	1.18E+03	2.28E+00	1.06E+00	0	1.24E+01	1.57E+02	3.24E+03	0	3.43E+01	1.42E+03	0	1.85E-02	0	4.39E-03	**6.05E+03**
ADPf	MJ, NCV	4.68E+03	6.55E+02	2.53E+01	0	4.10E+01	1.21E+03	1.51E+04	0	1.98E+04	1.09E+04	0	1.10E+02	0	6.36E+00	**5.25E+04**
Output flows and waste category indicators																
HWD	kg	1.38E-03	0	0	0	0	0	3.78E-03	0	0	0	0	0	0	0	**5.16E-03**
NHWD	kg	8.78E-05	0	1.23E+00	0	2.81E-01	1.04E+01	1.36E+02	0	0	0	0	0	0	4.82E+01	**1.96E+02**
HLRW	kg	1.34E-03	1.01E-05	1.94E-06	0	1.56E-05	2.09E-04	3.74E-03	0	2.60E-02	1.41E-02	0	1.91E-06	0	2.70E-06	**4.54E-02**
ILLRW	kg	4.40E-03	2.24E-05	4.19E-06	0	3.41E-05	5.82E-04	1.22E-02	0	5.79E-02	3.14E-02	0	4.27E-06	0	6.03E-06	**1.07E-01**
CRU	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MR	kg	2.15E+01	0	6.36E+00	0	0	0	7.65E+01	0	0	0	0	0	0	0	**1.04E+02**
MER	kg	0	0	3.01E-01	0	0	0	8.28E-01	0	0	0	0	0	0	0	**1.13E+00**
EE	MJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
BCRP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCEP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCRK	kg CO_2	1.46E+01	0	0	0	0	0	4.02E+01	0	0	0	0	0	0	0	**5.48E+01**
BCEK	kg CO_2	0	0	1.22+01	0	0	0	3.37E+01	0	0	0	0	0	0	5.03E-02	**4.60E+01**
CBCEW	kg CO_2	0	0	5.40E-01	0	0	0	1.49E+00	0	0	0	0	0	0	0	**2.03E+00**
CCE	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CCR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CWNR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

5.2. Life cycle impact assessment (LCIA)

It shall be reiterated at this point that the reported impact categories represent impact potentials; they are approximations of environmental impacts that could occur if the emitted molecules follow the underlying impact pathway and meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen declared unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

Life cycle impact assessment (LCIA) results are shown per functional unit. Unlike life cycle inventories, which only report sums for individual inventory flows, the LCIA includes a classification of individual emissions with regard to the impacts they are associated with and subsequently a characterization of the emissions by a factor expressing their respective contribution to the impact category indicator. The end result is a single metric for quantifying each potential impact, such as “Global Warming Potential”.

The impact assessment results are calculated using characterization factors published by the United States Environmental Protection Agency. The TRACI 2.1 (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts 2.1) methodology is the most widely applied impact assessment method for U.S. LCA studies. The SM 2013 Methodology is also applied to come up with single score results for the sole purpose of representing total impacts per life cycle phase to explain where in the product life cycle greatest impacts are occurring and what is contributing to the impacts.

TRACI impact categories are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development; however, the EPD users shall not use additional measures for comparative purposes. All impact categories from TRACI are used to calculate single score millipoints using the SM2013 Methodology, but it should be noted that there are known limitations related to these impact categories due to their high degree of uncertainty.

5.2.1. NEOREST® NX Dual Flush Toilet

In the cradle-to-grave life cycle of the product, when looking at individual life cycle modules, product replacement (B4) contributes the most to impact results for five evaluated impact categories: ozone depletion (~36.2%), smog (~46.1%), acidification (~36.2%), respiratory effects (~51.8%), and fossil fuel depletion (34.7%). A total of 2.75 product replacements are needed to meet the estimated service life of 75 years. Since each product replacement requires a complete set of new product manufacturing, distribution, installation, and disposal activities to replace the old product, the replacement impacts contribute significantly to the total life cycle impacts.

Operational energy use (B6) leads the impacts in terms of global warming (~34.9%) and follows B4 closely in terms of fossil fuel depletion impacts (~33%). Electricity required for washlet operations, with a mix of peak and nominal power consumption during each use of the washlet for the entirety of the ESL, causes B6 to contribute highly to global warming and fossil fuel depletion. Operational water use (B7) leads impacts for four impact categories in the overall life cycle:

eutrophication (~92.6%), carcinogenics (~64.2%), non-carcinogenics (~80.4%), and ecotoxicity (~54.2%). More than 98% of each of those comes from municipal sewage treatment of the sewage generated during B7.

The LCIA results of the NEOREST® NX toilet per functional unit are shown in **Table 27**. The percent contribution of each of the cradle-to-grave life cycle modules to the total impacts is tabulated in **Table 28**.

Table 27. Life cycle impact assessment results for NEOREST® NX per functional unit

Impact categories	Unit	Production	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	kg CFC-11 eq	2.39E-05	5.15E-06	2.86E-07	0	1.35E-07	1.58E-06	8.53E-05	0	6.31E-05	5.47E-05	0	1.58E-06	0	5.54E-08	**2.36E-04**
Global warming	kg CO_2 eq	4.23E+02	5.73E+01	4.31E+00	0	5.36E+00	3.61E+01	1.37E+03	0	1.52E+03	9.33E+02	0	7.88E+00	0	4.65E+00	**4.36E+03**
Smog	kg O_3 eq	2.60E+01	1.94E+01	2.44E-01	0	9.62E-01	1.83E+00	1.29E+02	0	5.03E+01	5.09E+01	0	1.28E+00	0	9.25E-02	**2.80E+02**
Acidification	kg SO_2 eq	2.16E+00	8.95E-01	9.75E-03	0	4.76E-02	1.40E-01	8.55E+00	0	5.98E+00	5.83E+00	0	4.35E-02	0	3.73E-03	**2.37E+01**
Eutrophication	kg N eq	5.17E-01	4.41E-02	4.59E-03	0	5.27E-02	3.08E-02	1.59E+00	0	4.86E-01	3.46E+01	0	4.46E-03	0	9.79E-03	**3.73E+01**
Carcinogenics	CTU_h	1.26E-05	2.85E-08	3.92E-09	0	3.41E-07	6.56E-07	3.48E-05	0	2.89E-06	9.19E-05	0	2.25E-09	0	1.38E-08	**1.43E-04**
Non-carcinogenics	CTU_h	1.04E-04	2.21E-06	9.88E-08	0	5.88E-06	2.35E-06	2.94E-04	0	4.71E-05	1.87E-03	0	3.76E-07	0	4.29E-08	**2.33E-03**
Respiratory effects	kg $PM_{2.5}$ eq	3.81E-01	5.42E-02	1.24E-03	0	7.88E-03	2.83E-02	1.22E+00	0	3.50E-01	3.03E-01	0	5.08E-03	0	4.35E-04	**2.35E+00**
Additional impact categories																
Ecotoxicity	CTU_e	8.69E+02	3.10E+01	5.00E-01	0	1.44E+02	7.34E+01	2.48E+03	0	1.14E+02	4.40E+03	0	1.01E+00	0	1.78E+00	**8.11E+03**
Fossil fuel depletion	MJ surplus	6.17E+02	1.06E+02	4.14E+00	0	4.22E+00	8.27E+01	2.04E+03	0	1.94E+03	1.07E+03	0	1.52E+01	0	7.20E-01	**5.89E+03**

Table 28. Percent contributions of each life cycle module to each impact category for NEOREST® NX per functional unit

Impact categories	Unit	Production	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	%	10.15%	2.19%	0.12%	0	0.06%	0.67%	36.17%	0	26.77%	23.18%	0	0.67%	0	0.02%	**100%**
Global warming	%	9.71%	1.32%	0.10%	0	0.12%	0.83%	31.38%	0	34.85%	21.40%	0	0.18%	0	0.11%	**100%**
Smog	%	9.29%	6.91%	0.09%	0	0.34%	0.65%	46.12%	0	17.95%	18.16%	0	0.46%	0	0.03%	**100%**
Acidification	%	9.12%	3.78%	0.04%	0	0.20%	0.59%	36.16%	0	25.26%	24.64%	0	0.18%	0	0.02%	**100%**
Eutrophication	%	1.39%	0.12%	0.01%	0	0.14%	0.08%	4.27%	0	1.30%	92.64%	0	0.01%	0	0.03%	**100%**
Carcinogenics	%	8.80%	0.02%	0.00%	0	0.24%	0.46%	24.30%	0	2.02%	64.15%	0	0.00%	0	0.01%	**100%**
Non-carcinogenics	%	4.48%	0.10%	0.00%	0	0.25%	0.10%	12.63%	0	2.03%	80.40%	0	0.02%	0	0.00%	**100%**
Respiratory effects	%	16.24%	2.31%	0.05%	0	0.34%	1.21%	51.81%	0	14.92%	12.89%	0	0.22%	0	0.02%	**100%**
Additional impact categories																
Ecotoxicity	%	10.71%	0.38%	0.01%	0	1.77%	0.91%	30.62%	0	1.40%	54.17%	0	0.01%	0	0.02%	**100%**
Fossil fuel depletion	%	10.47%	1.81%	0.07%	0	0.07%	1.40%	34.71%	0	32.99%	18.20%	0	0.26%	0	0.01%	**100%**

As evident in **Table 28**, the production stage (A1-A3) also demonstrates significant impacts across all impact categories. Product manufacturing (A3) follows the impacts from raw material acquisition (A1), with insignificant impacts from raw material transportation (A2). Most of the impacts within A3 come from energy usage in the ceramic manufacturing operations, while raw materials for the washlet make up the largest share (>97%) within A1. Product distribution (A4) is also responsible for considerable impacts, with most impacts coming from sea transportation of the product from Japan to the US and road transportation to end users.

Impacts in the product maintenance stage (B2) are driven by the use of SLS solution for cleaning various components and the periodic replacement of batteries. The replacement of other components has a minimal share of impacts within B2. The product repair (B3) stage also has considerable impacts, but they are dispersed across various replaced washlet components, so there is not a single standout component or process contributing heavily. Impacts coming from all other life cycle stages are minimal.

The percent contribution of each of the cradle-to-grave life cycle modules to the total impacts is also presented in **Figure 7**.

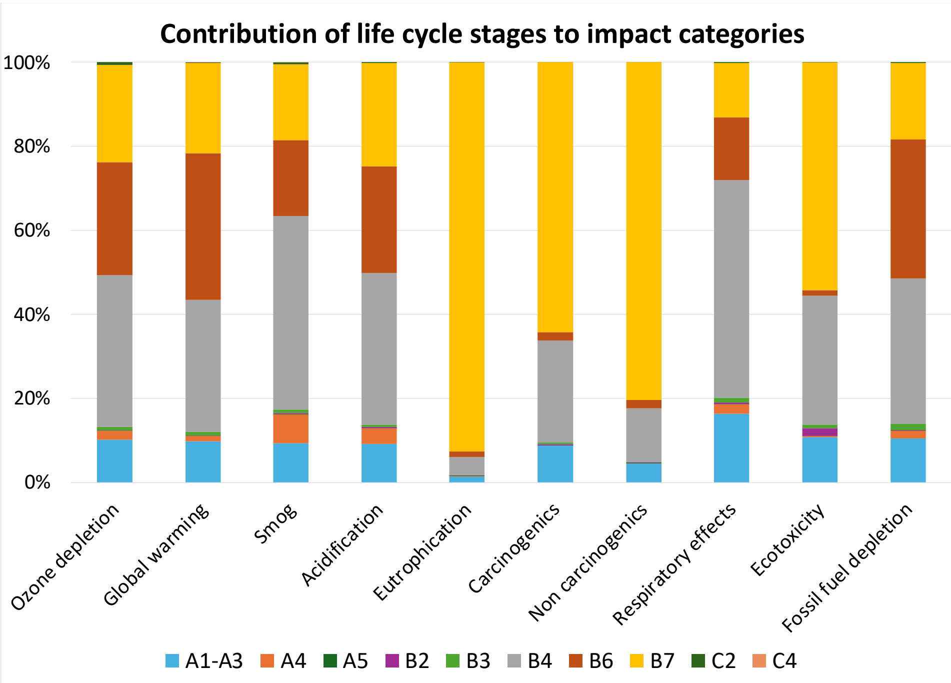

Figure 7. Contribution analysis of each impact category for NEOREST® NX per functional unit

The SM2013 Methodology single figure millipoint (mPt) score by life cycle module for this product is presented in **Table 29**. In terms of single figure scores and overall environmental impacts, operation water use (B7) dominates the results (~63%). This is followed by product replacement (B4) which accounts for ~21.3% of the total. The operational energy use (B7) contributes ~7.2%, while production stage (A1-A3) contributes 6.3% to the total.

Table 29. SM millipoint scores for NEOREST® NX per functional unit

Parameters	**Unit**	**Produc-tion**	**Construction/ Installation**		**Use**							**End of life**				**Total**
		A1-A3	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	
SM single figure score	mPts	5.20E+01	3.40E+00	1.41E-02	0	2.45E+00	3.38E+00	1.54E+02	0	5.18E+01	4.56E+02	0	3.53E-01	0	1.54E-01	**7.24E+02**

5.2.2. NEOREST® WX Wall-Hung Toilet with In-Wall Tank System

In the cradle-to-grave life cycle of the product, when looking at individual life cycle modules, product replacement (B4) contributes the most to impact results for five evaluated impact categories: ozone depletion (~47.3%), smog (~41.6%), acidification (~32.4%), carcinogenics (~42.1%), and respiratory effects (51.1%). A total of 2.75 product replacements are needed to meet the estimated service life of 75 years. Since each product replacement requires a complete set of new product manufacturing, distribution, installation, and disposal activities to replace the old product, the replacement impacts contribute significantly to the total life cycle impacts.

Operational energy use (B6) leads the impacts in terms of global warming (~38%) and fossil fuel depletion (~36.1%). Electricity required for washlet operations, with a mix of peak and nominal power consumption during each use of the washlet for the entirety of the ESL, causes B6 to contribute highly to global warming and fossil fuel depletion. Operational water use (B7) leads impacts for three impact categories in the overall life cycle: eutrophication (~95.1%), non-carcinogenics (~79.1%), and ecotoxicity (~53.2%). More than 98% of each of those comes from municipal sewage treatment of the sewage generated during B7.

The LCIA results of the NEOREST® WX toilet per functional unit are shown in **Table 30**. The percent contribution of each of the cradle-to-grave life cycle modules to the total impacts is tabulated in **Table 31**.

Table 30. Life cycle impact assessment results for NEOREST® WX per functional unit

Impact categories	Unit	Production	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	kg CFC-11 eq	5.42E-05	5.02E-06	2.18E-07	0	1.31E-07	2.46E-06	1.68E-04	0	6.65E-05	5.75E-05	0	1.64E-06	0	6.15E-08	**3.56E-04**
Global warming	kg CO_2 eq	3.45E+02	5.05E+01	3.27E+00	0	5.28E+00	6.07E+01	1.15E+03	0	1.60E+03	9.82E+02	0	8.17E+00	0	1.06E+01	**4.21E+03**
Smog	kg O_3 eq	2.01E+01	1.69E+01	1.87E-01	0	9.58E-01	3.04E+00	1.06E+02	0	5.30E+01	5.36E+01	0	1.33E+00	0	1.03E-01	**2.56E+02**
Acidification	kg SO_2 eq	1.86E+00	7.64E-01	7.73E-03	0	4.73E-02	2.41E-01	7.38E+00	0	6.29E+00	6.14E+00	0	4.51E-02	0	4.87E-03	**2.28E+01**
Eutrophication	kg N eq	2.67E-01	3.93E-02	3.52E-03	0	5.25E-02	2.86E-02	9.38E-01	0	5.12E-01	3.64E+01	0	4.62E-03	0	2.62E-02	**3.83E+01**
Carcinogenics	CTU_h	3.61E-05	2.45E-08	3.07E-09	0	3.40E-07	3.49E-07	9.94E-05	0	3.04E-06	9.67E-05	0	2.33E-09	0	3.60E-08	**2.36E-04**
Non-carcinogenics	CTU_h	1.20E-04	1.88E-06	7.73E-08	0	5.87E-06	4.77E-06	3.37E-04	0	4.97E-05	1.97E-03	0	3.90E-07	0	7.83E-08	**2.49E-03**
Respiratory effects	kg $PM_{2.5}$ eq	4.01E-01	4.63E-02	1.01E-03	0	7.82E-03	4.43E-02	1.25E+00	0	3.69E-01	3.18E-01	0	5.26E-03	0	5.16E-04	**2.44E+00**
Additional impact categories																
Ecotoxicity	CTU_e	9.76E+02	2.54E+01	3.83E-01	0	1.43E+02	2.93E+01	2.77E+03	0	1.20E+02	4.63E+03	0	1.05E+00	0	2.92E+00	**8.69E+03**
Fossil fuel depletion	MJ surplus	5.11E+02	9.40E+01	3.48E+00	0	4.04E+00	1.45E+02	1.72E+03	0	2.05E+03	1.13E+03	0	1.57E+01	0	8.31E-01	**5.67E+03**

As evident in **Table 31**, the production stage (A1-A3) also demonstrates significant impacts across all impact categories. Product manufacturing (A3) follows the impacts from raw material acquisition (A1), with insignificant impacts from raw material transportation (A2). Most of the impacts within A3 come from energy usage in the ceramic manufacturing operations, while raw materials for the washlet make up the largest share within A1 followed by the raw materials for the in-wall tank support system. Product distribution (A4) is also responsible for considerable impacts, with most impacts coming from sea transportation of the product and road transportation to end users.

Impacts in the product maintenance stage (B2) are driven by the use of SLS solution for cleaning various components and the periodic replacement of batteries. The replacement of other components has a minimal share of impacts within B2. The product repair (B3) stage also has considerable impacts, but they are dispersed across various replaced washlet components, so there is not a single standout component or process contributing heavily. Impacts coming from all other life cycle stages are minimal.

Table 31. Percent contributions of each life cycle module to each impact category for NEOREST® WX per functional unit

Impact categories	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	%	15.23%	1.41%	0.06%	0	0.04%	0.69%	47.26%	0	18.67%	16.16%	0	0.46%	0	0.02%	**100%**
Global warming	%	8.19%	1.20%	0.08%	0	0.13%	1.44%	27.25%	0	37.97%	23.30%	0	0.19%	0	0.25%	**100%**
Smog	%	7.88%	6.62%	0.07%	0	0.37%	1.19%	41.60%	0	20.74%	20.97%	0	0.52%	0	0.04%	**100%**
Acidification	%	8.17%	3.35%	0.03%	0	0.21%	1.06%	32.40%	0	27.62%	26.93%	0	0.20%	0	0.02%	**100%**
Eutrophication	%	0.70%	0.10%	0.01%	0	0.14%	0.07%	2.45%	0	1.34%	95.11%	0	0.01%	0	0.07%	**100%**
Carcinogenics	%	15.29%	0.01%	0.00%	0	0.14%	0.15%	42.11%	0	1.29%	40.99%	0	0.00%	0	0.02%	**100%**
Non-carcinogenics	%	4.82%	0.08%	0.00%	0	0.24%	0.19%	13.53%	0	2.00%	79.12%	0	0.02%	0	0.00%	**100%**
Respiratory effects	%	16.41%	1.90%	0.04%	0	0.32%	1.81%	51.11%	0	15.12%	13.05%	0	0.22%	0	0.02%	**100%**
Additional impact categories																
Ecotoxicity	%	11.23%	0.29%	0.00%	0	1.65%	0.34%	31.82%	0	1.38%	53.24%	0	0.01%	0	0.03%	**100%**
Fossil fuel depletion	%	9.01%	1.66%	0.06%	0	0.07%	2.55%	30.32%	0	36.13%	19.91%	0	0.28%	0	0.01%	**100%**

The percent contribution of each of the cradle-to-grave life cycle modules to the total impacts is also presented in **Figure 8**.

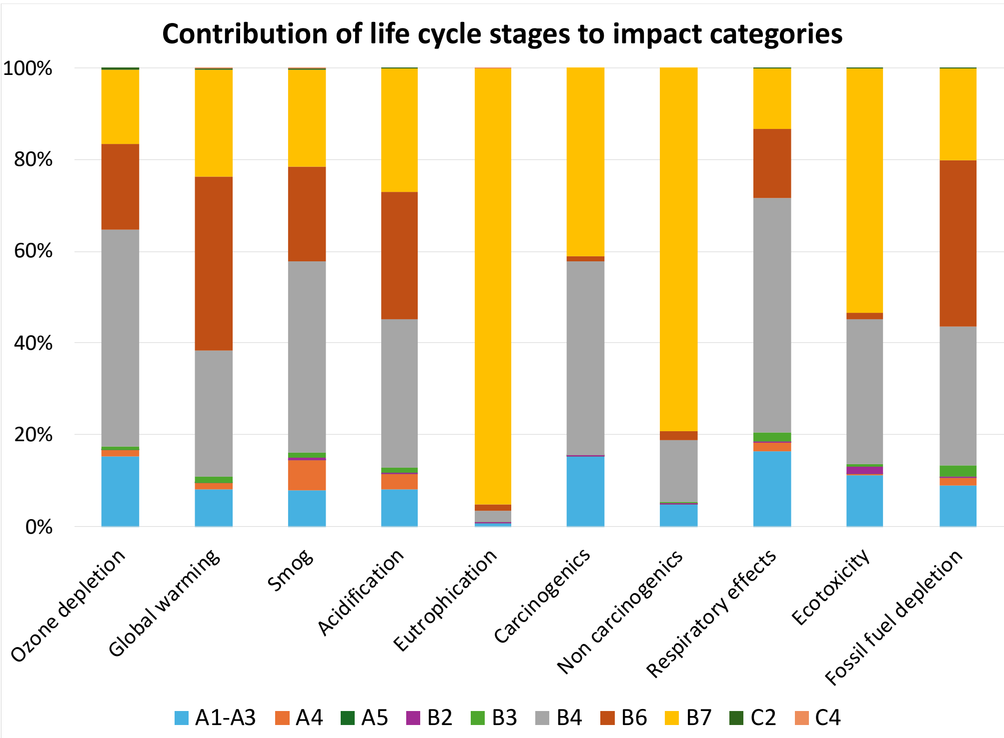

Figure 8. Contribution analysis of each impact category for NEOREST® WX per functional unit

The SM2013 Methodology single figure millipoint (mPt) score by life cycle module for this product is presented in **Table 32**. In terms of single figure scores and overall environmental impacts, operational water use (B7) dominates the results (~52.6%). This is followed by product replacement (B4) which accounts for ~29.9% of the total. The production stage (A1-A3) contributes ~10.5%, while operational energy use (B7) contributes 6% to the total.

Table 32. SM millipoint scores for NEOREST® WX per functional unit

Parameters	Unit	Production	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
SM single figure score	mPts	9.53E+01	2.96E+00	1.10E-01	0	2.44E+00	3.54E+00	2.72E+02	0	5.46E+01	4.80E+02	0	3.65E-01	0	3.48E-01	**9.12E+02**

5.2.3. Analysis of impact drivers

For each impact category of interest to TOTO, detailed analyses were performed to identify major unit processes that contribute significantly to the overall product life cycle impacts of both NEOREST® toilets. **Table 33** lists the major drivers with >5% contribution to the overall life cycle impacts of the product.

Table 33. Drivers of NEOREST® NX and WX life cycle impacts

Impact categories	Major flows (with impacts greater than 5%)	Actual contribution	
		NEOREST® NX	NEOREST® WX
Ozone Depletion	Product replacement	36.17%	47.26%
	Electricity consumption for washlet operations	26.77%	18.67%
	Sewage treatment	11.3%	7.88%
	Electricity for municipal upstream water supply, and downstream sewage treatment	10.99%	7.66%
Global warming	Electricity consumption for washlet operations	34.85%	37.97%
	Product replacement	31.38%	27.25%
	Electricity for municipal upstream water supply, and downstream sewage treatment	14.31%	15.58%
	Sewage treatment	6.06%	6.6%
Smog	Product replacement	46.12%	41.60%
	Electricity consumption for washlet operations	17.95%	20.74%
	Sewage treatment	9.63%	11.75%
	Electricity for municipal upstream water supply, and downstream sewage treatment	7.37%	8.51%
Acidification	Product replacement	36.16%	32.40%
	Electricity consumption for washlet operations	25.26%	27.62%
	Sewage treatment	13.41%	14.63%
	Electricity for municipal upstream water supply, and downstream sewage treatment	10.38%	11.34%
Eutrophication	Sewage treatment	92.07%	94.52%
Fossil fuel depletion	Electricity consumption for washlet operations	34.71%	36.13%
	Product replacement	32.99%	30.32%
	Electricity for municipal upstream water supply, and downstream sewage treatment	13.55%	14.83%

5.3. Sensitivity analysis

Two main parameters that influence the life cycle impacts of the NEOREST® toilets are the durability of the product, which affects product replacement during the ESL, and the consumption of electricity for washlet operations during product use. Electricity is required not only for the washlet operations, but also for the municipal water supply and sewage systems.

Impacts due to this electricity consumption are expected to vary depending on the location and its available electricity grid mix. Similarly, with product replacements the durability of the product is also expected to change the product impacts. Two sets of sensitivity analyses were performed, with the first varying the product use location and the second varying the product durability.

5.3.1. Change in product usage location

Sensitivity analyses were performed to check the impact of changing electricity grid mixes. After analyzing potential CO_2-equivalent emissions per unit of electricity for each of the 27 available eGRID subregions, the subregions with the highest and lowest impacts have been used for this analysis. MROE, *Midwest Reliability Organization – East*, is the regional mix with the highest CO_2 emissions per unit electricity. NYUP, *Northeast Power Coordinating Council – Upstate NY*, is the regional mix with the lowest. Life cycle impact assessment results have been generated for use of the NEOREST® toilets in both MORE and NYUP eGRID subregions and have been compared with the average results. Only the change in potential CO_2-equivalent emissions was evaluated; however, similar changes were expected to be observed in other impact categories.

As shown in **Table 34**, both B6 and B7 CO_2-equivalent emissions increased in the MORE subregion, while the emissions decreased in the NYUP subregion. The total life cycle CO_2-equivalent emissions in MROE were ~30% higher than the baseline, while they were ~32% lower in NYUP for the NEOREST® NX toilet. For the NEOREST® WX toilet, total life cycle CO_2-equivalent emissions in MROE were ~33% higher than the baseline, while they were ~35% lower in NYUP.

Table 34. Sensitivity analysis of electricity grid mix subregion choice on GWP emissions per functional unit

eGRID subregion	B6 (operational energy use)		B7 (operational water use)		Total life cycle	
	kg CO_2-eq emissions	% change	kg CO_2-eq emissions	% change	kg CO_2-eq emissions	% change
NEOREST® NX Dual Flush Toilet						
Baseline	1.52E+03	N/A	9.33E+02	N/A	4.36E+03	N/A
NYUP	5.39E+02	- 64.54%	5.30E+02	- 43.15%	2.97E+03	- 31.73%
MROE	2.44E+03	60.84%	1.31E+03	40.68%	5.66E+03	29.91%
NEOREST® WX Wall-Hung Toilet						
Baseline	1.60E+03	N/A	9.82E+02	N/A	4.21E+03	N/A
NYUP	5.67E+02	- 64.54%	5.58E+02	- 43.15%	2.76E+03	- 34.56%
MROE	2.57E+03	60.84%	1.38E+03	40.68%	5.59E+03	32.58%

The results of the sensitivity analyses show that the region of product use plays a significant role in the total life cycle impacts for the NEOREST® toilets, and the results are sensitive to the location where the product is used.

5.3.2. Change in product life

Sensitivity analyses were performed to check the impacts of changing product life. Product life is directly associated with product replacements. The higher the product durability, the smaller number of product replacements would be needed to meet the ESL and vice versa. As shown in **Table 35**, increased product durability decreases the CO_2-equivalent emissions in the B4 stage, and decreased durability increases B4 emissions. For a NEOREST® NX toilet with an RSL of 30 years, 1.5 times that of the baseline of 20 years, a significant reduction of ~14% was demonstrated for the total life cycle CO_2-equivalent emissions, and the reduction was ~12% for the NEOREST® WX toilet.

Table 35. Sensitivity analysis of product durability on GWP emissions per functional unit

Product life (RSL)	Number of Product replacements (per ESL)	B4 (product replacement)		Total life cycle	
		kg CO_2-eq emissions	% change	kg CO_2-eq emissions	% change
NEOREST® NX Dual Flush Toilet					
20 years (baseline)	2.75	1.37E+03	N/A	4.36E+03	N/A
25 years	2	9.94E+02	- 27.27%	3.98E+03	- 8.56%
30 years	1.5	7.46E+02	- 45.45%	3.74E+03	- 14.26%
15 years	4	1.99E+03	45.45%	4.98E+03	14.26%
10 years	6.5	3.23E+03	136.36%	6.22E+03	42.79%
NEOREST® WX Wall-Hung Toilet					
20 years (baseline)	2.75	1.15E+03	N/A	4.21E+03	N/A
25 years	2	8.35E+02	- 27.27%	3.90E+03	- 7.43%
30 years	1.5	6.26E+02	- 45.45%	3.69E+03	- 12.39%
15 years	4	1.67E+03	45.45%	4.73E+03	12.39%
10 years	6.5	2.71E+03	136.36%	5.78E+03	37.16%

The results of the sensitivity analyses show that the product lifetime plays a significant role in the total life cycle impacts for the NEOREST® toilets, and the results are sensitive to product durability.

5.4. Overview of relevant findings

This study assessed a multitude of inventory and environmental indicators. The primary finding for the TOTO NEOREST® toilets, across all environmental indicators, was that the product use phase (B1-B7) is responsible for most of the impacts across all impact categories.

With the use phase, environmental impacts are driven by the product replacement (B4), operational energy use (B6), and operational water use (B7) modules. Considerable impacts are generated from the production (A1-A3), product distribution (A4), product maintenance (B2), and product repair (B3) modules. B6 impacts are driven by the electricity consumed by washlet operations, whereas B7 impacts are driven by the downstream residential sewage treatment and the electricity consumed in municipal water systems. Production impacts are driven by the acquisition of raw materials making up the assemblies and the in-house manufacturing of ceramic bowls. The assembly of the washlet has relatively low impacts in comparison to the upstream production of its individual components. B2 impacts are driven via the use of cleaning solution and the replacement of batteries.

All other life cycle stages have relatively insignificant impacts to the total life cycle results of all studied NEOREST® NX and WX toilets.

5.5. Conclusion and recommendations

The goal of this study was to conduct a cradle-to-grave LCA on TOTO's NEOREST® NX and WX toilets so as to develop Transparency Reports [EPDs]™. This study covers TOTO's two NEOREST® NX toilets (NX1 and NX2) and two NEOREST® WX toilets (WX1 and WX2). The creation of the TRs will allow consumers in the building and construction industry to make better informed decisions about the environmental impacts associated with the products they choose.

Overall, the study found that environmental performance is driven primarily by the use phase of the product. The product's PCR-prescribed lifespan necessitates frequent replacements, significantly increasing the demand for manufacturing resources and energy. Each replacement cycle involves the entire manufacturing process from raw material extraction to assembly, multiplying the environmental footprint. Multiple product replacements require repeated transportation and logistics efforts, escalating fuel consumption and carbon emissions. Every product disposal adds to landfill waste, and if not properly managed, contributes to environmental pollution and resource depletion. The cumulative impact of manufacturing, distributing, and disposing of multiple units over the desired service period is substantially higher than that of a single, long-lasting product.

This also provides TOTO with the opportunity to reduce potential environmental impacts. Sensitivity analyses show that a NEOREST® NX toilet with a product lifetime 1.5 times that of the baseline demonstrates a significant reduction of ~14% of the total life cycle CO_2-equivalent emissions, and that reduction is ~12% for a NEOREST® WX toilet. Better product designs with enhanced durability and longevity reduces the need for frequent product replacements. Implementing more modular designs allows the easy replacement of certain components instead of the entire product. Promoting and facilitating repairability by designing products with easily replaceable parts and providing comprehensive repair guides and services can also be helpful.

Another important opportunity lies in the energy use phase for embedded washlet operations. This electricity consumption during the use phase contributes to ~49% and ~54% of potential CO_2-equivalent emissions across the life cycle of the NEOREST® NX and WX toilets, respectively. It is recommended that TOTO investigate strategies and technologies to engineer a washlet that uses less energy and minimal water per use. Focusing on energy efficiency and sustainable practices can significantly reduce the overall impacts. Energy efficient designs with more efficient elements for water and seat heating can reduce overall energy needs. Better insulation materials can be used for the water heater to maintain temperature with less energy. Providing a display that shows real time energy consumption and suggesting ways for the users to reduce it can be beneficial.

Ceramics manufacturing is also responsible for significant contributions to the overall life cycle impacts of both products. Integrating renewable energy into the ceramic production facility will help avoid emissions from the use of fossil-dominated grid electricity. Renewable sources can be solar, wind, hydropower, or purchasing renewable electricity certificates (RECs). Using more energy-efficient kilns, optimizing firing schedules, recovering waste heat, and improving insulation in kilns can help reduce overall energy consumption. Implementing energy management systems in TOTO's own facilities and supplier plants can help control energy use throughout the facility and helps in identifying inefficiencies and optimizing energy consumption. Even though the washlet component is comprised of parts being manufactured upstream where TOTO has little operational control, suppliers could be incentivized to adopt sustainable manufacturing practices and integrate renewable energy into their production facilities.

Additionally, an annual update to this LCA and the associated Transparency Reports [EPDs]™ would enable high-quality year-to-year comparisons. A post-project review could provide opportunities for improving the data collection process in future years and for continuing to align with TOTO's goals for sustainability.

6. References

[1] ISO 14040, “Environmental management – Life cycle assessment – Principles and framework”, ISO 14040:2006.

[2] ISO 14044, “Environmental management - Life cycle assessment - Requirements and guidelines”, ISO14044:2006.

[3] ISO 21930, “Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services”, ISO 21930:2017.

[4] Sustainable Minds, PCR Part A: LCA calculation rules and report requirements, 2023

[5] Sustainable Minds, PCR Part B: Product group definition | Residential toilets, 2024

[6] ISO 14025, “Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures”, ISO14025:2006.

[7] Joep Meijer, Sustainable Minds SM2013 Methodology and Database, April 25, 2013. For a summary, see the Sustainable Minds single score page: http://www.sustainableminds.com/showroom/shared/learn-single-score.html

[8] Bare, J. 2014. Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) TRACI version 2.1 User’s Guide. US EPA Office of Research and Development, Washington, DC, EPA/600/R-12/554, http://nepis.epa.gov/Adobe/PDF/P100HN53.pdf

[9] Ryberg, M., Vieira, M.D.M., Zgola, M. et al. (2014). ‘Updated US and Canadian normalization factors for TRACI 2.1.’ Clean Technologies and Environmental Policy 16: 329. doi:10.1007/s10098-013-0629-z

[10] Gloria, T. P., B. C. Lippiatt & J. Cooper (2007). ‘Life cycle impact assessment weights to support environmentally preferable purchasing in the United States.’ Environmental Science & Technology, 41(21), 7551-7557

[11] "ACLCA Guidance to Calculating Non-LCIA Inventory Metrics in Accordance with ISO 21930:2017”, ACLCA PCR committee working group for ISO 21930 metric calculation guidance, May 2019.

[12] Frischknecht R., Jungbluth N., et.al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000, Swiss Centre for LCI. Duebendorf, CH, www.ecoinvent.ch.

[13] Heijungs R., Guinée J.B., Huppes G., Lankreijer R.M., Udo de Haes H.A., Wegener Sleeswijk A. Environmental Life Cycle Assessment of Products: Guide and Backgrounds. CML. Leiden University, Leiden, 1992.

ACRONYMS

ACLCA	American Center for Life Cycle Assessment
BOM	Bill of materials
ESL	Estimated service life
ISO	International Standardization Organization
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact analysis
PCR	Product Category Rule document
REC	Renewable energy certificates
RSL	Reference service life
TR	Transparency Report [EPD]™

GLOSSARY

For the purposes of this report, the terms and definitions given in ISO 14020, ISO 14025, the ISO 14040 series, and ISO 21930 apply. The most important ones are included here.

Allocation	Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems
Close loop & open loop	A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials. An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties.
Cradle to grave	Addresses the environmental aspects and potential environmental impacts (e.g., use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of life
Cradle to gate	Addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of the production process ("gate of the factory"). It may also include transportation until use phase
Declared unit	Quantity of a product for use as a reference unit in an EPD based on one or more information modules
Life cycle	Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal
Life cycle assessment - LCA	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle
Life cycle impact assessment - LCIA	Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product
Life cycle inventory - LCI	phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle
Life cycle interpretation	Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations

APPENDIX

- S7_NX_WX_WT_complete BOM.xlsx
- Factory data_NX-WX_Toilet bowls.xlsx
- LCI_NX.xlsx
- LCI_WX.xlsx
- Invenotry_NX-WX Toilet Bowls.xlsx
- Results_NX.xlsx
- Results_WX.xlsx