LIFE CYCLE ASSESSMENT (LCA) OF TOTO WASHLET® T1SW2491

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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.

The company commissioned this study to evaluate the potential environmental impacts of the WASHLET® T1SW2491, using a cradle-to-grave approach. This model is designed exclusively for sale through Costco. This washlet is assembled in two TOTO's facilities, one in Malaysia and another in Thailand, with product parts coming from various suppliers globally.

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) is 15 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 potential CO_2-equivalent emissions, fossil fuel depletion potential, eutrophication impacts, and SM single score results for the WASHLET® T1SW2491. For other impact categories and a detailed breakdown by each life cycle stage, refer to section 5.2 in the full report. Overall, the study found that the environmental performance of the product is primarily driven by the use phase. The impacts within this phase are largely influenced by product replacements and electricity consumption for washlet operations. The product needs to be replaced four times to meet the prescribed estimated service life (ESL) of 75 years. The cumulative impact of manufacturing, distributing, and disposing of multiple units throughout the service period makes product replacement both resource- and energy-intensive. Additionally, the washlet consumes a significant amount of electricity with each use, which accumulates over the ESL period and leads to considerable potential environmental impacts. While raw material extraction, upstream transportation, and product manufacturing also contribute to the overall impacts, their share is lower compared to those generated during the use phase.

Impact categories	**Unit**	**Production**	**Construction/ Installation**	**Use**	**End of life**	**Total**
		A1-A3	**A4-A5**	**B1-B7**	**C1-C4**	
Global warming	kg CO_2 eq	1.12E+02	1.55E+01	1.81E+03	1.64E+00	**1.94E+03**
	%	5.80%	0.80%	93.32%	0.08%	**100%**
Fossil fuel depletion	MJ surplus	1.49E+02	2.70E+01	2.40E+03	1.40E+00	**2.58E+03**
	%	5.79%	1.05%	93.11%	0.05%	**100%**
Eutrophication	kg N eq	1.99E-01	3.18E-03	1.99E+00	1.86E-03	**2.20E+00**
	%	9.06%	0.14%	90.71%	0.08%	**100%**
SM single figure score	mPts	1.20E+01	6.46E-01	1.06E+02	6.68E-02	**1.19E+02**
	%	10.09%	0.54%	89.31%	0.06%	**100%**

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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, with its flagship product being the Washlet, an advanced toilet seat with integrated bidet functionality. In 1980, TOTO introduced the Washlet, the first luxury toilet seat with electronic bidet functionality. Today, millions in North America have shifted from wiping to washing with Washlet, experiencing a new kind of clean. The warm-water cleansing, heated seat, and warm air dryer offer complete cleansing and comfort. Easy to install on most standard toilets, TOTO has sold over 60,000,000 Washlet bidet seats worldwide, revolutionizing personal cleanliness.

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.

After successfully publishing an Environmental Product Declaration (EPD) for its flagship WASHLET® S7, TOTO is advancing its commitment to environmental sustainability by launching a new project to develop an EPD for the WASHLET® T1SW2491. This model is designed exclusively for sale through Costco. TOTO wants to transparently communicate the potential environmental impacts and performance associated with the WASHLET® T1SW2491. As a result, it is important to conduct life cycle assessments (LCAs) to evaluate the potential environmental impacts from raw materials acquisition through manufacturing. 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 WASHLET® T1SW2491, 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 WASHLET® T1SW2491 to be able to obtain a Sustainable Minds Transparency Report [EPD]™ (TR), which is an ISO 14025 Type III environmental declaration 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 electronic bidet seats [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), and cradle to grave (which includes all other stages including the use phase 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**.

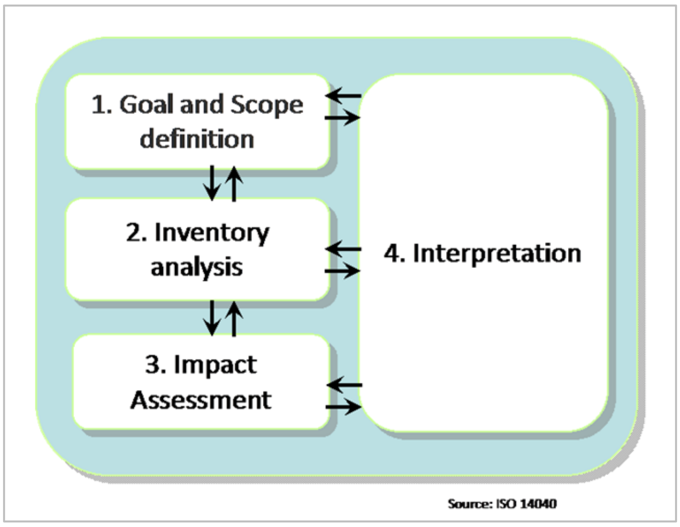

Figure 1. Phases of an LCA

- **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 several opportunities 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 TR 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 2024 – December 2024 from TOTO's manufacturing facilities in Malaysia and Thailand. 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 manufacturing facilities and background data to complete the inventory and fill gaps where necessary.

This is a supporting LCA report for the TOTO Transparency Report [EPD]™ and was evaluated for conformance to the PCRs according to the ISO 14025 [6] and ISO 14040/14044 [1][2] standards. The LCA review and verification of the Sustainable Minds Transparency Report [EPD]™ 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 under study and the depth and breadth of the analysis.

2.1. Intended application and audience

This report intends to define the specific application of the LCA methodology to the life cycle of the WASHLET® T1SW2491 manufactured by TOTO and sold via Costco. 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 a Sustainable Minds Transparency Report [EPD]™ (a Type III environmental declaration per ISO 14025), which are 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 product type covered in this study is its washlet product manufactured specifically for sale via Costco, WASHLET® T1SW2491. This is a high-tech elongated bidet seat with following major features:

- Gentle aerated, warm water, dual action spray with oscillating and pulsating features
- Adjustable water temperature and volume settings
- Warm air drying with three variable temperature settings
- Automatic air deodorizer
- Heated seat with temperature control
- Multifunction remote control with 4-users personalized memory settings
- Water PREMIST of the bowl before each use

Only one colored finish (cotton) is available currently for WASHLET® T1SW2491. It is assembled in two TOTO facilities, one located in Malaysia and another in Thailand. Product parts come from various suppliers to the TOTO facilities where the washlet is assembled and shipped to TOTO distribution centers in the US and later to Costco outlets.

Figure 2 provides representative image for the product evaluated in this study.

Figure 2. Visual representation of product

Table 1 lists the product information in accordance with PCR, including declaration name, CSI MasterFormat® classification, manufacturing locations, complaint standards, and the type of declaration. As shown in the table, a single Transparency Report [EPD]™ was developed from this study to represent TOTO's WASHLET® T1SW2491.

Table 1. Declared product information and type of declaration

Transparency Report [EPD]™ name	CSI MasterFormat® classification	Manufacturing locations	Standards/Certifications	Type of declaration
TOTO WASHLET® T1SW2491	22 41 13	TOTO Malaysia TOTO Thailand	Meets and exceeds: ASME A112.4.2, ASME A112.18.1/CSA B125.1, UL1431, CSA C22.2#68 Code compliance with UPC, IPC, NSPC, NPC Canada, and others.	Specific product as an average from several of the manufacturer's plant

For more information about WASHLET® T1SW2491, visit the TOTO website.

2.3. Functional unit

This LCA covers the cradle-to-grave stages for TOTO's WASHLET® T1SW2491. A functional unit of one electronic bidet seat used in an average residential environment 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 washlet is 15 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. **Table 2** 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 2. System boundary inclusions and exclusions

Included	Excluded
• Raw material extraction for components • Transport of raw materials/ purchased components to the manufacturing facility • 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, refurbishment, 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

The WASHLET® T1SW2491 in this study is assembled in TOTO's Malaysia and Thailand plants with all parts being purchased directly from suppliers. All parts are assembled, tested, and packaged in the facilities and later shipped to the TOTO distribution centers in Fairburn, GA and Ontario, CA. From there, the product is transported to the Costco stores and then later to the end user sites for installation and use. 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 as well. 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.

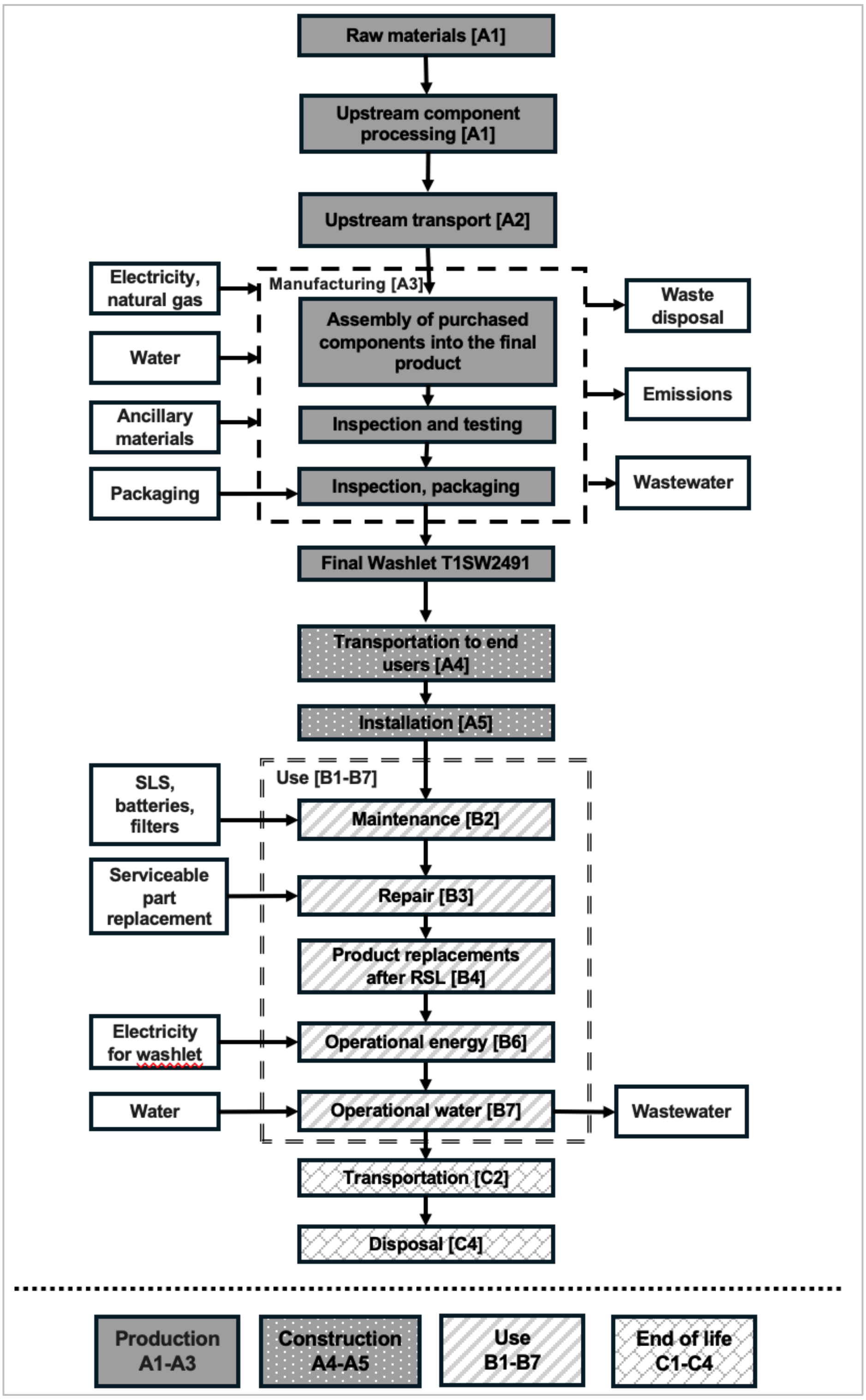

Figure 4. System boundary and product flow diagram of TOTO WASHLET® T1SW2491

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 WASHLET® T1SW2491. 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 2024 (January 2024 to December 2024) was collected at the manufacturing facilities in Malaysia and Thailand for the assembly of the washlet. It should be noted that all TOTO sister companies are under the same efficiency guidance by TOTO Japan and that the same amount of energy is consumed for the assembly of a unit washlet in all TOTO facilities. Weighted inventory was developed using the production volume of both plants and 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 taking the recommendations of TOTO personnel into account.

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, 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 final 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.

The full bill of materials (BOM) included a detailed breakdown of the product into parts, components, and raw materials for each part. Raw materials are extracted and processed by suppliers before being transported to component manufacturing plants. The manufactured components are then shipped to the TOTO plant, where they are assembled into the final product. Primary supply chain data, including component supplier locations, shipping distances, and transportation modes to the final assembly plants, were provided. The material composition of the WASHLET® T1SW2491 remains consistent across both plants. However, the average upstream road transport distances per component differ, with approximately 278 km for the Malaysia plant and 303 km for the Thailand plant. The upstream sea transport distance applies only to components shipped from overseas, averaging approximately 5,849 km for the Malaysia plant and 3,299 km for the Thailand plant. It is important to note that the packaging materials used for shipping to the final assembly plants were not included in this study.

The product does not contain hazardous substances according to the standards or regulations of the Resource Conservation and Recovery Act (RCRA), Subtitle C.

All components used in the WASHLET® T1SW2491 are purchased directly from suppliers. Each plant uses a single supplier for a specific component. Upstream manufacturing activities have been modeled separately in addition to the raw material extraction. The raw material composition and total reference flow is reported below in **Table 3**. 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 result generation.

Table 3. WASHLET® T1SW2491 raw material mass per functional unit and associated transportation

Submitted to the verifier

Once the raw materials reach the supplier processing plants, they are transformed into components. The TOTO team identified manufacturing operations for each component and depending on the material type, manufacturing method, and manufacturing country, components were categorized for both plants. Existing ecoinvent data sets were modified manually, and embedded unit processes (mainly electricity and water) were appropriately substituted to represent the component production in a particular country. The production of the WASHLET® T1SW2491 in Malaysia sourced parts from eight countries: Malaysia, Japan, Hong Kong, Vietnam, China, Singapore, Italy, and the Philippines. In Thailand, production sourced parts from all eight of these countries plus Thailand and Taiwan, totaling ten countries. 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 facility. For the WASHLET® T1SW2491, all components are purchased from suppliers and shipped directly to the manufacturing facilities in Malaysia and Thailand. The assembly process is a combination of manual and automated processes. The heated seat sub-assembly is manually put into the lower seat, which is later stamped into the upper seat. Other sub-assemblies (including baseplate assembly, flush assembly, remote control assembly, lever assembly, etc.) are separately assembled and sequentially integrated into the final product. Robots and skilled technicians work together to assemble the seat, electronics, and plumbing systems. Electronic components are carefully integrated, ensuring that all features such as the nozzle system, drying functions, and remote control work seamlessly together. Each unit undergoes rigorous testing and quality control to ensure all electronic and mechanical functions operate correctly.

Resources (energy, water, and ancillary materials) consumed for the assembly of a unit product were calculated using the annual production units in each plant. Annual resources consumed for the washlet assembly lines were provided.

$$Resource\ per\ unit\ product\ (in\ each\ plant) = \frac{\text{Annual facility resource consumption for assembly}}{\text{Annual production units (in each plant)}}$$

Wastes generated during the assembly process are assumed to be 100% landfilled and a waste transport distance of 100 km is used. Manufacturing inputs and outputs per unit product are listed in **Table 4**. All TOTO sister companies adhere to the same efficiency guidelines established by TOTO Japan, maintaining uniform energy usage per washlet assembly across all facilities. However, the consumption of ancillary materials, i.e., lubricants, oil, and grease, varies across Malaysia and Thailand plants. The production volume of WASHLET® T1SW2491 in each plant is used to develop the final weighted inventory.

Table 4. WASHLET® T1SW2491 manufacturing inputs per functional unit

Resource category	Flow	TOTO Malaysia	TOTO Thailand	Weighted	Unit
Energy	Electricity	*Submitted to the verifier*			kWh
Ancillary materials	Lubricants	*Submitted to the verifier*	*Submitted to the verifier*	*Submitted to the verifier*	kg
	Motor oil[1]	*Submitted to the verifier*	*Submitted to the verifier*	*Submitted to the verifier*	L
	Grease[2]	*Submitted to the verifier*	*Submitted to the verifier*	*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*	*Submitted to the verifier*	*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 facilities to the sites where the products are installed and used.

The WASHLET® T1SW2491 manufactured in Malaysia/Thailand is first shipped to TOTO's distribution center either Ontario, CA or Fairburn, GA. It is then transported to end users and building sites via Costco distribution centers and outlets. Per

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

PCR, energy consumption in the warehouses and distribution centers have been excluded in this study.

The first leg of product distribution, involving the shipment of washlets from TOTO's plants in Malaysia and Thailand to the TOTO distribution centers in the US, will differ due to the use of different sea routes. The production volume of WASHLET® T1SW2491 in each plant is used to develop the final weighted inventory. The second leg of transportation, which covers distribution from the TOTO centers to end users, follows these routes:

- 60% of the products are transported from TOTO, CA to Costco's distribution center on the west coast via semitrucks and then to multiple Costco outlets.
- 40% of the products are transported from TOTO, GA to Costco's distribution center on the east coast via semitrucks and then to multiple Costco outlets.

It is assumed that end users will pick up the product from Costco outlets, with a round-trip distance of 50 km using gasoline-powered cars.

The weighted values for the first leg are determined based on the annual production share of the two TOTO plants. 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 5**.

Table 5. WASHLET® T1SW2491 distribution distances and methods per functional unit

Resource category	Flow	TOTO Malaysia	TOTO Thailand	Weighted	Unit
Manufacturing plants to TOTO distribution centers)	Road transport in source country (Malaysia/Thailand)	105.80	94.90	99.35	km
	Sea transport (from source country to US)	7927.00	7817.00	7861.96	km
	Rail transport from port to TOTO centers in GA/CA	2190.90			km
Transport to final users	Road transport from TOTO distribution centers to Costco outlets	1744.89			km
	Final transport to end users (passenger pick-up)	50			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 with no additional resources being consumed. The inputs in this module include the disposal of packaging waste (plastic bags, corrugated board, and partition packaging) with a waste transportation distance of 100 km. The disposal scenario for corrugated board and partition 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[3]. 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[4].

[3] 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
[4] Product specific data for plastic containers and packaging, EPA 2018.

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 the WASHLET® T1SW2491.

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 15 years were used per the PCR.

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 comprises 10 grams of SLS and 0.99 liters of water. The following maintenance activities have been included in this study:

- Main unit cleaning (seat and lid) – Twice per month
- Cleaning of electric plug and gap between toilet tank & seat – Monthly
- Deodorizing filter cleaning – Monthly
- Nozzle/wand cleaning – Weekly
- Water filter parts cleaning – Twice a year
- Replacement of deodorizer filter every 10 years – Replaced once per RSL
- Replacement of water filter every 10 years – Replaced once per RSL
- Replacement of battery every 6 years – Replaced twice 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. The components are assumed to be sourced from within the US using road transport. All maintenance activity inputs have been quantified in **Table 6**.

Table 6. WASHLET® T1SW2491 maintenance inputs per functional unit

Name	Value	Unit
Reference service life (RSL)	15	years
Estimated service life (ESL)	75	years
Number of uses over ESL	109,500	uses
Maintenance cycles		
Main unit 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
Deodorizer filter replacement	5	per ESL
Water filter replacement	5	per ESL
Battery replacement	10	per ESL
Water consumption	75.735	liters
Auxiliary material (cleaning agent)	0.765	kg
Other resources	-	kg
Electricity	-	kWh
Other energy carriers	-	MJ
Maintenance waste	0.308	kg per ESL
Disposal sent for landfill	100	%

3.2.7. Repair (B3)

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

As prescribed by the PCR, the lid assembly, lid bumpers, seat bumpers, deodorizer assembly, and flexible hose assembly are assumed to be fully replaced once during the RSL. Those components were identified in the product BOM with assistance from TOTO team. Material inputs, upstream component processing (grouped by material type and processing operations), component transportation to users, and end disposal are all included. Since replacement components can be purchased separately by the user, an upstream transport 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 transport distance of 100 km. The repair activity inputs have been listed in **Table 7**. There is no separate air filter in this washlet, as the air filtering function is performed by the deodorizer filter. The replacement of the deodorizer filter is excluded at this stage to prevent double counting, as it is already accounted for in the B2 stage.

Table 7. WASHLET® T1SW2491 repair inputs per functional unit

Name	Value	Unit
Information on the repair process	Replacement of lid assembly, lid bumpers, seat bumpers, deodorizer assembly, and flexible hose assembly once during the RSL.	
Repair cycle	1	cycle/RSL
	5	cycles/ESL
Repair waste	5.902	kg per ESL
Disposal 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 tenth of a product and must include the sum of impacts from stages A1-A5 and C1-C4 multiplied by the number of replacements.

Since the RSL is 15 years, 4 product replacements are needed to fulfill the ESL. The replacement activity inputs have been listed in **Table 8**.

Table 8. WASHLET® T1SW2491 replacement inputs per functional unit

Name	Value	Unit
Replacement cycles over ESL	4	(ESL/RSL) -1
Electricity consumption	-	kWh
Liters of fuel	-	liters/100 km
Replacement of worn parts	-	kg
Auxiliary materials	-	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 WASHLET® T1SW2491; 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.

Energy directly used by the washlet is included in this stage. There are two modes during the washlet operation. The startup mode lasts for 30 seconds and uses a peak wattage of 514 W for seat heating, nozzle spraying, and water heating. The second mode uses a nominal energy of 50 W for seat warming and lasts for a period of 20 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 9**.

Table 9. WASHLET® T1SW2491 operational energy use consumption per functional unit

Name	Value	Unit
Number of uses over ESL	109,500	uses
Electricity consumption	2,248.40	kWh/ESL
Natural gas consumption	0	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.

Water used directly by the washlet is included in this stage. It is assumed that incoming water is municipal tap water with no filtration required. As reported in the product specification, the water spray volume for rear cleansing and front cleansing are averaged to get 0.0925 gallons of water sprayed per minute. 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 WASHLET® T1SW2491 also features pre-misting which consumes 28 ml water per use.

An electricity factor of 0.000961 kWh per liter of water is prescribed by the PCR, which includes energy for upstream municipal water collection, treatment, supply, and downstream sewage management. The operational water use inputs have been listed in **Table 10**.

Table 10. WASHLET® T1SW2491 operational water use consumption per functional unit

Name	Value	Unit
Number of uses over ESL	109,500	uses
Water flow rate		
Spray cleansing	0.0925	gallons/min
Premisting	28	ml/use
Water consumption	6,684.71	gallons
Electricity consumption	24.33	kWh
Wastewater generation	6,684.71	gallons

3.2.12. Deconstruction/demolition (C1)

This module includes the dismantling or demolition of the product from the building and associated energy consumption. The WASHLET® T1SW2491 is 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 11**. Processes specific to each material type were selected.

Table 11. WASHLET® T1SW2491 end of life inputs per functional unit

Name	Value	Unit
Transport from building site to landfill	100	km
Mixed construction waste	4.903	kg
Reuse	-	kg
Recycling	-	kg
Energy recovery	-	kg
Landfilling total	4.903	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 WASHLET® T1SW2491. 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 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 or proxies were used. Where country-specific data were unavailable, global or rest-of-world averages were used to represent production in those locations.

Table 12 lists the most relevant LCI data sets used in modeling the raw materials.

Table 12. Key material data sets used in inventory analysis

Raw material(s)	Data set	Database	Technology	Reference year	Geography[1]
Polypropylene & Polyphenylene ether	Polypropylene, granulate {GLO}| market for polypropylene, granulate | 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
Instruction manuals & guides	Printed paper, offset {RoW}| offset printing, per kg printed paper | 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

Printed wiring board	Printed wiring board, surface mounted, unspecified, Pb free {GLO}| printed wiring board production, surface mounted, unspecified, Pb free | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
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
Polyphenylene sulfide (PPS)	Polyphenylene sulfide {GLO}| market for polyphenylene sulfide | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Polyethylene terephthalate (PET)	Polyethylene terephthalate, granulate, amorphous {GLO}| market for polyethylene terephthalate, granulate, amorphous | 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	RoW
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
Aluminum	Aluminium, primary, ingot {RoW}| market for aluminium, primary, ingot | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Magnet	Permanent magnet, for electric motor {GLO}| market for permanent magnet, for electric motor | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Polyoxymethylene	Polyoxymethylene (POM)/EU-27	Industry data 2.0	Appropriate technology	2024	EUR
Battery (Alkaline AA)	LCI based on an external research paper, with DOI 10.1007/s11367-016-1134-5	Manually developed	Appropriate technology	-	GLO
Polyurethane foam	Polyurethane, rigid foam {RoW}| market for polyurethane, rigid foam | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
High density polyethylene (HDPE)	Polyethylene, high density, granulate {GLO}| market for polyethylene, high density, granulate | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Rubber Epdm	Synthetic rubber {GLO}| market for synthetic rubber | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Polyurethane flexible foam	Polyurethane, flexible foam {RoW}| market for polyurethane, flexible foam | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Styrene butadiene rubber	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
Germanium	Silicon, electronics grade {GLO}| market for silicon, electronics grade | Cut-off, U *This silicon data set has been adopted as a proxy as it is chemically similar.*	Ecoinvent v3.10	Appropriate technology	2023	GLO
Kraft paper	Kraft paper {RoW}| market for kraft paper | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Corrugated board	Corrugated board box {RoW}| market for corrugated board box | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Stainless steel	Steel, chromium steel 18/8 {GLO}| market for steel, chromium steel 18/8 | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Plastic wraps	Polyethylene, linear low density, granulate {GLO}| market for polyethylene, linear low density, granulate | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2020	GLO
Lubricating oil	Lubricating oil {RoW}| market for lubricating oil | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Silicone grease	90% silicone oil: Polydimethylsiloxane {GLO}| market for polydimethylsiloxane | Cut-off, U & 10% fumed silica: Silica fume, densified {GLO}| market for silica fume, densified | Cut-off, U	Manually developed	Appropriate technology	-	GLO

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

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. Existing ecoinvent data sets were modified manually, and embedded unit processes (mainly electricity and water) were appropriately substituted, as applicable, to represent the component production in a particular country. **Table 13** below shows the component categories developed and associated data set updates for representing the component processing.

Table 13. 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 China, Hongkong, Japan Malaysia, Vietnam)	Base dataset: Sheet rolling, copper {RoW}| sheet rolling, copper | Cut-off, U *Updates made: Electricity datasets, water related inputs & outputs updated to specific country (CN, HK, JP, MY & VN). Municipal solid waste also updated to JP for Japan. Separate datasets developed for each country.*	Ecoinvent v3.10	Appropriate technology	China (CN) Hongkong (HK) Japan (JP) Malaysia (MY) Vietnam (VN)
Plastic extrusion (in China, Japan, Malaysia, Thailand)	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, MY & TH. Separate datasets developed for each country.*	Ecoinvent v3.10	Appropriate technology	China (CN) Japan (JP) Malaysia (MY) Thailand (TH)
Plastic foaming (in China, Malaysia, Philippines)	Base dataset: Polymer foaming {CA-QC}| polymer foaming | Cut-off, U *Updates made: Electricity datasets, water related inputs & outputs updated to CN, MY & PH. Separate datasets developed for each country.*	Ecoinvent v3.10	Appropriate technology	China (CN) Malaysia (MY) Philippines (PH)
Blow molding (in Malaysia, Thailand)	Blow moulding {RoW}| blow moulding | Cut-off, U *Updates made: NO*	Ecoinvent v3.10	Appropriate technology	RoW
Plastic injection molding (in China, Hongkong, Italy, Japan, Malaysia, Philippines, Singapore, Taiwan, Thailand, 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, HK, IT, JP, MY, PH, SG, TW, TH & VN. Municipal solid waste dataset also updated to JP for Japan. Separate datasets developed for each country.*	Ecoinvent v3.10	Appropriate technology	China (CN) Hongkong (HK) Italy (IT) Japan (JP) Malaysia (MY) Philippines (PH) Singapore (SG) Taiwan (TW) Thailand (TH) Vietnam (VN)
Average aluminum metalworks (in Malaysia, Thailand, Vietnam)	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 Hongkong, Malaysia)	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 metalworks (in China, Malaysia, Thailand, 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
Average steel metalworks (in China, Japan, Malaysia, Thailand, 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

[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, US 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 14** shows the most relevant LCI data sets used in modeling transportation.

Table 14. Transportation data sets used in inventory analysis

Transport mode & legs	Data set	Database	Technology	Reference year	Geography[1]
Upstream road transport (Malaysia/ Thailand/supplier countries)	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	2023	RoW
Sea transport	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Road transport (Malaysia/ Thailand facility 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	2023	RoW
Rail transport (from US port TOTO distribution center)	Transport, freight train {US}| market for transport, freight train | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	United States
Road transport (TOTO distribution centers to Costco stores)	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	2023	RoW
Final transport to users/building sites	Transport, passenger car, small size, petrol, EURO 5 {GLO}| market for transport, passenger car, small size, petrol, EURO 5 | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
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	Ecoinvent v3.10	Appropriate technology	2023	GLO

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

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 and Thailand, so the country-specific electricity datasets were used to represent assembly in either of the countries. 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 15** shows the most relevant LCI data sets used in fuels and energy.

Table 15. Key energy data sets used in inventory analysis

Energy source	Data set	Database	Technology	Reference year	Geography
China electricity	Electricity, medium voltage {CN}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	China
Hongkong electricity	Electricity, medium voltage {HK}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Hongkong
Italy electricity	Electricity, medium voltage {IT}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Italy
Japan electricity	Electricity, medium voltage {JP}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Japan
Malaysia electricity	Electricity, medium voltage {MY}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Malaysia
Philippines electricity	Electricity, medium voltage {PH}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Philippines
Singapore electricity	Electricity, medium voltage {SG}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Singapore
Taiwan electricity	Electricity, medium voltage {TW}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Taiwan
Thailand electricity	Electricity, medium voltage {TH}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Thailand
Vietnam electricity	Electricity, medium voltage {VN}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	Vietnam
Use phase electricity	Electricity mix 2021/US US-EI U	US-EI 2.2	Appropriate technology	2023	United States

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, since country-specific data sets were not available. **Table 16** lists the relevant disposal data sets used in the model.

Table 16. Key disposal data sets used in inventory analysis

Material disposal	Data set	Database	Technology	Reference year	Geography[1]
Municipal waste, landfilled	Municipal solid waste {RoW}| treatment of municipal solid waste, sanitary landfill | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	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	2023	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	2018	United States
Landfilled, cardboard packaging	Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW

Incinerated, cardboard packaging	Waste paperboard {GLO}| treatment of waste paperboard, municipal incineration | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Landfilled, polyethylene	Waste polyethylene {RoW}| treatment of waste polyethylene, sanitary landfill | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Incinerated, polyethylene	Waste polyethylene {GLO}| treatment of waste polyethylene, municipal incineration | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Landfilled, polypropylene	Waste polypropylene {RoW}| treatment of waste polypropylene, sanitary landfill | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Landfilled, battery	Used Ni-metal hydride battery {GLO}| treatment of used Ni-metal hydride battery, pyrometallurgical treatment | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	GLO
Landfilled, plastics	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Landfilled, paper	Waste graphical paper {RoW}| treatment of waste graphical paper, sanitary landfill | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Landfilled, printed wiring boards	Used printed wiring boards {RoW}| treatment of scrap printed wiring boards, shredding and separation | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Landfilled, aluminum	Waste aluminium {RoW}| treatment of waste aluminium, sanitary landfill | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW
Landfilled, polyurethane	Waste polyurethane {RoW}| treatment of waste polyurethane, sanitary landfill | Cut-off, U	Ecoinvent v3.10	Appropriate technology	2023	RoW

[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. No known mass flow has 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 known mass flow has been omitted in this study.

In this report, 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.

Annual resources provided for the assembly of WASHLET® T1SW2491 in each plant were evenly distributed based on the annual production quantity. Both plants have a production line solely dedicated to assembling washlets. Since the annual resources were reported specifically for this line and no other co-products are manufactured, there was no need for co-product allocation or allocation of multi-input processes. Allocation of reuse, recycling, and energy recovery is not applicable for this study. No allocation situation occurred requiring the allocation of product inputs and outputs.

The model used in this report ensures that the sum of the allocated inputs and outputs of a unit process is 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.

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 2024 – December 2024, 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 and Thailand. 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 washlet 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 amount of electricity was consumed for the assembly of a single washlet in both TOTO plants.
- It is assumed that incoming water is municipal tap water, and no filtration is required.
- 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.
- 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 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 17**). The impact indicators are derived using the 100-year time horizon[5] 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[6] 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 17. 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 category calculations. The biogenic carbon measured in this study originates from packaging materials, and no raw materials in the WASHLET® T1SW2491 product

[5] 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.
[6] USEtox is available in TRACI and at http://www.usetox.org/

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 WASHLET® T1SW2491.

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 18** 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 18. 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 amount 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 19** represents all the resource use and waste flow indicators evaluated in this study, along with the acronyms used.

Table 19. 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**

Table 20 shows resource use, output and waste flows, and carbon emissions and removals for the WASHLET® T1SW2491 per functional unit.

Table 20. Resource use, output and waste flows, and carbon emissions and removals for the WASHLET® T1SW2491 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	2.05E+02	6.74E-01	1.52E-02	0	7.03E+01	2.32E+01	8.22E+02	0	1.85E+03	3.25E+01	0	1.61E-02	0	3.44E-02	**3.00E+03**
RPR_M	MJ, NCV	7.50E+00	0	0	0	0	0	3.00E+01	0	0	0	0	0	0	0	**3.75E+01**
RPR_{total}	MJ, NCV	2.12E+02	6.74E-01	1.52E-02	0	7.03E+01	2.32E+01	8.52E+02	0	1.85E+03	3.25E+01	0	1.61E-02	0	3.44E-02	**3.04E+03**
$NRPR_E$	MJ, NCV	1.54E+03	1.86E+02	5.06E+00	0	3.43E+01	4.88E+02	6.96E+03	0	2.22E+04	3.19E+02	0	8.48E+00	0	1.45E+00	**3.17E+04**
$NRPR_M$	MJ, NCV	1.31E+02	0	0	0	1.19E+00	2.11E+02	5.25E+02	0	0	0	0	0	0	0	**8.68E+02**
$NRPR_{total}$	MJ, NCV	1.67E+03	1.86E+02	5.06E+00	0	3.55E+01	6.99E+02	7.48E+03	0	2.22E+04	3.19E+02	0	8.48E+00	0	1.45E+00	**3.26E+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	6.08E+02	2.45E+00	7.43E-02	0	2.15E+01	9.99E+01	2.44E+03	0	2.65E+01	2.90E+01	0	7.10E-02	0	1.97E-01	**3.23E+03**
ADPf	MJ, LHV	1.52E+03	1.85E+02	5.04E+00	0	3.27E+01	6.74E+02	6.89E+03	0	1.53E+04	2.22E+02	0	8.46E+00	0	1.40E+00	**2.49E+04**
Output flows and waste category indicators																
HWD	kg	6.79E-04	0	0	0	0	0	2.72E-03	0	0	0	0	0	0		**3.39E-03**
NHWD	kg	7.58E-05	0	4.98E-01	0	3.08E-01	5.90E+00	2.16E+01	0	0	0	0	0	0	4.90E+00	**3.32E+01**
HLRW	kg	6.73E-04	3.88E-06	1.02E-07	0	1.34E-05	1.08E-04	2.71E-03	0	2.01E-02	2.87E-04	0	1.15E-07	0	2.13E-07	**2.39E-02**
ILLRW	kg	2.12E-03	1.14E-05	2.41E-07	0	2.90E-05	2.51E-04	8.51E-03	0	4.47E-02	6.39E-04	0	2.65E-07	0	5.36E-07	**5.63E-02**
CRU	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MR	kg	0	0	2.20E+00	0	0	0	8.80E+00	0	0	0	0		0		**1.10E+01**
MER	kg	0	0	1.21E-01	0	0	0	4.86E-01	0	0	0	0	0	0	0	**6.07E-01**
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	5.92E+00	0	0	0	0	0	2.37E+01	0	0	0	0	0	0	0	**2.96E+01**
BCEK	kg CO_2	0	0	4.95E+00	0	0	0	2.37E+01	0	0	0	0	0	0	9.74E-01	**2.96E+01**
CBCEW	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
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. Impact assessment results

In the cradle-to-grave life cycle of the product, operational energy use (B6) dominates the lifecycle impact results for five TRACI impact categories. B6 accounts for the majority of impacts in global warming (~57%), ozone depletion (~46%), smog (~45%), acidification (~52%), and fossil fuel depletion (~57%). The electricity consumed by the washlet during each use, with a mix of peak and nominal power demands over its estimated service life (ESL) is the sole driver for the B6 impacts. The electricity is typically sourced from the power grid, which is often reliant on fossil fuels such as coal, natural gas, and oil. This reliance results in the depletion of fossil fuels and the release of carbon dioxide and other greenhouse gases, driving global warming and ozone depletion. Additionally, the burning of these fuels produces pollutants that contribute to smog and acidification, while the overall demand for fossil fuels exacerbates fossil fuel depletion, making electricity use a key factor in these environmental impacts.

For the remaining five TRACI impact categories: eutrophication, carcinogenics, non-carcinogenics, respiratory effects, and ecotoxicity, product replacement dominates the life cycle impacts. These categories are primarily influenced by the environmental impacts associated with the production, transportation, and disposal of the product. Since a total of 4 product replacements are required to meet the estimated service life of 75 years, each replacement involves the full set of activities, including manufacturing, resource extraction, and waste management. These activities result in significant emissions and chemical releases, which contribute to the environmental burdens in these specific impact categories. The repeated need for product replacements amplifies the impact of these processes, as each cycle of production and disposal generates pollutants that directly affect ecosystems, human health, and air and water quality.

Operational water use (B7) also shows significant impacts in the overall life cycle, mainly in eutrophication (~34%), carcinogenics (~16%), non-carcinogenics (~13%), and ecotoxicity (~6%). More than 98% of B7 impacts for these four impact categories comes from the municipal sewage treatment of the sewage.

The LCIA results of the WASHLET® T1SW2491 per functional unit are shown in **Table 21**.

Table 21. Life cycle impact assessment results for the WASHLET® T1SW2491 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	1.14E-05	2.74E-07	6.42E-09	0	5.90E-08	8.51E-07	4.66E-05	0	5.13E-05	1.17E-06	0	1.07E-08	0	1.74E-09	**1.12E-04**
Global warming	kg CO_2 eq	1.12E+02	1.46E+01	8.98E-01	0	3.70E+00	3.33E+01	5.18E+02	0	1.24E+03	2.00E+01	0	6.48E-01	0	9.94E-01	**1.94E+03**
Smog	kg O_3 eq	8.20E+00	9.62E-01	5.81E-02	0	8.04E-01	1.48E+00	3.73E+01	0	4.09E+01	1.09E+00	0	9.73E-02	0	1.02E-02	**9.10E+01**
Acidification	kg SO_2 eq	7.99E-01	5.07E-02	1.97E-03	0	2.96E-02	1.14E-01	3.42E+00	0	4.86E+00	1.25E-01	0	3.16E-03	0	5.08E-04	**9.40E+00**
Eutrophication	kg N eq	1.99E-01	2.43E-03	7.50E-04	0	2.72E-02	1.37E-02	8.16E-01	0	3.96E-01	7.41E-01	0	2.00E-04	0	1.66E-03	**2.20E+00**
Carcinogenics	CTU_h	1.51E-06	6.37E-09	6.64E-10	0	4.15E-07	8.82E-08	6.07E-06	0	2.35E-06	1.97E-06	0	1.39E-10	0	1.80E-09	**1.24E-05**
Non-carcinogenics	CTU_h	4.65E-05	6.52E-07	3.95E-08	0	3.48E-06	1.31E-06	1.89E-04	0	3.83E-05	4.01E-05	0	2.86E-08	0	1.22E-07	**3.20E-04**
Respiratory effects	kg $PM_{2.5}$ eq	1.36E-01	4.45E-03	2.43E-04	0	5.78E-03	2.21E-02	5.66E-01	0	2.85E-01	6.49E-03	0	3.95E-04	0	7.86E-05	**1.03E+00**
Additional impact categories																
Ecotoxicity	CTU_e	2.57E+02	1.21E+01	1.90E-01	0	7.78E+01	2.36E+01	1.08E+03	0	9.27E+01	9.42E+01	0	8.36E-02	0	9.19E-01	**1.64E+03**
Fossil fuel depletion	MJ surplus	1.49E+02	2.62E+01	7.21E-01	0	3.16E+00	8.21E+01	7.10E+02	0	1.58E+03	2.30E+01	0	1.21E+00	0	1.82E-01	**2.58E+03**

Impacts in other use phase modules are minimal compared to B4 and B7. Product repair (B3) module impacts has considerable impacts, but they are dispersed across various replaced components, so there is not a single standout component or process contributing heavily. Product maintenance module (B2) impacts are much lower but are driven by the use of SLS solution for cleaning various components and the periodic replacement of batteries.

The upstream raw material extraction and processing module (A1) also plays a significant role in the life cycle impacts. Impacts from the upstream production of wiring boards account for about half of the total A1 impacts, while the remaining impacts are distributed across various components of the washlet. Product distribution (A4) also contributes significantly to the life cycle impacts, with the majority of these impacts arising from sea transportation of the product from Malaysia/Thailand to the US and road transportation to the end users.

Impacts from all other life cycle stages are minimal. It is important to note that the product manufacturing stage (A3) contributes negligibly to total impacts across most categories, except for ozone depletion, which is influenced by the use of greases in assembly plants.

The SM2013 Methodology single figure millipoint (mPt) score by life cycle module for this product is presented in **Table 22**. In terms of single figure scores and overall environmental impacts, product replacements (B4) dominate the results (~43%). This is followed by operational energy use (B6) which accounts for ~35% of the total. The production stage (A1-A3) contributes ~10% while operational water use (B7) contributes 8% of the total.

Table 22. SM millipoint scores for the WASHLET® T1SW2491 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	1.20E+01	6.17E-01	2.93E-02	0	1.81E+00	1.72E+00	5.09E+01	0	4.22E+01	9.78E+00	0	2.74E-02	0	3.94E-02	**1.19E+02**

5.2.2. Contribution analysis

The percent contribution of each of the cradle-to-grave life cycle stages to the total impacts is tabulated in **Table 23** and is also presented in **Figure 5**.

Across all impact categories, the use phase (B1–B7) is the most dominant stage of the product's life cycle, primarily stemming from two major activities: product replacements and electricity use (for bidet operations). These activities account for at least 84% of total environmental impacts across all categories. Looking specifically at global warming potential (GWP), the use stage makes approximately 93% of total GWP emissions. Operational energy use (B6) is the largest contributor, making up about 64% of total GWP impacts followed by approximately 27% impacts from the product replacements (B4). These results highlight the critical role of electricity consumption and product durability in the overall environmental impacts of the product.

Table 23. Percent contributions of each life cycle stage to each impact category for the WASHLET® T1SW2491 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	%	10.17%	0.25%	0.01%	0	0.05%	0.76%	41.72%	0	45.98%	1.05%	0	0.01%	0	0.00%	**100%**
Global warming	%	5.80%	0.75%	0.05%	0	0.19%	1.72%	26.72%	0	63.67%	1.03%	0	0.03%	0	0.05%	**100%**
Smog	%	9.02%	1.06%	0.06%	0	0.88%	1.63%	41.02%	0	45.01%	1.20%	0	0.11%	0	0.01%	**100%**
Acidification	%	8.49%	0.54%	0.02%	0	0.31%	1.21%	36.36%	0	51.69%	1.33%	0	0.03%	0	0.01%	**100%**
Eutrophication	%	9.06%	0.11%	0.03%	0	1.24%	0.62%	37.14%	0	18.00%	33.71%	0	0.01%	0	0.08%	**100%**
Carcinogenics	%	12.16%	0.05%	0.01%	0	3.35%	0.71%	48.91%	0	18.93%	15.88%	0	0.00%	0	0.01%	**100%**
Non-carcinogenics	%	14.53%	0.20%	0.01%	0	1.09%	0.41%	59.18%	0	11.99%	12.54%	0	0.01%	0	0.04%	**100%**
Respiratory effects	%	13.28%	0.43%	0.02%	0	0.56%	2.15%	55.13%	0	27.74%	0.63%	0	0.04%	0	0.01%	**100%**
Additional impact categories																
Ecotoxicity	%	15.68%	0.74%	0.01%	0	4.74%	1.44%	65.95%	0	5.65%	5.74%	0	0.01%	0	0.06%	**100%**
Fossil fuel depletion	%	5.79%	1.02%	0.03%	0	0.12%	3.19%	27.55%	0	61.36%	0.89%	0	0.05%	0	0.00%	**100%**

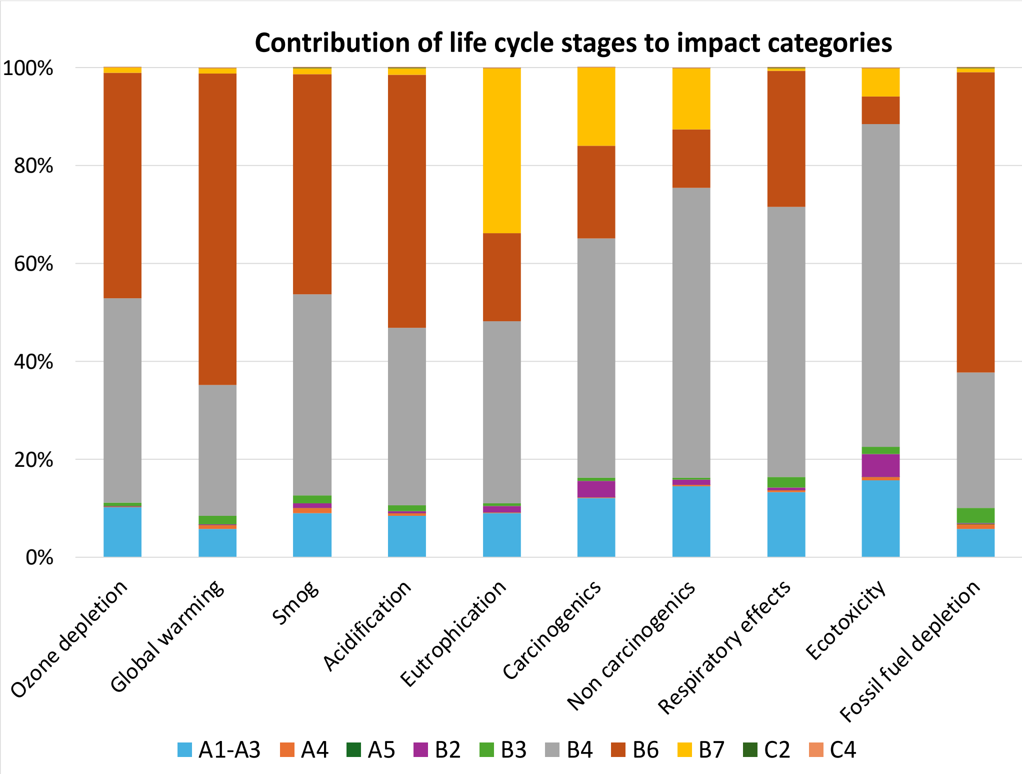

Figure 5. Contribution analysis of each impact category for the WASHLET® T1SW2491 per functional unit

For each impact category of interest to TOTO, a detailed analysis was performed to identify major unit processes that contribute significantly to the overall product life cycle impacts of the WASHLET® T1SW2491 which have been tabulated in **Table 24**.

Table 24. Drivers of WASHLET® T1SW2491 life cycle impacts

Impact categories	Major flows (with impacts greater than 4%)	Actual contribution
Ozone Depletion	Electricity consumption for washlet operations	45.98%
	Product replacement	41.72%
Global warming	Electricity consumption for washlet operations	63.67%
	Product replacement	26.72%
Smog	Electricity consumption for washlet operations	45.01%
	Product replacement	41.02%
	Material extraction and upstream production of wiring boards	4.83%
Acidification	Electricity consumption for washlet operations	51.69%
	Product replacement	36.36%
Eutrophication	Product replacement	37.14%
	Sewage treatment	33.50%
	Electricity consumption for washlet operations	18.00%
	Material extraction and upstream production of wiring boards	4.72%
Fossil fuel depletion	Electricity consumption for washlet operations	61.36%
	Product replacement	27.55%

5.3. Sensitivity analysis

Two main parameters that influence the life cycle impacts of the washlet 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 assembly location

Since this LCA study examines the TOTO WASHLET® T1SW2491, which is assembled in two TOTO plants located in Malaysia and Thailand, it is essential to assess the impact differences between these locations. To achieve this, the environmental impacts of the washlet produced at each plant were quantified and compared as shown in **Table 25**. The difference in assembly location leads to minor variations in the impacts of the upstream processing (A1), upstream transport (A2), and distribution (A4) modules. However, since these modules contribute only a small share of the product's overall life cycle impacts, the results remain largely unaffected by the assembly location. Focusing solely on global warming potential, the variation is negligible (±0.01%).

Table 25. LCIA variation of WASHLET® T1SW2491 for different assembly locations

Impact categories	TOTO Malaysia	TOTO Thailand
Ozone depletion	3.57%	-2.47%
Global warming	0.01%	-0.01%
Smog	-0.22%	0.16%
Acidification	-0.13%	0.09%
Eutrophication	0.01%	-0.01%
Carcinogenics	-0.00%	0.00%
Non carcinogenics	-0.01%	0.01%
Respiratory effects	0.46%	-0.31%
Ecotoxicity	-0.04%	0.03%
Fossil fuel depletion	0.04%	-0.03%

5.3.2. 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 thew WASHLET® T1SW2491 in both MORE and NYUP eGRID subregions and have been compared with the average results. Three different impact categories were evaluated: global warming potential, fossil fuel depletion, and eutrophication. However, other impact categories are expected to follow a similar pattern.

Table 26. Sensitivity analysis of electricity grid mix region choice on GWP emissions per functional unit

eGRID subregion	B6 (operational energy use)		B7 (operational water use)		Total life cycle	
	Environmental impact	**% change**	**Environmental impact**	**% change**	**Environmental impact**	**% change**
Global warming (kg CO_2-eq emissions)						
Baseline	1.24E+03	N/A	2.00E+01	N/A	1.94E+03	N/A
NYUP	4.38E+02	-64.54%	1.14E+01	-43.15%	1.13E+03	-41.53%
MROE	1.99E+03	60.84%	2.81E+01	40.68%	2.70E+03	39.15%
Fossil fuel depletion (MJ surplus)						
Baseline	1.58E+03	N/A	2.30E+01	N/A	2.58E+03	N/A
NYUP	9.46E+02	-40.15%	1.61E+01	-29.90%	1.93E+03	-24.91%
MROE	1.57E+03	-0.66%	2.29E+01	-0.49%	2.57E+03	-0.41%
Eutrophication (kg N eq)						
Baseline	3.96E-01	N/A	7.41E-01	N/A	2.20E+00	N/A
NYUP	4.38E-02	-88.93%	7.37E-01	-0.51%	1.84E+00	-16.18%
MROE	8.74E-01	120.89%	7.46E-01	0.70%	2.68E+00	21.99%

As shown in **Table 26**, the global warming potential of CO_2-equivalent emissions increased for both B6 and B7 in the MROE subregion, whereas emissions decreased in the NYUP subregion. Total life cycle CO_2-equivalent emissions were approximately 42% higher than the baseline in MROE but about 39% lower in NYUP. Regarding fossil fuel depletion potential, product use in MROE showed only a slight reduction, while the NYUP subregion experienced a more significant decrease of approximately 25%. For eutrophication impacts, the NYUP subregion saw a reduction of about 16% compared to the baseline, whereas product use in the MROE subregion resulted in approximately 22% higher eutrophication impacts over the product life cycle.

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 WASHLET® T1SW2491, and the results are sensitive to the location where the product is used.

5.3.3. Change in product life

Sensitivity analyses were performed to check the impacts of changing product life. Product life is directly linked to the number of replacements required over its service period. Higher durability reduces the need for replacements to meet the ESL, while lower durability increases them. As in the previous sensitivity analysis, three impact categories were evaluated: global warming potential, fossil fuel depletion, and eutrophication.

Table 27. 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	
		Environmental impact	% change	Environmental impact	% change
Global warming (kg CO_2-eq emissions)					
Baseline (15 years)	4	5.18E+02	N/A	1.94E+03	N/A
30 years	2	2.59E+02	-50.00%	1.68E+03	-13.36%
20 years	2.75	3.56E+02	-31.25%	1.78E+03	-8.35%
10 years	6.5	8.42E+02	62.50%	2.26E+03	16.70%
Fossil fuel depletion (MJ surplus)					
Baseline (15 years)	4	7.10E+02	N/A	2.58E+03	N/A
30 years	2	3.55E+02	-50.00%	2.22E+03	-13.77%
20 years	2.75	4.88E+02	-31.25%	2.35E+03	-8.61%
10 years	6.5	1.15E+03	62.50%	3.02E+03	17.22%
Eutrophication (kg N eq)					
Baseline (15 years)	4	8.16E-01	N/A	2.20E+00	N/A
30 years	2	4.08E-01	-50.00%	1.79E+00	-18.57%
20 years	2.75	5.61E-01	-31.25%	1.94E+00	-11.61%
10 years	6.5	1.33E+00	62.50%	2.71E+00	23.21%

As shown in **Table 27**, a longer product life (e.g., 30 years) lowers B4-related global warming potential by about 50%, reduces B4 fossil fuel depletion by approximately 50%, and decreases B4 eutrophication by about 50% compared to the baseline (15 years). This also leads to lower total life cycle impacts, with reductions of about 13% in global warming potential, 14% in fossil fuel depletion, and 19% in eutrophication. In contrast, a shorter lifespan (10 years) significantly increases B4 impacts, raising global warming, fossil fuel depletion, and eutrophication by approximately 63%, which also contributes to higher total life cycle emissions and resource consumption. These results highlight the importance of improving product longevity to reduce the environmental burden of frequent replacements.

The results of the sensitivity analyses show that the product lifetime plays a significant role in the total life cycle impacts for the WASHLET® T1SW2491, and the results are sensitive to product durability.

5.4. Overview of relevant findings

This study evaluated a wide range of inventory and environmental indicators. The main finding for the TOTO WASHLET® T1SW2491 is that the product use phase (B1-B7) accounts for the majority of impacts across all environmental indicators.

Within the use phase, environmental impacts are primarily driven by the product replacement (B4), operational energy use (B6), and operational water use (B7) modules. Notable impacts also stem from the production (A1-A3), product distribution (A4), product maintenance (B2), and product repair (B3) stages. The impacts from B6 and B7 are largely driven by the electricity consumed during washlet operations and the energy used in municipal water systems, respectively. Production impacts arise from the materials and upstream processing of components, particularly the wiring boards. The assembly of the final product has relatively low impacts in comparison to the upstream production of individual components. The impacts from B2 are mainly driven by the use of cleaning solutions and the replacement of batteries.

All other life cycle stages have relatively insignificant impacts to the total life cycle results.

5.5. Conclusion and recommendations

The goal of this study was to conduct a cradle-to-grave LCA on TOTO's WASHLET® T1SW2491 so as to develop a Transparency Report [EPD]™. The creation of this TR 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 for reducing potential environmental impacts. Sensitivity analyses show that a washlet with a product life double the baseline demonstrates a significant reduction of ~13% of the total life cycle CO_2-equivalent emissions. Better product designs with enhanced durability and longevity reduces the need for frequent product replacements. Implementing 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 washlet operations. This electricity consumption during the use phase contributes to ~64% of potential CO_2-equivalent emissions across the life cycle of the product. It is recommended that TOTO look into 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.

Since TOTO is assembling the product and all components are manufactured upstream, TOTO has little control over the impacts being generated upstream. However, it should incentivize suppliers to adopt sustainable manufacturing practices and integrate renewable energy into their production facilities. Renewable sources can be solar, wind, hydropower, or purchasing renewable electricity certificates (RECs). 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.

Additionally, an annual update to this LCA and the associated Transparency Report [EPD]™ would enable high-quality year-to-year comparisons and serve as the basis for potential optimized EPDs. 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

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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

- T1SW2491_complete BOM.xlsx
- LCI_ T1SW2491Washlet.xlsx
- Results_ T1SW2491Washlet.xlsx