LIFE CYCLE ASSESSMENT (LCA)
OF TOTO COMMERCIAL LAVATORIES

Status: Public

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Author(s): Gary Soe

TOTO

Contents

1 INTRODUCTION

1.1 Opportunity

TOTO USA is committed to innovating products that make people's lives better, protect the environment and keep our water pure. To honor our commitment to sustainability, it is important that we conduct Life Cycle Assessments to evaluate the environmental impacts of our products in all stages of life, from raw materials to manufacturing and even through to the end of life. The goal of conducting a Life Cycle Assessment is to explore the full range of environmental impacts our products have and to identify ways to improve processes and lessen any negative effects. This project is critical to TOTO's PeoplePlanetWater mission of innovating products for the benefit of people, the planet and our water supply.

In order to understand the true impact of products throughout all life cycle stages, TOTO has chosen to conduct the Life Cycle Assessment using a cradle-to-grave approach. By factoring in all stages, it is more informed on how to reduce impacts on a broader scale.

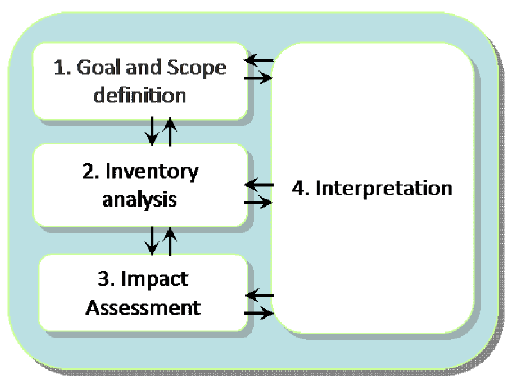
TOTO is continuing to have Life Cycle Assessment (LCA) data available for its most important products to be able to obtain SM Transparency Reports [EPDs]™, type III environmental declarations that can be used for communication with and amongst other companies, architects and consumer communication, and can also be utilized in whole building LCA tools.

1.2 Life Cycle Assessment

Performing a life cycle assessment (LCA) follows the Sustainable Minds Transparency Report [EPD]™ Framework, which is based on ISO 14040-44 & 14025 standards [1, 2]. Such an LCA includes the following phases:

- Goal and Scope
- Inventory Analysis
- Impact Assessment
- Interpretation

This report includes all phases.



Source: ISO 14040

According to the Framework, a stakeholder procedure is required when LCA results are intended to be used for external communication *and* a comparison is made to products that are not produced by the commissioning party. This report concerns products from TOTO only. An ISO 14040-44 third-party review and a third-party report verification for Transparency Reports [EPDs]™ are required in the Framework in order to be able to use Transparency Reports [EPDs]™ as Type III environmental declarations. Both the review and the verifications will be completed in this project.

In order to use LCA to make ‘comparative assertions’ (asserting that one product is definitively better than another), standards (ISO, CEN) have very prescriptive criteria that must be met. These include (among others):

a. The description (function, performance and use) must be identical.
b. The ISO 14040 goal and scope are equivalent.
c. The data collection methods, calculation procedure and allocation methods are equivalent.
d. The impact categories and calculation methods are identical.

One cannot compare 75 years of use of the studied product to another unless the following conditions, which are unequivocally impossible to meet: materials are functionally equivalent (same strength, durability, thermal properties, etc.), environment it is installed is the same (same usage, maintenance cleaning schedule, etc.) and equivalent installation method with same structural integrity of the wall. And while it is theoretically possible to compare functionally equivalent assemblies, it is quite difficult in practice to design two truly functionally equivalent systems using the multiple criteria by which a performance can be analyzed. Hence, the report is not intended for comparative assertions.

1.3 Status

All information in the report reflects the best possible inventory by TOTO at the time it was collected, and a best practice of TOTO employees to transform this information into this LCA report. The data covers annual manufacturing data during the calendar year 2023. The purpose is to create average LCA models for the studied products. This study includes primary data from the processes at TOTO, secondary data from suppliers that have been contracted and literature data to complete the inventory and fill the gaps. Most data was supplied directly from energy providers or collected by TOTO employees, while the rest of the data was calculated by TOTO specialists via engineering calculations and was validated and quality assured by the LCA manager. TOTO relies on vendors for the components and assembly of some of the products that are sold under its name.

TOTO has chosen to have the LCA data and report go through third-party review against ISO 14040/14044 [1]. A third-party review has been performed by NSF. The review concluded that the LCA report is in conformance with ISO 14040-44.

TOTO has also chosen to have the Transparency Reports [EPDs]™ undergo third-party verification against ISO 14025 [2], SM Part A [3] and the following SM Part B:

- Sustainable Minds Transparency Report™ / EPD Framework, Part B: Product group definition | Commercial lavatories | Part B #24-001, version 1.0, October 7, 2024 [4]

A third-party Transparency Report [EPD]™ verification has been performed by NSF. The verification concluded that the Transparency Reports [EPDs]™ are in conformance with the Sustainable Minds Transparency Report™ / EPD Framework Part A and the relevant Part B.

1.4 Team

This report is based on the work of the following LCA project leader on behalf of TOTO:

- Gary Soe, Engineering Manager

He has been assisted by TOTO subsidiaries and numerous TOTO employees during the product group definition, data collection, reporting and interpretation.

1.5 Structure

This report follows the structure of the life cycle assessment methodology defined in the Sustainable Minds Framework as well as the Part B of the respective products. It starts with the goals and scope in Chapter 2. Chapter 3 includes the inventory, and the impact assessment can be found in Chapter 4. Chapter 5 details the interpretation phase.

This report includes LCA terminology. To assist the reader, special attention has been given to list definitions of important terms used at the end of this report.

2 GOAL AND SCOPE

This chapter explains the starting points for the LCA. The aim of the goal and scope is to define the products under study and the depth and width of the analysis.

The objective of the report is to develop a Life Cycle Inventory (LCI) and Assessment (LCA) Model for the products below from cradle to grave, to apprehend the environmental impact of products throughout all life cycle stages, and to be informed of the range of impactful aspects to initiate serious conversations regarding how to reduce the impacts on a broader scale.

The Life Cycle Inventory (LCI) developed includes all resource inputs (materials, energy, etc.), all waste (e.g., overburden waste, fines, etc.) and emission streams (e.g., all gaseous emissions including CO2, Particulate Matter, etc.) throughout the system and enable the user of the LCA Model to ascertain and quantify the relevant environmental impacts at each phase in the product life cycle.

The LCI system developed also provides the facility to consider the relative proximity of sources of primary aggregates and recycled aggregates to the marketplace as well as disposal options for inert construction and demolition wastes.

2.1 Intended application and audience

This report intends to define the specific application of the LCA methodology to the life cycle of TOTO commercial lavatories. It is intended for both internal and external business-to-consumer communication purposes. The Transparency Report, a Type III Environmental Declaration per ISO 14025, will communicate the results of this study which is focused on products that are available and sold in the US market.

2.2 TOTO products

TOTO is the world's largest plumbing products manufacturer and offers a complete line of commercial and decorative plumbing fixtures and fittings, including toilets, lavatory sinks, urinals, faucets, flush valves, showerheads and valves, bathtubs, and their accessories. TOTO products infuse style with substance, optimize water conservation and strive for consistent and high performance. TOTO embraced water and energy conservation years before government mandates. Through their consistently evolving manufacturing practices, they aim to develop and manufacture plumbing fixtures that are efficient and sustainable. For more information on TOTO products, go to www.totousa.com.

The products studied in this report include ceramic commercial lavatories manufactured at TOTO Mexico. These products and their categories of Transparency Reports [EPDs]™ and manufacturing location, as well as other product information, are presented in Tables 2.1a-b below.

Table 2.1a Product codes, names and project concepts

Product Code	Product Description	Project concept	Production plant/vendors	Production Location	Declaration Type
LT307R(A)	Commercial Wall Hung Lavatory	LCA of a TOTO lavatory	TOTO Mexico (TMX)	Monterrey, Mexico	Product-specific, plant-average EPD (product-specific tabs)
LT569	Commercial Undercounter Lavatory				

Table 2.1b Product information

Product code	CSI master format classification	ASTM or ANSI product specification	Physical properties and technical information or any other market identification
LT307R(A)	22 42 16.13	ASME A112.19.2/CSA B45.1 Certifications: IAPMO(cUPC)	Commercial Lavatory
LT569			

Table 2.2 lists the 2023 production volumes of the modeled products which are used in the declaration of the corresponding product. Additionally, the weights of the products are listed in Table 2.3.

Table 2.2 Production volumes of the modeled products for 2023

Product code	Product name	Production volume (pieces)
LT307R(A)	Commercial Wall Hung Lavatory	Submitted to the verifier
LT569	Commercial Undercounter Lavatory	Submitted to the verifier

Table 2.3 Lavatory raw material weights per functional unit

Product code	Lavatory body (ceramic)		Packaging (corrugated board, paper inserts)		Mounting hardware (stainless steel)	
	Mass (kg)	%	Mass (kg)	%	Mass (kg)	%
LT307R(A)	16.6	88.8%	1.74	9.33%	0.346	1.85%
LT569	7.00	86.3%	1.08	13.3%	0.132	0.408%

Presented below are images and descriptions of the modeled products.

Table 2.4 Description of the modeled products

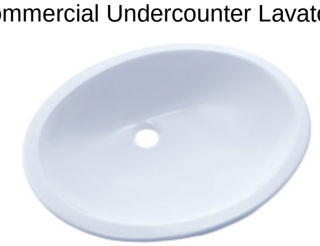
Commercial Wall-Hung Lavatory

This sink basin has the following features:

- Anti-Splash Rim
- Concealed Front Overflow
- Punching for Concealed Arm Carrier
- Durable and Easy to Maintain
- Available for 4 inch or 8 inch spread faucets
- Soap dispenser hole option

See more at the following websites:
https://www.totousa.com/commercial-wall-hung-lavatory-with-soap-dispenser

Commercial Undercounter Lavatory



This sink basin has the following features:

- 17" x 14" Undercounter Lavatory
- Installation Template and Mounting Hardware Included
- Spacious Basin
- Large Backsplash
- Concealed Front Overflow

See more at:
https://www.totousa.com/undercounter-lavatory-5

2.3 Functional units

The results of the LCA in this report are expressed in terms of a functional unit as it covers the entire life cycle of the product. The functional unit of the products is presented in Table 2.5. The Transparency Reports [EPDs]™ of the corresponding products listed are expressed in terms of one respective piece of the product as well as all life cycle modules which are presented later in this report. The functional units in Table 2.5 serve as the reference unit for the products' LCA. These functional units are taken from Part B of the SM Transparency Report Framework [4]. TOTO products comply with the functional performance specifications defined in the aforementioned Part B.

Table 2.5 Functional unit of the modeled products

Product	Functional Unit
LT307R(A)	One commercial lavatory in an average commercial environment over the estimated service life of the building
LT569	

The Expected Service life (ESL) for the study is 75 years and all use stage activity and impacts are counted for the full ESL period. The reference service life (RSL) of the product category is 20 years. The RSL is an industry accepted average lifespan that is based on the economic lifespan of a product.

2.4 System boundaries

To define what is included and what is excluded in an LCA, the system boundaries are described in this section. In general, the system boundaries as defined in Part A [3] are followed. This section details some of the aspects to assist the reader to understand what is included in the models.

The system boundaries reflect the life cycle phases that have been modeled. It defines which life cycle phases and processes are included and which are not. The LCA is modeled according to specific system boundaries and is quantified in such a way that they reflect the respective reference units of the modeled products. This study follows the modularity principle, where all environmental impacts and potential impacts are declared in the life cycle stage where they can be attributed.

This LCA's system boundaries include the following life cycle phases:

- Production
- Construction/Installation
- Use
- End of life

These boundaries apply to the modeled products and can be referred to as "cradle-to-grave" which means that it includes all life cycle stages and modules as identified in Part A [3].

The system boundaries for TOTO commercial lavatory products are detailed below.

	Product assessment information															
	Product life cycle information															Supplementary information (benefits and loads) beyond the product life cycle
Transparency Report aggregated modules	Production			Construction		Use							End of life			Recovery
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Transparency Reports system boundary	Raw Materials	Transport	Manufacturing	Transport	Construction / installation stage	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
Cradle-to-grave Functional unit	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	MND

X = a declared module

Figure 1. Applied system boundaries for the modeled commercial lavatory products

Table 2.6 System boundary inclusions and exclusions

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

2.4.1. Production stage [A1-A3]

The product stage includes, where relevant, information modules for:
- A1: Extraction and processing of raw materials (e.g., mining processes) and biomass production and processing (e.g., agricultural or forestry operations)
- A1: Reuse of products or materials from a previous product system
- A1: Processing of secondary materials (e.g., scape metals to hold the primary products) used as input for manufacturing the product, but not including those processes that are part of the waste processing in the previous product system
- A1: Generation of electricity, steam and heat from primary energy resources, including extraction, refining and transport thereof
- A1: Energy recovery and other recovery processes from secondary fuels, but not including those processes that are part of waste processing in the previous product system
- A2: Transportation up to the factory gate in addition to internal transport
- A3: Production of ancillary materials or pre-products
- A3: Manufacturing of packaging

- A1-A3: Processing up to the end-of-waste state or disposal of final residues including any packaging not leaving the factory gate with the product.

A description of the most important modeling parameters is included below.

2.4.1.1. Raw Materials

The lavatory raw materials have been majorly grouped into three categories: body slip and glaze (ceramic materials), casting materials, and installation parts.

Ceramic constitutes the body of the lavatory and inputs to the system are body slip and glaze. The recipe of raw materials for the body slip and glaze for the different ceramic products manufactured in TMX including the transportation mode and distances when purchased are listed in the tables below. Also provided below is BOM of each product. The material inputs to the production system of the modeled ceramics are provided in Table 2.6. All materials that have a contribution greater than 0.15% weight of the total bill of materials are included. Additional raw materials data of the products as required by Part A is presented in appendix A.

Table 2.7 Ceramic production raw materials and transportation

TOTO Mexico ceramic body slip materials purchased in 2023					
Constituents	**% of materials**	**Ocean (miles)**	**Truck (miles)**	**Train (miles)**	**Origin**
Kaolin	1.76%	Submitted	Submitted	Submitted	Submitted to the verifier
Silica	10.7%	Submitted	Submitted	Submitted	Submitted to the verifier
Feldspar	33.0%	Submitted	Submitted	Submitted	Submitted to the verifier
Ball clay	8.95%	Submitted	Submitted	Submitted	Submitted to the verifier
Sodium Silicate	0.0970%	Submitted	Submitted	Submitted	Submitted to the verifier
China Clay_Old Mine	11.6%	Submitted	Submitted	Submitted	Submitted to the verifier
China Clay_Martin 5	16.1%	Submitted	Submitted	Submitted	Submitted to the verifier
China Clay_Kaolin KT Cast	17.8%	Submitted	Submitted	Submitted	Submitted to the verifier
TOTO Mexico ceramic glaze materials purchased in 2023					
Constituents	**% of materials**	**Ocean (miles)**	**Truck (miles)**	**Train (miles)**	**Origin**
Silica	1.87%	Submitted	Submitted	Submitted	Submitted to the verifier
Feldspar	7.86%	Submitted	Submitted	Submitted	Submitted to the verifier
Aluminum Oxide	1.48%	Submitted	Submitted	Submitted	Submitted to the verifier
Glass Frit	0.347%	Submitted	Submitted	Submitted	Submitted to the verifier
Soda ash	0.0109%	Submitted	Submitted	Submitted	Submitted to the verifier
Carboxy methyl cellulose (Veegum - CER)	0.0568%	Submitted	Submitted	Submitted	Submitted to the verifier
Clay-Cellulose blend	2.49%	Submitted	Submitted	Submitted	Submitted to the verifier
Calcium Carbonate	4.89%	Submitted	Submitted	Submitted	Submitted to the verifier
Sodium Carboxymethylcellulose (CMC)	0.217%	Submitted	Submitted	Submitted	Submitted to the verifier
Calcium Sulfate	74.6%	Submitted	Submitted	Submitted	Submitted to the verifier
Calcium Sulfate Hidrated	0.199%	Submitted	Submitted	Submitted	Submitted to the verifier
Zirconium Silicate	4.13%	Submitted	Submitted	Submitted	Submitted to the verifier
Dolomite	0.695%	Submitted	Submitted	Submitted	Submitted to the verifier
Zinc Oxide	0.802%	Submitted	Submitted	Submitted	Submitted to the verifier
Borosilicate	0.348%	Submitted	Submitted	Submitted	Submitted to the verifier

Ceramics manufacturing data for 2023 was collected and compiled for TOTO Mexico. Some raw material data, such as dolomite and kaolin which represent only 2% and 1% respectively in the total raw materials, was not available from TOTO Mexico for 2023; therefore, material data from 2019 was used to model products made at TMX. Among the various casting methods, such as manual bench casting and pressure and bench casting, which are utilized at different TOTO factories, TMX uses bench casting and a similar method referred to a spagless casting.

Non-ceramic parts that are included with the lavatories are the wall bracket and mounting screws. All parts with a weight of >1% weight of the parts (excluding ceramic and packaging materials) are included in the LCA model. A check has been performed to make sure that the completeness of the overall material use is >99.0%wt. of the finished product after cut-off and including the ceramic and packaging materials. A yield loss of 10% for metals and 2% for plastics was assumed. Table 2.3 shows an aggregation of materials that make up the non-ceramic parts of the product that are > 1%. The commercial lavatory products have no materials considered hazardous or toxic according to the TRI or local regulations.

Since data on recycled content was not provided, it was assumed that only primary materials were used and modeled accordingly. This is typically a worst-case scenario which would require an effort to improve future LCA modeling results. A more detailed raw materials definition of the products as required by Part A is presented in Appendix A.

For all manufactured components purchased from suppliers, upstream manufacturing data sets were applied to the raw materials to represent the upstream production of those parts.

The specific level of completeness is listed in Table 2.7.

Table 2.8 Completeness of the parts after 1% weight cut-off of the non-ceramic parts

Product code	%wt covered
LT307R(A)	99.75%
LT569	98.76%

2.4.1.2. Manufacturing

The lavatories at the TMX plant are manufactured as follows:

- Raw materials arrive by diesel truck and are unloaded / stored into silos or designated area.
- The preparation materials, primarily materials that embody the mass of the lavatory, are batched into two different clay slurries called *slip;* the first is *casting slip* and the second is *glazing slip*.
- The casting slip is pumped into molds and a portion of the water is squeezed out, producing the lavatories. While still wet, the body is drilled for installation holes and shaped, and the product is sent to the dryer to be dried.
- The dry product is inspected. Minor defects can often be repaired prior to glazing; however, products with irreparable defects are recycled back into casting slip and placed into the system. Products that pass inspection are then

sprayed with glaze. The water in the glaze absorbs into the dry body and leaves a powder coat of glaze.

- The glazed product is fired in a process called *vitrification* during which organic components in the raw materials are burned out to form CO_2, NO_x, and SO_x and released with exhaust gas stream through wet scrubber to the atmosphere. During vitrification, the pores close up. The glassy raw materials melt and make the body solid and impermeable, and the same materials in the glaze make the surface shiny and hard.
- The fired product is inspected. Products that pass inspection have the fixtures installed and are boxed. Products with defects are repaired and re-fired if possible. Products with irreparable defects are recycled as raw material for construction materials (e.g., tiles) or road bed aggregate.
- Finished products are boxed and shipped to the distribution center for distribution.

For the most part, the casting materials are process aids. Exceptions are soluble salts majorly within the bonding slip, which are applied to the lavatories during casting and do remain as part of the toilet body. However, compared to the rest of the ceramic part, bonding slip is less than 0.02% of total weight.

The process flows for the production stage are presented in Figure 2.

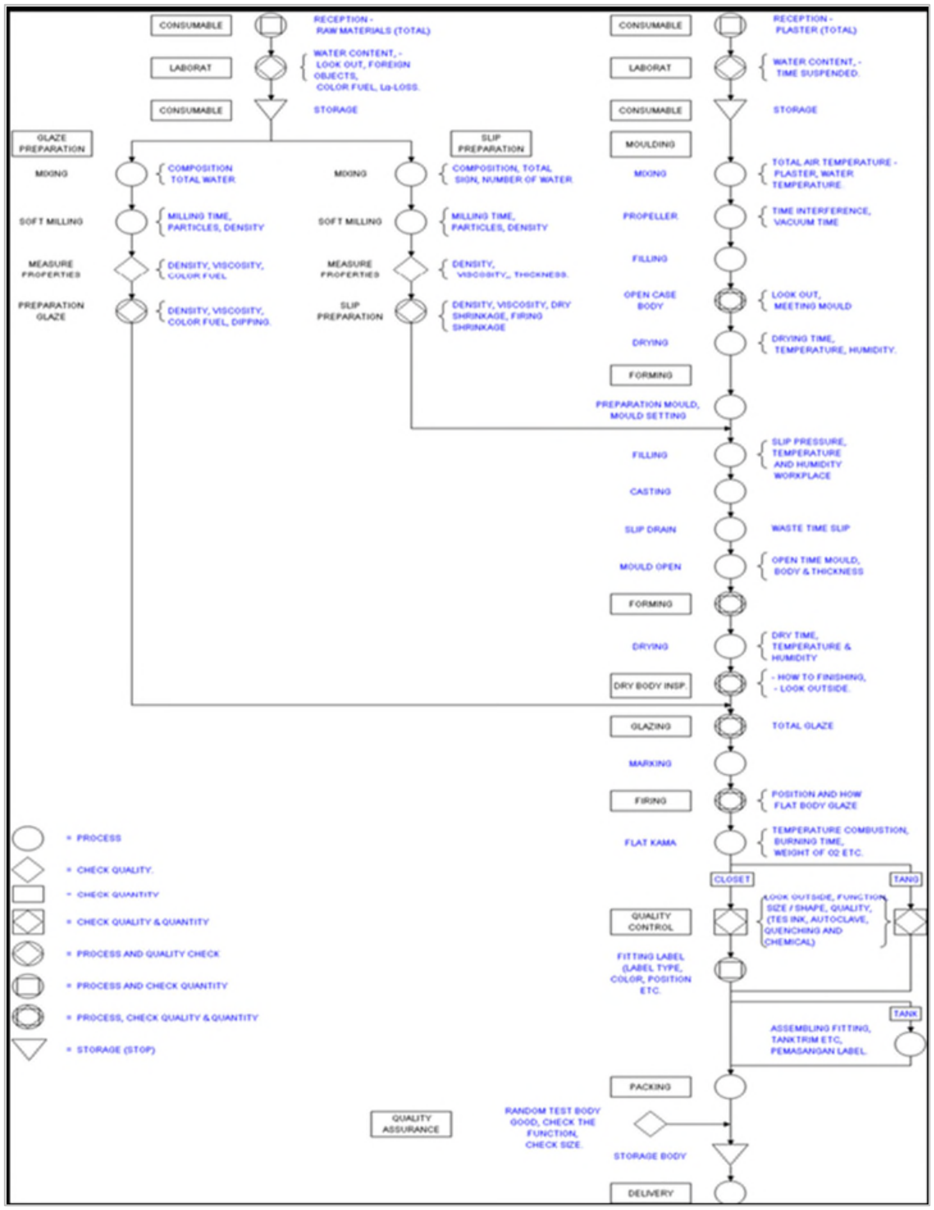


Figure 2. TOTO Ceramics Manufacturing Process Flow

A summary of the plant-wide mass balance calculations for TOTO Mexico in 2023 is provided in Table 2.8a. The sludge, ceramic scrap, pallet scrap, carton scrap, and waste paper mass was not captured well in the data reported by the plant for calendar year 2023; therefore, it was assumed in the model that a higher amount of waste was produced than was reported in order to reflect the amount of raw material inputs provided. Individual inputs and outputs can be viewed in Appendix A.

Table 2.8a Plant-wide mass balance calculation in 2023

Category	Wt.	TOTO Mexico
Raw materials	kg	Submitted to the verifier
Raw materials (excluding loss of ignition)	kg	Submitted to the verifier
Product weight	kg	Submitted to the verifier
Product waste	kg	Submitted to the verifier

In order to allocate manufacturing data to the different products, it is necessary to have insight into the number of ceramic products made in the TMX facility as well as the overall yield percentage of the plant. Overall yield is a composite of production losses at different stages in the manufacturing process. The product-specific overall yield is the percentage of final product compared to raw material input; while total plant overall yield is the average yield percentage for all the products manufactured in the plant (approximately 68.6%). Differences in yield percentages between individual products are due to complexity of the products produced and differences in process (e.g., method of casting). The product-specific overall yield for lavatories is typically higher than the total plant overall yield, since their manufacturing processes are less complex than other products made in the same plant.

All processes are assigned to the final product based on the yields presented in Table 2.8b using the product-specific overall yield and production efficiency, with the exception of natural gas use and associated emissions from the kiln. Natural gas usage and associated kiln emissions are allocated by using the last column, the firing yield.

Production efficiency is the ratio of finished goods to the outgoing goods from the furnace, and it is dependent on the ability to use resources to produce the products in the most effective way possible. It involves balancing speed, quality, and cost while minimizing waste and downtime.

Table 2.8b Product-specific yield percentages and production efficiency for lavatories

Product Yield for TOTO Mexico			
Product code	**[1]Overall yield percentage (during the entire stage)**	**[2]Production efficiency (during the making of lavatories)**	**[3]Firing yield (during the firing process of lavatories)**
LT307R(A)	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
LT569	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier

1) Overall yield percentage (actual yield of sellable finished goods **vs** % of TMX's production target/goal)
2) Production efficiency (during the packaging of lavatories: % of sellable Finished Goods after outgoing inspection and packaging **vs** Goods coming in from manufacturing factory floor)
3) Firing yield (during the firing process of lavatories: % of outgoing goods from furnace **vs** goods in the furnace during manufacturing)

The loss of ignition is an important factor that influences the mass balance. Because water content, crystal water, and organic material in the raw materials are eliminated during the firing process, the ceramic loses mass. Loss of ignition is a good measure for these mass losses. This factor is included in calculating the overall mass balance and is presented in the table below.

Table 2.8c Loss of ignition in 2023

Loss of Ignition	
TMX	Submitted to the verifier

A more detailed description of the modeled processes as required by Part A is presented in Appendix A. The modeling of primary and secondary processes was conducted via the utilization of datasets from Ecoinvent, USLCI, US-Ecoinvent or a modification of them to meet geographical boundaries.

Table 2.8d Primary processes, materials and yield for LT307R(A) and LT569

Primary Process	Material(s)	Average Yield (%)
Injection Molding	Polyurethane	Submitted to the verifier
Casting & molding	Ceramic (porcelain)	Submitted to the verifier
Sheet rolling & extrusion	Steel, SUS, SUS303, SUS304	Submitted to the verifier

Table 2.8e Secondary processes and materials for LT307R(A) and LT569

Secondary and Tertiary Process	Material(s)	Average Yield (%)
Threading	Steel, SUS, SUS303, SUS304	Submitted to the verifier
Polishing	Steel, SUS, SUS303, SUS304	Submitted to the verifier
Turning, Steel, CNC	Steel, SUS, SUS303, SUS304	Submitted to the verifier
Stamping, Steel	Steel, SUS, SUS303, SUS304	Submitted to the verifier

Secondary data for the lavatories are provided in the tables in Appendix A with an asterisk (*).

2.4.1.3. Energy Requirements

The major manufacturing processes were described in section 2.4.1.4. Table 2.9 below provides the energy requirement to produce one kg of ceramic in TOTO Mexico.

Table 2.9 Energy usage for ceramics manufacturing per 1kg of ceramic

Energy Source	Unit	TMX
Electricity from grid	kWh/kg	Submitted to the verifier
Natural gas	Cu.ft./kg	Submitted to the verifier

Electricity for TMX is modeled after the Mexican grid mix using Ecoinvent data. In the manufacturing process, drying takes 30-35 hours, at 140 degrees Fahrenheit (60 degrees Celsius). Firing takes 12-18 hours, with the hottest temperature at 2,200 degrees Fahrenheit (1,200 degrees Celsius). TMX has a new kiln approximately 8 years old which is very efficient due to its newer construction. Generation sources in in Mexico are 44.3% from oil, 39% from natural gas, 5.4% from coal and 5% from Biofuels and waste[1]. Impact factors for this electricity source were created when modeling in SimaPro.

[1] Mexico Facts and Figures 2022 https://www.iea.org/countries/mexico

2.4.1.4. Water consumption

The ceramics manufacturing operation requires the consumption of water. Table 2.10 shows the amount of water per kilogram of ceramic produced per year in TOTO Mexico facility.

Table 2.10 Water usage in ceramics production per kilogram of ceramic

Water usage TMX	
Liters per kg ceramic	Submitted to the verifier

Despite the relatively high water usage, TOTO Mexico's operations attempt to reduce the use of natural resources. For example, over 6,000 gallons of on-site recycled greywater per day are reused in the plant. The remainder of the water is treated and discharged to the public sewer system. TOTO's operations are always evolving in order to find ways to reduce the use of natural resources. For example, programs implemented in TOTO Morrow in the USA casting department (highest water consuming department) resulted in significant reductions in water use. Also, Morrow utilizes roughly 20,000 gallons of on-site recycled greywater per production day, thereby setting a great example for its sister companies.

There is no major additional water consumed resulting from the commercial lavatory assembly process.

2.4.1.5. Environmental outputs

The major air emission during manufacturing from materials is carbon dioxide, coming from natural gas combustion as well as through carbonate decomposition and organic combustion of raw materials during the firing process during ceramics manufacturing. Because the drying and firing temperature is high enough for carbonation, we assume the worst-case scenario that all possible raw materials are carbonated and combusted during the process.

Table 2.11 Air emissions for ceramics manufacturing in 2023 per kg ceramic

Air emission	**Grams per kg of ceramic**
NO_x	Submitted to the verifier
SO_2	Submitted to the verifier
CO	Submitted to the verifier
CO_2	Submitted to the verifier

Wastewater treatment plants treat all wastewater before it is returned to the water authority. Discharged water is tested for various effluents in accordance with local ordinances. Wastewater emissions are listed in the table below:

Table 2.12 Water effluents for ceramics manufacturing in 2023 per kg ceramic

Water effluents	Grams per kg ceramic
Chemical Oxygen Demand	Submitted to the verifier
Total Kjeldahl Nitrogen (TKN)	Submitted to the verifier
Phosphorous matter	Submitted to the verifier
Aluminum	Submitted to the verifier
Copper	Submitted to the verifier
Zinc	Submitted to the verifier
NO3-NO2	Submitted to the verifier
Total Suspended Solids	Submitted to the verifier
Biochemical Oxygen Demand	Submitted to the verifier
Chloroform	Submitted to the verifier
Bis(2-ethylhexyl)phthalate	Submitted to the verifier
Grease & Oil	Submitted to the verifier
Antimony	Submitted to the verifier
Beryllium	Submitted to the verifier
Cadmium	Submitted to the verifier
Chromium	Submitted to the verifier
Lead	Submitted to the verifier

There are no major additional air or water emissions resulting from the commercial lavatory assembly process.

2.4.1.6. Other materials: parts and packaging

Finished products are packaged in carton boxes, most of which contain a top and bottom pad, along with some inserts and stickers. After packing, boxes are stapled, palletized and wrapped with stretch wrap. Because all the stickers and paper are less than 0.1kg, which is less than 1% of total weight, they are not included in the model. The corrugated board that makes up the boxes, pads, and insert are included for each product and are listed in Table 2.3.

The packaged product is ready for transportation to the distribution centers and ultimately to the US market. After the products are packaged, they are sent to the warehouse for final shipment. The boxes are stacked on pallets and wrapped in stretch wrap. The stretch wrap is below the cutoff of 1%wt and impact. The pallets are included based on purchasing data.

2.4.1.7. Transportation

Transportation distances of the components and processing aids were provided by TOTO's purchasing, production, and logistics department. Trucks and ocean freighters are assumed to be diesel-powered. 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. All materials are transported by truck and trailer and are from the Monterrey metropolitan area, with the exception of dolomite, which has a transportation distance of 150 km.

2.4.1.8. Solid waste

Solid waste from TMX includes sludge, ceramic/slip scrap, mold scrap, carton boxes, metal scrap and other wastes. Among them, ceramic/slip scrap, mold scrap and metal scrap can all be reused, and carton box packaging is sent to off-site recycling facilities. All the wastes and their weight as well as their fate are listed below. Sludge, also known as filter cake, refers to the slip and glaze solids removed during the wastewater treatment process. Sludge contains approximately 30-40% water, as measured by samples taken from the plant. The percentage water weight of sludge is not routinely monitored; however, wastewater specialists have measured the content in the past and observe the process every day. They confirmed that the consistency is constant due to the efficiency of the press. The content was measured again for this study in order to verify. Transportation of solid wastes to the sites for treatment is included in the model. It was assumed that all the solid wastes were conveyed by diesel-powered trucks.

Table 2.14 Solid waste from ceramics production per kg ceramic

Solid waste (g per kg of ceramic)	Weight (g)	Fate
Sludge	Submitted to the verifier	Landfill
Wasted gypsum	Submitted to the verifier	Reuse
Ceramic scrap	Submitted to the verifier	Reuse
Slip scrap	Submitted to the verifier	Landfill
Pallet scrap	Submitted to the verifier	83% recycled, others to landfill
Carton scrap	Submitted to the verifier	Recycle
Hazardous waste	Submitted to the verifier	Incineration
Wastepaper	Submitted to the verifier	Recycle
Metal scrap	Submitted to the verifier	Recycle
Waste plastic containers	Submitted to the verifier	Recycle
Waste oil	Submitted to the verifier	Hazardous Landfill

2.4.2. Construction/Installation stage [A4-A5]

The construction process stage includes the following information modules:

- A4: Transport to the building site
- A5: Construction / installation in the building

2.4.2.1. Transportation to site

Both lavatories and their components are packaged at TMX and are shipped directly to TOTO owned distribution centers. The distribution center for products in the report is the Fairburn Assembly Plant (FAP), located in Fairburn, GA (east distribution center). The lavatories from TMX arrive finished and require no further assembly. The distance from Monterrey Mexico to FAP is approximately 2036 miles (3,277 km) via diesel-powered trucks.

After products are purchased by distributors, dealers, and showrooms for purchase by the end users, they are transported from the FAP warehouse to these purchasers. Transportation and distance would vary and are dependent on the locations of the purchasers and shipping mode. Outbound shipments to customers travel via rail and/or diesel truck. In 2023, outbound shipments were transported an average of 883 miles (1,421 km) by diesel truck and an average of 1269 miles (2,042 km) by rail. When factoring the quantity transported by truck and rail (83% and 17% respectively), the weighted average transported distance comes to approximately 949 miles.

TOTO lavatory sourcing data is based on actual 2023 shipment averages. All transportation LCI data comes from the U.S. LCI database.

2.4.2.2. Construction / Installation

After customers purchase the products from distribution centers, they are installed. Other than packaging, which mainly consists of cartons, becoming waste, nothing else is required or removed at this stage. Waste processing of the waste from product packaging up to the end-of-waste state or disposal of final residues is included in this module.

2.4.3. Use stage [B1-B5]

The use stage includes the following information modules:
- B1: Use or application of the installed product
- B2: Maintenance
- B3: Repair
- B4: Replacement
- B5: Refurbishment
- B6-B7: Operational energy and water use

2.4.3.1. Use or application of the installed product

There are no additional activities or construction work needed or associated with the installation of the product during the use phase. Therefore, this module's LCIA is considered to be zero.

2.4.3.2. Maintenance

Maintenance of the lavatories would include regular cleaning.

For the lavatories, the use of 10mL/clean over 260days/year for 75 years gives a total of 195L of solution. Taking a density of 1.01kg/L for a 1% SLS solution, 195kg of solution will be required over the course of 75 years. Hence, 2kg of SLS plus 195kg of water will be required.

Table 2.15 Calculation of cleaning solution used in the use phase

Cleaning Spec	(L)/Use	Time Span for Model (year)	Total Number of Uses	Total Consumption for Life (L)
10 mL 1% SLS/day	0.01	75	19,500	195.00

2.4.3.3. Repair

For lavatories, the service life is defined in such a way that for a typical installation, no repair is required. Repair would be incidental.

2.4.3.4. Replacement

Replacements for the duration of the building estimated service life (ESL) of 75 years for the lavatories are counted proportionally to the nearest tenth of each product category in the report. Hence, 2.75 replacement lavatories are considered in B4 for the 20 RSL years. Replacements must include the sum of impacts from stages A1-A5 and C1-C4 multiplied by the number of replacements.

2.4.3.5. Refurbishment

The service life is defined in such a way that for a typical installation, no refurbishment is required. There is no refurbishment as such included in the model.

2.4.3.6. Operational energy and water use

The use stage related to the operation of the building includes:
- B6: Operational energy use
- B7: Operational water use

The use phase of the modeled products in this report follows the declared default life cycle use phase scenario in the approved Part B of the Sustainable Minds Transparency Framework referenced herein [4].

The report will include the lavatories only, with no integrated faucets or faucets packaged together with them, resulting in no water flow and no water use impacts.

2.4.4. End-of-life stage [C1-C4]

The end-of-life stage includes:
- C1: Deconstruction / demolition
- C2: Transport to waste processing
- C3: Waste processing for reuse, recovery and/or recycling
- C4: Disposal

The lavatories are assumed to have a useful life beyond the 20-year RSL. At the end of life, it is assumed that the products are landfilled. TOTO ceramic and alloy materials can be recycled as aggregate in several applications; however, this is not a common practice at the moment for ceramics. According to the data from the U.S. EPA's Municipal Solid Waste Generation, Recycling, and Disposal in the United States Report for 2018[2], 66.54% of paper and paperboard, 33.8% of the steel, 70.50% of other non-ferrous metals, 15.0% of rubber and 4.47% of plastics in municipal wastes are recycled. All burdens for the landfill of the primary product are assigned to the product system and no credits for energy recovery are given (cut-off, "polluter pays" principle). Secondary materials, including shredded and sorted metal waste used to hold the primary product, are valuable goods that will lose their waste status after the sorting process, and no additional waste processing is needed (e.g., melting); therefore, no credits for material recovery are given.

[4] United States Environmental Protection Agency, Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2018.
https://www.epa.gov/environmental-topics/land-waste-and-cleanup-topics

2.4.4.1. De-construction / demolition stage

At the end of life, de-construction of the products which include their dismantling as well as the initial on-site sorting is assumed to be manual. Therefore, no deconstruction activities were included in the model.

2.4.4.2. Transport to waste processing stage

The transport stage involves the transportation of the discarded products to waste processing either to recycling or to final disposal. The transport stage included in the model is based on the assumption that the product will travel 100 km on a truck either to a landfill as a final disposal or to a recycling site.

2.4.4.3. Waste processing stage

Since 100% of products are assumed to be disposed in a sanitary landfill at the end of life, no waste processing activity is applicable in this stage.

2.4.4.4. Disposal stage

The landfilling of 100% of the products is included in this stage, modeled based on the mass of the different materials in each product.

3 INVENTORY

This chapter includes an overview of the obtained data and data quality that has been used in this study.

3.1 Data categories

The impacts have been inventoried for the following data categories:

- energy inputs
- material inputs
- emissions to air, water and soil
- production of waste and treatment
- produced products

The abovementioned flows are called data categories. They define the scope of the inventory.

3.2 Data selection and quality

Most of the manufacturing data came from primary sources for the calendar year 2023. The production department associated with production data at TOTO Mexico collected all data using electric bills, purchasing orders, TOTO's production volume, data on waste and damaged final products, and production yield and efficiency. TOTO's project managers worked together on collecting data and undergoing a data validation process using mass balances and other calculation methods. No materials, components, emissions or energy flows have been left out, except for minor parts where the primary sources' data was incomplete or contradictory to the average industry data. This follows the general rule that either specific data or average data derived from specific production processes shall be the first choice as outlined in Part A of the Framework. Where products are declared together, weighted averages have been used based on the processes and materials for the individual products.

Materials Data and Modeling. The materials are modeled with facility data compiled from individual departmental data. Data validation/verification was done using the know-how and information on processes, equipment age and efficiency, machine power ratings, site conditions and labor force, electricity consumptions, yield and production efficiency information, production rates, and mass balances. The product was modeled according to the facility where it was manufactured. An overview of used data sources is presented in excel data sheets submitted with the report:

- LCA of TOTO Ceramic Products –Commercial Lavatories Modeling Data and Results 10-2024.xlsx

Product composition data have been provided by TOTO Mexico. Data on composition and manufacturing for upstream and missing data were used and have been supplemented with literature data that is representative for the products on the US market.

Electricity is modeled with country specific grid mixed based on EcoInvent definitions. This relates to the country of manufacturing and the use phase in America. When transforming the inputs and outputs of combustible material into inputs and outputs of energy, the lower caloric value specific to the material was applied based on scientifically accepted values.

This study included products in a standard cotton finish. Products are offered in several different finishes to meet the customers' demands. The results included in this study are intended to represent an average performance for all available options, using a production-weighted average for all models produced in CY2023. Since the differences in finish are due to slight color variations, the variability between the options is assumed to be negligible. These properties are used to calculate the mass reference flow, which was normalized to 1 kg for products with a standard cotton finish.

All manufacturing data used is primary data from the calendar year 2023, with regionally specific data. All background data used to model the LCA is reported in the appendices. Literature data is comprised of the best available data from consistent sources but varies from material to material in geographical, time related and technology coverage due to limited availability of specific data. Data from the EcoInvent database was aimed to be used mostly. However, this does not warrant full consistency between all data sets. Different data can result in differences per material and that can influence the comparison. By using the EcoInvent data, the report follows the data quality in these data sets as they relate to time period coverage. The main criterion for data selection was the technological coverage as to reflect the physical reality of the declared product or product group as closely as possible.

3.3 Limitations

The LCA is limited in the following ways:

- Vendors of raw materials and parts have responded to the request for data and cooperated with the LCA project manager in varying levels. Assumptions listed below originate from the quality of their response. This is the third time the vendors have been contacted with LCA related questions. It is therefore recommended that the vendors be contacted and engaged for future LCA work again and focus on some more details for the most important processes.
- No data on recycled content for any component of the modeled products was provided by vendors. No assumption of secondary material was made even when information was provided informally. This is likely a worst-case scenario. These assumptions need to be revisited in future LCA projects. There is a significant improvement potential for using more recycled content.
- Scenarios have been used for the end-of-life treatment of the materials.
- 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.

- Literature data has been used based on the USLCI database and the Ecoinvent database. With future updates and more and more LCA information becoming available, more representative and less generic data should be used for future LCA projects where possible.
- 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. However, additional variations and deviations are possible. For example, different LCA software and background LCI datasets may lead to different results for the life cycle stages declared.
- The LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

A short summary of the most relevant assumptions that were made is presented here:

- Raw materials in TMX plant are from reported use data inventories.
- Casting materials, inspection materials and installation materials are cut off.
- Maintenance and parts replacement of capital equipment, such as CNC machines, injection machines, mold equipment, etc. was not considered.
- Energy consumption in the warehouses, distribution centers, and retail facilities during the course of transport to the final customer was excluded from the system boundary.
- Transportation via diesel trucks of Kaolin and products from vendors was collected.
- Water content of sludge was measured and reported; however, this measurement not performed routinely.
- General waste treatment data from EPA was used to create waste scenarios of products.
- Pallet use is assumed based on the average numbers per unit of product and reported pallet quantity of specific models.

Data quality is further discussed in Section 5.4 herein.

3.4 Criteria for the exclusion of inputs and outputs

The time period over which inputs to and outputs from the system are 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:

- *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.
- *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.
- *Environmental relevance* – If a flow meets the above criteria for exclusion yet is thought to potentially have a significant environmental impact, it is included. Material flows which leave the system (emissions) and whose environmental impact is greater than 1% of the whole impact of an impact category that has been considered in the assessment have been covered. This judgment is done based on experience and documented as necessary, but also relies on the used literature data.

- 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).

In this report, almost all flows in the primary data for TMX have been reported; therefore, these criteria have been met. The completeness of the bill of materials is reported in the previous chapter and satisfies the above-defined cut-off criteria.

3.5 Allocation

Whenever a system boundary is crossed, environmental inputs and outputs have to be assigned to the different products. Where multi-inputs or multi-outputs are considered, the same applies. Since all lavatory models manufactured in the Mexico facility follow the same manufacturing and assembly process and consume the same amount of resources, annual resources provided for the assembly were evenly distributed based on the physical annual production quantity. No co-product allocations had to be made in the model. When possible, datasets via cut-off approach were used that avoid allocation or substitution. The model used in this report ensures that the sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation. This means that no double counting or omissions of inputs or outputs through allocation is occurring.

3.5.1 Use of secondary materials

In the manufacturing of the products, secondary materials (such as scape metals and metal bars to hold the primary products in place) were partly used for the manufacturing of the primary products but were not considered due to lack of background data in the LCA model. Secondary products and materials could be part of the intermediary products from the upstream supply chain and background datasets used in the LCA model. The specific time coverage of secondary datasets can be found in Table 5.4.2.

3.5.2 Allocation for reuse, recycling and recovery

According to the cut-off, waste content approach, all burdens were attributed to the product system, without giving credits for the energy and material recovery.

Packaging/cardboard waste from up- and downstream processes were assumed to be recycled without giving credits for the energy and thermal recovery.

In the modelling of the end-of-life of the primary products, it was assumed that 100% goes to landfill after the use phase. All burdens for the treatment of waste are assigned to the product system, without giving credits for energy and material recovery.

3.6 Software and database

The LCA model was created using SimaPro Analyst 9.6.0.1. The ecoinvent v3.10, US-EI 2.2 and USLCI databases provided the life cycle inventory data of the raw materials and processes for modeling the products.

4 IMPACT ASSESSMENT

4.1 Impact assessment

The environmental indicators required by the PCR are included as well as other indicators required to use the SM2013 Methodology [5] (see Table 4.1). The impact indicators are derived using the 100-year time horizon[3] factors, where relevant, as defined by TRACI 2.1 classification and characterization [6]. Long-term emissions (> 100 years) are not taken into consideration in the impact estimate. USEtox indicators[4] 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 4.1 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.

[3] The 100 year period relates to the period in which the environmental impacts are modeled. This is different from the time period of the functional unit. The two periods are related as follows: all environmental impacts that are created in the period of the functional unit, are modeled through life cycle impact assessment using a 100 year time horizon to understand the impacts that take place.
[4] USEtox is available in TRACI and at http://www.usetox.org/

With respect to global warming potential, biogenic carbon is included in impact category calculations. Greenhouse gas emissions from land-use change are expected to be insignificant and were assumed to be zero.

A definition of these impact categories is included in Appendix C. During the impact assessment stage of the modeling, the list of life cycle inventory (LCI) indicators for substances that may have not been recognized by the impact assessment methods was reviewed. SimaPro was used to perform the impact assessment.

This 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.

4.2 Normalization and weighting

To arrive to the single score indicator, normalization [7] and weighting [8] as shown in Table 4.2 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 [5].

Table 4.2 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

4.3 Life Cycle Inventory Results: LCI Indicators

Non-hazardous waste is calculated based on the amount of waste generated during the manufacturing, installation, and disposal life cycle stages. There is no hazardous or radioactive waste associated with the life cycle for the lavatories. Additionally, all materials are assumed to be landfilled at the end of life rather than incinerated or reused/recycled, so no materials are available for energy recovery or reuse/recycling. Waste occurs at product end-of-life when it is disposed of in a landfill.

LCI flows were calculated with the help of American Center for Life Cycle Assessment's (ACLCA) guidance to the ISO 21930:2017 metrics [9]. The consumption of freshwater indicator, which was calculated in accordance with this guidance, is reported in compliance with ISO 14046. Abiotic depletion potential was calculated using the CML impact assessment methodology [10]. LCI flows were reported in conformance to ISO 21930:2017 [11].

The biogenic carbon content of bio-based materials was reported per module. CO_2 from calcination and carbonation does not apply to this study. Carbon emissions from combustion arose from bio-based packaging materials going to incineration.

4.3.1. Wall-mount Lavatory (LT307R(A))

Resource use indicators

Parameter	RPRe	RPRm	RPRt	NRPRe	NRPRm	NRPRt	SM	RSF	NRSF	RE	FW	ADPf
Unit	MJ, LHV	MJ, LHV	MJ, LHV	MJ, LHV	MJ, LHV	MJ, LHV	kg	MJ, LHV	MJ, LHV	MJ, LHV	m3	MJ
A1-A3	-9.06E+01	1.57E+02	6.60E+01	7.30E+02	2.18E-01	7.30E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-02	6.30E+02
A4	-3.02E+01	3.04E+01	2.04E-01	7.00E+01	4.24E-02	7.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.80E-04	6.55E+01
A5	-3.04E+01	3.04E+01	9.46E-03	2.41E-01	4.24E-02	2.84E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E-02	2.34E-01
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	-1.52E+01	3.04E+01	1.53E+01	2.03E+02	4.24E-02	2.03E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-04	1.75E+02
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	-3.47E+02	6.08E+02	2.61E+02	4.73E+03	6.46E-01	4.73E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E-04	4.10E+03
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	-2.99E+01	2.99E+01	7.44E-03	3.42E+00	4.24E-02	3.46E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.02E-04	3.21E+00
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	-3.04E+01	3.04E+01	2.73E-02	4.09E+00	4.24E-02	4.14E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.95E-04	3.80E+00
Total	-5.74E+02	9.13E+02	3.43E+02	5.74E+03	1.08E+00	5.74E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.42E-02	4.98E+03

Output flows and waste category indicators

Parameter	HWD	NHWD	HLRW	ILLRW	CRU	MR	MER	EE
Unit	kg	kg	kg	kg	kg	kg	kg	MJ, LHV
A1-A3	2.70E-01	4.70E-01	3.09E-01	5.69E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A4	0.00E+00	1.20E+00	1.30E-05	6.66E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A5	0.00E+00	1.43E+00	4.78E-07	4.31E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	0.00E+00	2.93E+01	7.64E-04	1.72E-06	0.00E+00	2.93E+01	0.00E+00	0.00E+00
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	0.00E+00	7.74E+01	2.61E-01	4.75E-05	0.00E+00	5.33E+01	0.00E+00	0.00E+00
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	0.00E+00	5.40E-01	6.72E-07	6.43E-09	0.00E+00	2.09E+00	0.00E+00	0.00E+00
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	0.00E+00	1.87E+01	2.16E-06	1.06E-08	0.00E+00	2.09E+00	0.00E+00	0.00E+00
Total	2.70E-01	1.30E+02	5.71E-01	1.06E-04	0.00E+00	8.67E+01	0.00E+00	0.00E+00

Carbon emissions and removals

Parameter	BCRP	BCEP	BCRK	BCEK	BCEW	CCE	CCR	CWNR
Unit	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2
A1-A3	0.00E+00	0.00E+00	1.74E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A5	0.00E+00	0.00E+00	0.00E+00	1.74E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	0.00E+00	0.00E+00	4.79E+00	4.79E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	6.53E+00	6.53E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

4.3.2. Undercounter Lavatory (LT569)

Resource use indicators

Parameter	RPRe	RPRm	RPRt	NRPRe	NRPRm	NRPRt	SM	RSF	NRSF	RE	FW	ADPf
Unit	MJ, LHV	MJ, LHV	MJ, LHV	MJ, LHV	MJ, LHV	MJ, LHV	kg	MJ, LHV	MJ, LHV	MJ, LHV	m3	MJ
A1-A3	-1.20E+02	1.57E+02	3.68E+01	3.09E+02	2.18E-01	3.09E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-02	2.67E+02
A4	-3.03E+01	3.04E+01	8.62E-02	2.95E+01	4.24E-02	2.95E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.29E-04	2.76E+01
A5	-3.04E+01	3.04E+01	5.62E-03	1.26E-01	4.24E-02	1.69E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E-04	1.39E-01
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	-1.52E+01	3.04E+01	1.53E+01	2.03E+02	4.24E-02	2.03E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-04	1.75E+02
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	-4.49E+02	6.08E+02	1.59E+02	2.32E+03	6.46E-01	2.32E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.61E-03	2.01E+03
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	-2.99E+01	2.99E+01	3.13E-03	1.41E+00	4.24E-02	1.46E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.27E-04	1.35E+00
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	-3.04E+01	3.04E+01	9.59E-03	1.41E+00	4.24E-02	1.45E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-04	1.34E+00
Total	-7.05E+02	9.13E+02	2.12E+02	2.86E+03	1.08E+00	2.86E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.36E-02	2.48E+03

Output flows and waste category indicators

Parameter	HWD	NHWD	HLRW	ILLRW	CRU	MR	MER	EE
Unit	kg	kg	kg	kg	kg	kg	kg	MJ, LHV
A1-A3	-1.20E+02	-3.03E+01	-3.04E+01	0.00E+00	-1.52E+01	0.00E+00	-4.49E+02	0.00E+00
A4	1.57E+02	3.04E+01	3.04E+01	0.00E+00	3.04E+01	0.00E+00	6.08E+02	0.00E+00
A5	3.68E+01	8.62E-02	5.62E-03	0.00E+00	1.53E+01	0.00E+00	1.59E+02	0.00E+00
B1	3.09E+02	2.95E+01	1.26E-01	0.00E+00	2.03E+02	0.00E+00	2.32E+03	0.00E+00
B2	2.18E-01	4.24E-02	4.24E-02	0.00E+00	4.24E-02	0.00E+00	6.46E-01	0.00E+00
B3	3.09E+02	2.95E+01	1.69E-01	0.00E+00	2.03E+02	0.00E+00	2.32E+03	0.00E+00
B4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	1.28E-02	3.29E-04	1.87E-04	0.00E+00	1.57E-04	0.00E+00	9.61E-03	0.00E+00
C2	2.67E+02	2.76E+01	1.39E-01	0.00E+00	1.75E+02	0.00E+00	2.01E+03	0.00E+00
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	1.57E+02	3.04E+01	3.04E+01	0.00E+00	3.04E+01	0.00E+00	6.08E+02	0.00E+00
Total	1.57E+02	3.04E+01	3.04E+01	0.00E+00	3.05E+01	0.00E+00	6.08E+02	0.00E+00

Carbon emissions and removals

Parameter	BCRP	BCEP	BCRK	BCEK	BCEW	CCE	CCR	CWNR
Unit	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2
A1-A3	0.00E+00	0.00E+00	1.07E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A5	0.00E+00	0.00E+00	0.00E+00	1.07E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	0.00E+00	0.00E+00	2.94E+00	2.94E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	4.01E+00	4.01E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

- [RPRE - Renewable primary energy used as energy carrier (fuel)];
- [RPRM - Renewable primary resources with energy content used as material];
- [NRPRE - Non-renewable primary resources used as an energy carrier (fuel)];
- [NRPRM - Non-renewable primary resources with energy content used as material];
- [SM - Secondary materials];
- [RSF - Renewable secondary fuels];
- [NRSF - Non-renewable secondary fuels];
- [RE - Recovered energy];
- [FW - Use of net fresh water resources]
- [HWD - Hazardous waste disposed];
- [NHWD - Non-hazardous waste disposed];
- [HLRW - High-level radioactive waste, conditioned, to final repository];
- [ILLRW - Intermediate- and low-level radioactive waste, conditioned, to final repository];
- [CRU - Components for re-use];
- [MR - Materials for recycling];
- [MER - Materials for energy recovery];
- [EE - Exported energy];
- [BCRP - Biogenic Carbon Removal from Product];
- [BCEP - Biogenic Carbon Emission from Product];
- [BCRK - Biogenic Carbon Removal from Packaging];
- [BCEK - Biogenic Carbon Emission from Packaging];
- [BCEW - Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes];
- [CCE - Calcination Carbon Emissions];
- [CCR - Carbonation Carbon Removals];
- [CWNR - Carbon Emissions from Combustion of Waste from Non- Renewable Sources used in Production Processes]
- [ADPf - Abiotic Depletion Potential, fossil]

5 INTERPRETATION

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

5.1 Wall-Mount Lavatory (LT307R(A))

Cradle-to-gate

Figure 3 shows the results for the finished product. It shows that the ceramic parts dominate the material contribution except for ecotoxicity, non-carcinogenics and eutrophication. These categories are more impacted by stainless steel, the extrusion and turning manufacturing process of steel, and/or truck transport. Stainless steel and truck transport also have a relevant impact on all other categories, except ozone depletion. Corrugated board has a significant contribution to the eutrophication category, while stainless steel has the greatest impact on the carcinogenics category. The paper used for this product has very little impact on each category. The injection molding process has a significant contribution to the ozone depletion impact category.

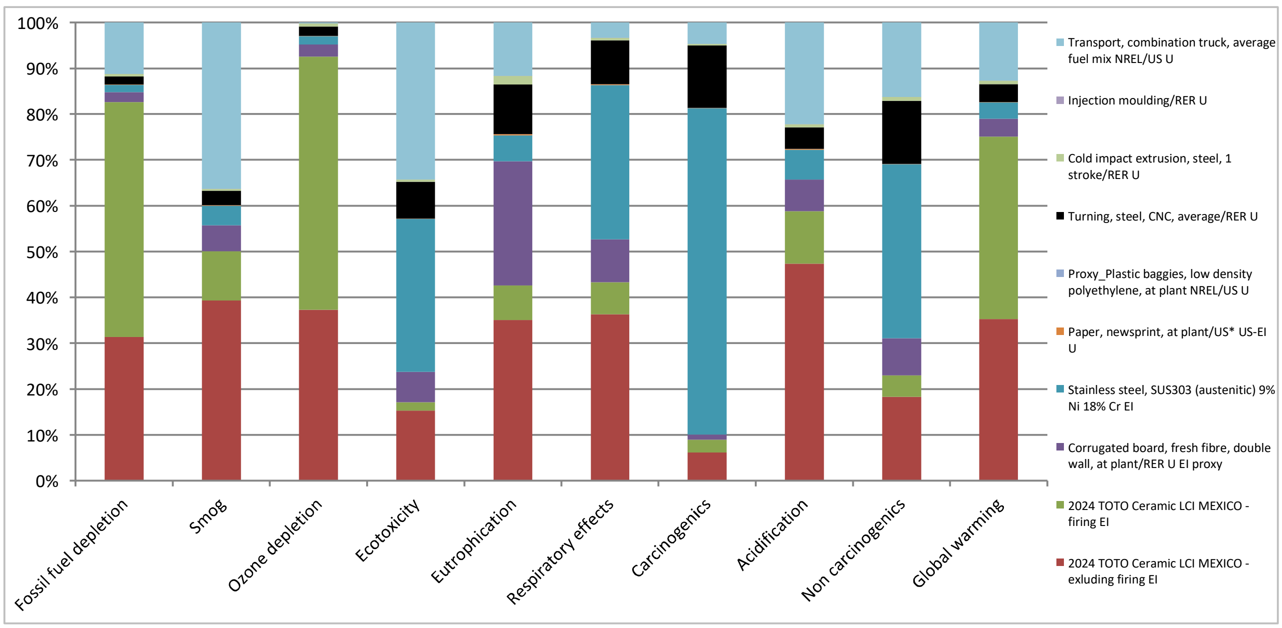


Figure 3. Cradle-to-gate impacts for average of LT307R(A)– relative results

Full life cycle

Figure 4 and Tables 5.1a-c show the results for the full life cycle of the product. While the product itself [A1-A3] is significant in all impact categories, the use phase, which includes the 2.75 replacements [B4] to meet the 75-year estimated service life (ESL), is highly dominating in all categories. For the use phase, the significant contribution is solely due to the cleaning agents required for maintenance [B2]. The product itself [A1-A3] has a significant contribution to ozone depletion and carcinogenics, and a relatively significant contribution to global warming and fossil fuel depletion. The replacements [B4] needed during the 75 years of the building's life have the most significant contributions to all categories, followed by A1-A3, which contributes fossil fuel depletion (mostly defined by crude oil, and natural gas extraction activities as well as production and processing of stainless steel and corrugated boards for packaging and spacers), non-carcinogenics (mostly defined by stainless steel production and processing and transportation by diesel trucks from Mexico to the state of Georgia as well as the natural gas used at the kiln and the disposal of hard coal ash) and ecotoxicity (mainly caused by electricity production and manufacturing of stainless steel using natural gas and crude oil as well as the disposal of slags and hard coal ash). The contribution of the delivery and installation of the product [A4-A5] which are covered under the construction stage is associated with the transportation for delivery to the market and the disposal of packaging materials which are mainly corrugated cardboard.

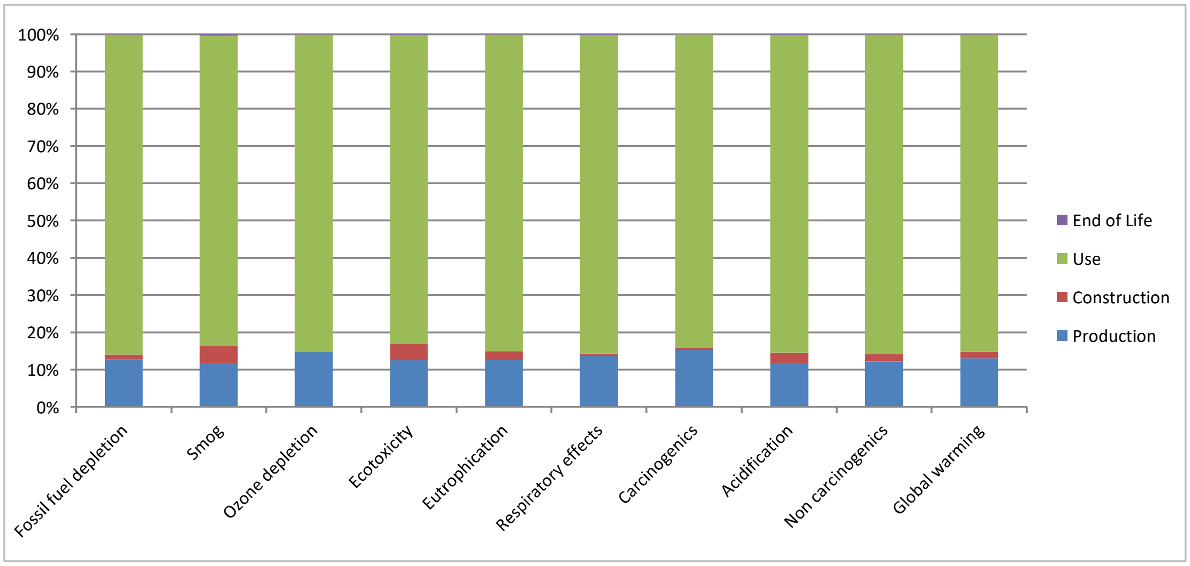


Figure 4. LCIA results for LT307R(A)– relative results

The results above shall reflect the production data at TMX and transportation distance from the multiple suppliers for each mode of transport used.

Table 5.1a LCIA results for Wall-Mount Lavatory LT307R(A)

Parameter	Smog	Ozone depletion	Eutrophication	Respiratory effects	Acidification	Global warming
Unit	kg O3 eq	kg CFC-11 eq	kg N eq	kg PM2.5 eq	kg SO2 eq	kg CO2 eq
A1-A3	2.35E+00	5.72E-06	1.66E-02	1.41E-02	1.34E-01	4.24E+01
A4	8.90E-01	5.92E-09	1.96E-03	6.92E-04	3.22E-02	5.28E+00
A5	1.98E-03	2.67E-09	1.13E-03	1.42E-05	1.75E-04	7.32E-01
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	3.76E-01	4.95E-07	4.83E-03	3.73E-03	4.33E-02	7.79E+00
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	1.62E+01	3.27E-05	1.07E-01	8.41E-02	9.23E-01	2.69E+02
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	4.09E-02	4.52E-10	9.24E-05	2.22E-05	1.42E-03	2.57E-01
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	3.19E-02	5.87E-08	1.14E-04	1.18E-04	1.12E-03	1.54E-01
Total	1.99E+01	3.90E-05	1.32E-01	1.03E-01	1.14E+00	3.25E+02

SM results

The SM millipoint scores per functional unit by life cycle phase for this product are presented below (Tables 5.1b). They confirm the trends in the results using the impact assessment results prior to normalization and weighting.

Table 5.1b SM millipoint scores for Wall-Mount Lavatory LT307R(A) by life cycle phase – absolute results

Impact category	Unit	Total	PRODUCTION (A1-A3)	CONSTRUCTION (A4-A5)	USE (B1-B7)	END OF LIFE (C1-C4)
SM single figure score	mPts	34.3	4.94	0.48	29.6	0.04

Additional LCIA impact categories are reported as additional environmental information.

Table 5.1c: Additional Environmental Information: Wall-Mount Lavatory LT307R(A)

Parameter	Fossil fuel depletion	Ecotoxicity	Carcinogenics	Non carcinogenics
Unit	MJ surplus	CTUe	CTUh	CTUh
A1-A3	8.48E+01	3.85E+01	1.60E-06	4.27E-06
A4	9.15E+00	1.29E+01	7.25E-08	6.90E-07
A5	3.01E-02	1.77E-02	3.41E-10	3.47E-09
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	2.27E+01	3.82E+00	1.59E-07	1.56E-06
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	5.52E+02	2.48E+02	8.42E-06	2.81E-05
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	4.54E-01	6.32E-01	3.55E-09	3.31E-08
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	5.35E-01	5.79E-02	1.58E-09	8.30E-09
Total	6.69E+02	3.04E+02	1.03E-05	3.47E-05

5.2 Undercounter Lavatory (LT569)

Cradle-to-gate

Figures 5 illustrate the results per functional unit for the undercounter lavatory, LT569 manufactured at TOTO Mexico. The ceramic parts dominate all impact categories, with the exception of ecotoxicity, eutrophication, carcinogenics, and non-carcinogenics. Truck transport is relevant to all categories except ozone depletion. Stainless steel is a significant contributor to ecotoxicity, carcinogenics, non-carcinogenics, and respiratory effects. The plasticated board is also relevant to most impact categories, especially eutrophication. Turning and the extrusion of steel for mounting hardware are somewhat relevant to many of the impact categories, especially carcinogenics, non-carcinogenics, and respiratory effects. The plastic bag manufacturing process used for this product has very little impact to each category. Paper production process has less significant contribution to the impact categories while stainless steel have the most significant contribution to the carcinogenics.

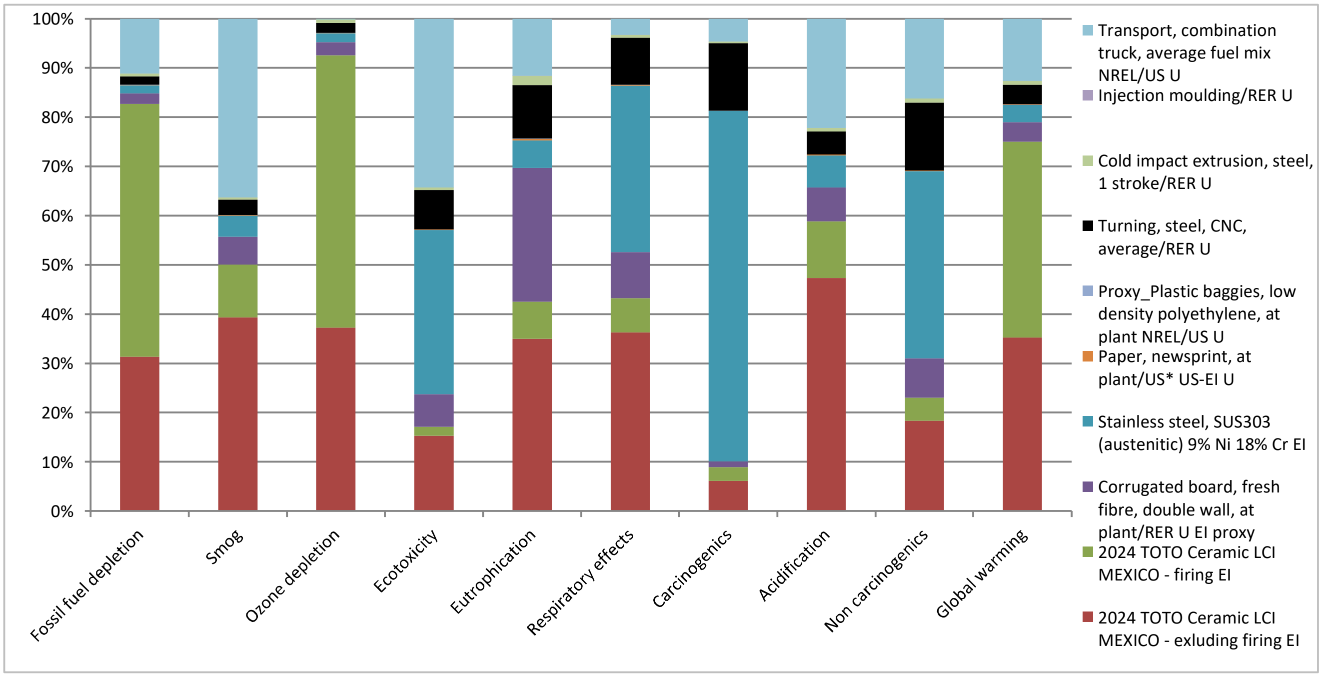


Figure 5. Cradle-to-gate impacts for Undercounter Lavatory (LT569) – relative results

Full life cycle

Figures 6 shows the results per functional unit for the full life cycle of the product. While the product itself [A1-A3] is significant in all impact categories, the use phase, which includes the 2.75 replacements [B4] to meet the 75-year estimated service life (ESL), is highly dominating in all categories. For the use phase, the significant contribution is solely due to the cleaning agents required for maintenance [B2] of the product. The replacements [B4] needed during the 75 years of the building's life have the most significant contributions to all categories, followed by A1-A3, which contributes fossil fuel depletion (mostly defined by crude oil, and natural gas extraction activities as well as transportation from Mexico by trucks and manufacturing process of steel), non-carcinogenics (mostly defined by stainless steel production and processing of corrugated board as well as the natural gas used at the kiln and the disposal of hard coal ash), and ecotoxicity (mainly caused by transportation by diesel trucks, electricity production using natural gas and crude oil as well as the disposal of slags and hard coal ash and stainless steel production and processing). The impacts for the product itself [A1-A3] are discussed above in the cradle-to-gate section. The installation of the product [A5] is associated with the disposal of packaging materials, which are mainly corrugated cardboard and spacers, and is relevant in almost all of the impact categories. Additionally, the delivery and the processes for dismantling and final waste treatment [C1-C4] of the product are slightly relevant in the majority of the impact categories.

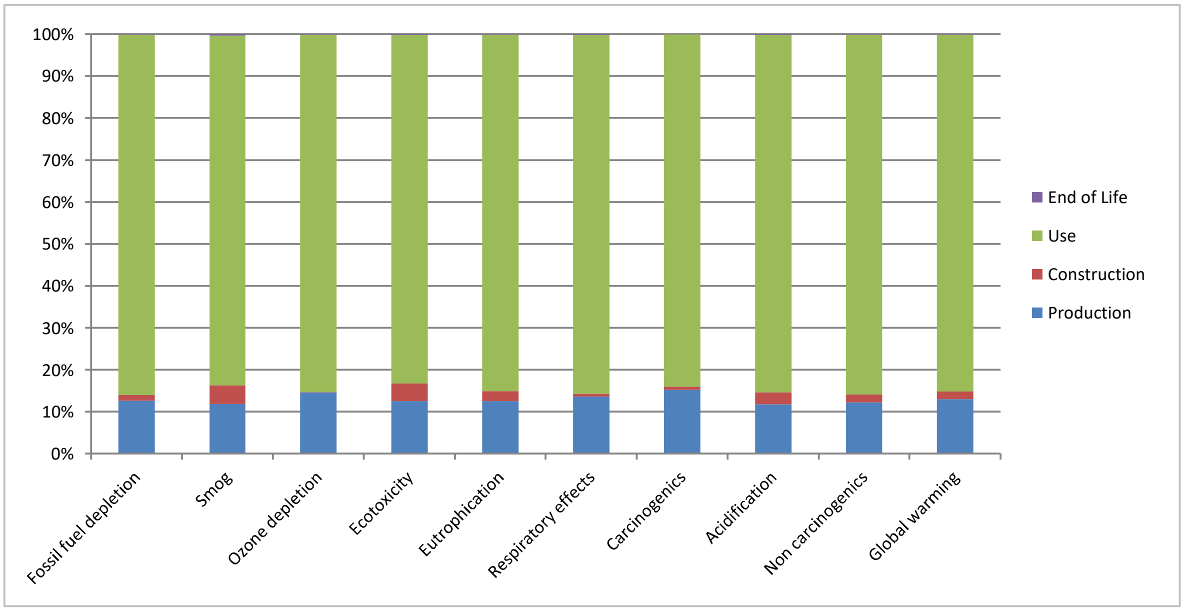


Figure 6. LCIA results for Undercounter Lavatory (LT569) -- relative results

Table 5.2a LCIA results for Undercounter Lavatory (LT569)

Parameter	**Smog**	**Ozone depletion**	**Eutrophication**	**Acidification**	**Respiratory effects**	**Global warming**
Unit	kg O3 eq	kg CFC-11 eq	kg N eq	kg SO2 eq	kg PM2.5 eq	kg CO2 eq
A1-A3	1.03E+00	2.37E-06	7.56E-03	5.84E-03	5.75E-02	1.80E+01
A4	3.75E-01	2.49E-09	8.28E-04	2.92E-04	1.36E-02	2.23E+00
A5	1.18E-03	1.58E-09	6.73E-04	8.47E-06	1.04E-04	4.35E-01
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	3.76E-01	4.95E-07	4.83E-03	3.73E-03	4.33E-02	7.79E+00
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	7.57E+00	1.43E-05	5.53E-02	4.05E-02	4.62E-01	1.26E+02
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	1.72E-02	1.90E-10	3.89E-05	9.33E-06	5.98E-04	1.08E-01
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	1.12E-02	2.06E-08	4.00E-05	4.14E-05	3.93E-04	5.42E-02
Total	9.38E+00	1.72E-05	6.93E-02	5.04E-02	5.77E-01	1.55E+02

SM results

The SM millipoint scores per functional unit by life cycle phase for this product are presented below (Tables 5.2b). They confirm the trends in the results using the impact assessment results prior to normalization and weighting.

Table 5.2b SM millipoint scores for Undercounter Lavatory (LT569) by life cycle phase – absolute results

Impact category	Unit	Total	PRODUCTION (A1-A3)	CONSTRUCTION (A4-A5)	USE (B1-B7)	END OF LIFE (C1-C4)
SM single figure score	mPts	15.6	2.00	0.21	13.7	0.02

Additional LCIA impact categories are reported as additional environmental information.

Table 5.2c Additional Environmental Information: Undercounter Lavatory (LT569)

Parameter	Fossil fuel depletion	Ecotoxicity	Carcinogenics	Non carcinogenics
Unit	MJ surplus	CTUe	CTUh	CTUh
A1-A3	3.60E+01	1.64E+01	6.22E-07	1.78E-06
A4	3.86E+00	5.44E+00	3.06E-08	2.91E-07
A5	1.79E-02	1.05E-02	2.03E-10	2.06E-09
B1	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B2	2.27E+01	3.82E+00	1.59E-07	1.56E-06
B3	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B4	2.70E+02	1.12E+02	3.57E-06	1.43E-05
B5	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C2	1.91E-01	2.66E-01	1.49E-09	1.39E-08
C3	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C4	1.88E-01	2.04E-02	5.54E-10	2.92E-09
Total	3.32E+02	1.38E+02	4.39E-06	1.79E-05

5.3 Sensitivity analysis

Part A mandates that a sensitivity analysis must be performed using the highest and lowest values for the most important choices and assumptions to check the robustness of the results of the LCA. However, given that this study adheres strictly to the system boundary and scoping requirements as set forth in the PCR, no additional sensitivity analysis of the system boundary is justified.

5.4 Data quality

5.4.1 Data quality requirements

Secondary datasets utilized in the model are disclosed in Appendix A along with data quality indicators related to the geographic, temporal, and technological coverage of the dataset. Additionally, details on proxies are provided, if applicable.

Geographic Coverage

The geographical scope of the manufacturing portion of the life cycle is in Table 5.4.1.

Table 5.4.1: Products and their manufacturing locations

Product Names		Product Numbers	Plant	Location
1	Wall-Mount Lavatory	LT307R(A)	TMX	Monterrey, Mexico
2	Undercounter Lavatory	LT569		

All primary data was collected from the manufacturers. The geographic coverage of primary data is considered excellent. The geographical scope of the raw material acquisition is international.

In selecting secondary data (i.e., components data from suppliers), priority was given to the accuracy and representativeness of the data. When available and deemed of significant quality, country-specific data was used. However, priority was given to technological relevance and accuracy in selecting secondary data. This often led to the substitution of regional and/or global data for country-specific data. The geographical coverage of secondary datasets can be referenced in the dataset references table in Appendix A. Overall geographic data quality is considered good.

Time Coverage

Primary data was provided by the manufacturer and represents all information for calendar year 2023 with the exception of some raw materials making up less than 3% of the total composition, which used primary data from calendar year 2019. Using this data meets the PCR requirements. Time coverage of this primary data is considered excellent. Data necessary to model cradle-to-grave unit processes were sourced from SimaPro v9.6.0.1. Time coverage of the secondary datasets ranges from 2012 to 2023 and is considered good. Data sets older than 10 years were chosen because the closest represent the technology used to manufacture the material and are assumed to be more accurate than other potential proxies with more precise geography and temporal representativeness. The specific time coverage of secondary datasets can be found in Table 5.4.2.

Technological Coverage

Primary data provided by the manufacturers is specific to the technology the company uses in manufacturing their product. It is site-specific and considered good quality. It is worth noting that the energy and water used in manufacturing the product includes overhead energy such as lighting, heating, and sanitary use of water. Sub-metering was not available to extract process-only energy and water use from the total energy use. Sub-metering would improve the technological coverage of data quality. Data necessary to model cradle-to-grave unit processes were sourced from SimaPro. Technological coverage of the datasets is considered good relative to the actual supply chain of the manufacturer. While improved life cycle data from suppliers would improve technological coverage, the use of lower-quality generic datasets does meet the goal of this LCA.

Treatment of Missing Data

Primary data were used for all manufacturing processes. Whenever available, supplier data was used for raw materials used in the production process. When primary data did not exist, secondary data for raw material production were obtained from the SimaPro database, as shown in Table 5.4.2. Any proxies used for raw materials have also been detailed in Table 5.4.2.

Data Quality Assessment

Appendix A shows an assessment for the data quality of all secondary processes included in the model. The following sections provide details on the data quality of the model itself.

Precision

The precision of the data is considered high. Product engineers provided detailed bills of materials, and facility managers provided utility information for the TMX manufacturing facility. The raw material transportation distances were calculated based on the raw material manufacturers' addresses, extracted from the relevant SDSs. Proxy datasets were utilized in the LCA model when secondary data were not available, as shown in Table 5.4.2. Precision can be increased via sub-metering individual manufacturing processes to better account for manufacturing processes rather than including overhead utility information.

Adjustments to the background data used in the model were made to improve the accuracy of the data sets. Tap water consumption was modified to reflect the average electricity usage per gallon of water consumed during production as per the PCR. For some data sets, US data was used where possible to represent production in North America in order to be representative of production in Mexico.

Completeness

The data included is considered complete. The LCA model included all known material and energy flows. As pointed out in that section, no known flows above 1% were excluded and the sum of all excluded flows totals less than 5%, whether evaluated by mass, energy, or potential environmental impact.

Consistency

The consistency of the model is considered high. The bills of materials provided by the product engineers were developed for multiple internal departments' use and are maintained regularly. The LCA practitioner also cross-referenced the installation documents and other relevant information to ensure consistency. Furthermore, modeling assumptions were consistent across the model, with preference given towards SimaPro data, where available.

Reproducibility

This study is considered reproducible. Descriptions of the data and assumptions through this report would allow a practitioner to utilize the LCA tool to generate results for the products.

Uncertainty

Uncertainty for the secondary datasets is discussed in the documentation published by Ecoinvent for the SimaPro LCI database. The uncertainty of the primary data comes from the utility data allocated to each product. The yearly total energy use changes over time due to more efficient operations, warmer or cooler seasons and other factors. Because energy data comes directly from utility bills, the uncertainty is mainly based on the accuracy of the utility meters. The allowable error for a water meter remaining in service can be varied from 4% to 7% in the manufacturing countries. For watthour meters and gas meters, the allowable error can be varied from 2% to 6%.

Table 5.4.2 Key datasets used in inventory analysis

Dataset	Source	Year of Last Update	Time Coverage	Geographical Coverage	Technological Coverage	Overall Representatives	Relevant Module	Description
*Stainless steel, SUS303 (austenitic) 9% Ni 18% Cr US-EI China	Ecoinvent	2023	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
**China clay, Kaolin KTcast A/F US-EI 2.2	Ecoinvent	2023	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Silica sand, at plant/US US-EI U	Ecoinvent	2023	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Feldspar, at plant/RER S	Ecoinvent	2023	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
**Limestone, milled, packed, at plant/US* US-EI U	Ecoinvent	2023	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
*Corrugated board, fresh fibre, double wall, at plant/RER U US-EI 2.2	USLCI	2021	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
**Dolomite, milled, loose US-EI 2.2	USLCI	2012	within 12-year period	US	Appropriate technology	good[1]	A1-A3	Raw materials
**Tap water, at user/US-US-EI U	Ecoinvent	2023	within 10-year period	US	Appropriate technology	Good; technologic proxy	A1-A3	Raw materials
**Polypropylene, granulate, at plant/US-US-EI U	USLCI	2012	within 12-year period	US	Appropriate technology	good[1]	A1-A3	Raw materials
*Electricity, low voltage, at grid, Mexico US-EI 2.2	USLCI	2020	within 10-year period	Mexico	Appropriate technology	good	A1-A3	Energy
*Heat, natural gas, at boiler modulating <100kW/RER S	USLCI	2020	within 10-year period	Mexico	Appropriate technology	good	A1-A3	Energy
*Transport, combination truck, average fuel mix NREL/US U	USLCI	2021	within 10-year period	Mexico	Appropriate technology	good	A4	Transport
*Transport, lorry >16t, fleet average/RER S	USLCI	2021	within 10-year period	Mexico	Appropriate technology	good	A4	Transport

* Contributed 5% or more to the total results for the impact categories.
**Contributed 2-4% to the total results for the impact categories.

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

5.4.2 Discussion on data quality

Life cycle assessment (LCA) requires accurate, relevant, and representative data to ensure the credibility of results. The quality of data used in an LCA can significantly influence the outcomes, making it crucial to understand the sources, reliability, and appropriateness of the data employed.

Primary Data: This refers to original data collected directly from the source, specific to the processes or products being assessed, which includes the specific data for the energy intensity of manufacturing or material used for a single process or component.

Secondary Data: These are data obtained from existing sources, such as literature, the USLCI database and the US-ecoinvent database, and previous studies. While they might not be specific to the exact processes or products in question, they can be adjusted and tailored to fit the requirements of the current LCA.

The study faced challenges in accessing primary data for all upstream processes, particularly regarding the specific energy intensity or material used. However, based on a comprehensive materials teardown and other primary product data from the main plant and some suppliers, an accurate and detailed bill of materials (BOM) could be compiled.

In the absence of primary process data, the following steps were taken to ensure the robustness of the LCA model:

1. **Use of secondary datasets**: Secondary datasets were sourced from respected the USLCI database and the US-ecoinvent database. These databases contain aggregated data from multiple studies and are a credible source of industry averages.

2. **Adjustment to fit specifications:** Recognizing that secondary data may not perfectly match the component specifications, adjustments were made to these data sets and documented in detail for the unit processes. Adjustments were based on known relationships, scaling factors, or other relevant parameters to ensure that the data were as close as possible to the specific components. Using secondary data with adjustments offers a pragmatic approach to address data gaps. However, it's important to recognize that:
    - There's an inherent level of uncertainty associated with using adjusted secondary data.
    - The results should be interpreted with caution, especially when making direct comparisons or drawing definitive conclusions.
    - Further studies or updates to this LCA could benefit from more specific primary data, if available in the future.

Data collection and calculation procedure

Depending on availability and relevance, different data collection methods are used to specify the product system and related processes, which is described as a multi-stage process in Figure 7 below.

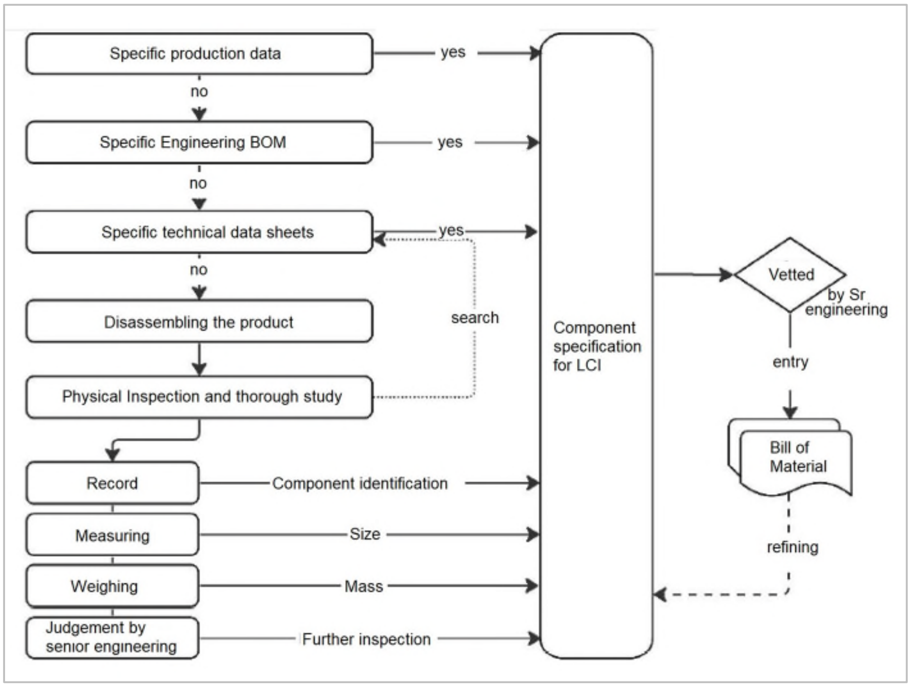


Figure 7. Data collection procedure

The data collection has two main objectives: The first is to describe the product system as completely as possible (e.g. mass, number of components, component types and materials, etc.). The second is to collect as much primary data as possible on the origin and production methods of the various components, or to make plausible approximations that will later allow modelling that is as granular and accurate as possible. As the availability of primary data is relatively scarce or not always accessible to the LCA manager or OEM (i.e. confidentiality, lack of supplier data, etc.), TOTO applies a multi-stage collection procedure which combines already available information (e.g. technical datasheets, BOMs, etc.) with dedicated technical analysis (e.g. disassembling, cutting, measuring, etc.).

All data collection is consolidated into a comprehensive Bill of Material (BOM) for the entire product system (including all components, packaging, etc.), where each data point is given unique identifiers, Source and Type, as can be noted in the Excel data sheet, to ensure seamless documentation and appropriate modelling. The consolidated BOM list as part of the LCA documentation is confidential and will not be published but may be viewed by authorized third parties upon request (submitted during verification to NSF).

The manufacturing phase was modelled on the basis of technical information from TOTO Mexico and its suppliers and an analysis of the actual components. For some modules, a bill of materials was provided by TOTO Mexico and the manufacturers of the various components. In addition, a complete disassembling of the product was undertaken to further specify components and fill data gaps. The product was first disassembled into its various modules. Wherever possible, these modules were subsequently disassembled into their different components and material fractions. If possible, all components and materials where specified according to their type, quantity, material, mass, size, finishing and other relevant information (e.g., part numbers or labels).

When visual inspection was unclear or impossible for the LCA manager, expert judgment (i.e., senior engineering team in the US and Japan) and additional literature searches were conducted to gather modeling data.

Discussion of the role of excluded elements
This study followed the completeness criteria stated in Section 2.4.1.1 herein. Small amounts of input materials have not been included based on the mass criteria. These materials were identified and evaluated on the environmental relevance and are deemed to have a negligible impact on the results of the LCA as the main driver of impacts of the modeled products is ceramics.

Discussion of the precision, completeness and representativeness of data
Not all vendors have responded to the level of detail as the request for data entailed. For example, vendors chose to fill their own bills of materials giving little insight to the LCA manager as to how data was calculated. The LCA manager used back calculations and mass balance calculations in order to assure data was plausible, consistent and complete.

Raw materials vendors refused to cooperate with the LCA practitioner because they had strict confidentiality and proprietary policy. This report used literature data where supplier data was not made available based on the USLCI database and the US-ecoinvent database. With future updates and more and more LCA information becoming available, more representative and less generic data should be used for future LCA projects where possible. The impact of this limitation could be relevant as it relates to recycled content, yield and processing energy which are relevant drivers of the LCA results. It is recommended that vendors should be contacted and engaged for future LCA work especially as TOTO moves towards a more integrated People, Planet, Profit strategy. Another example is that no data on the recycled content of the components of the modeled products was provided. The LCA manager made no assumption in that regard and assumed the worst-case scenario in that all materials were primary.

Discussion related to the impact of value judgments
The Sustainable Minds indicator expressed in millipoints is a part of the reporting requirements. It is important to note, however, that the indicator is not only based on scientific impact assessment and normalization, but also on weighting which is based on expert judgment. This last step is a value judgment and can change between different experts and will likely change over time since environmental priorities change over time. This change is not annual but rather it takes a decade. With the limited validation of any LCA and the 5-year validity of a Transparency Report [EPD]™, any changes in these value judgments will be reflected in future updates.

5.5 Recommendations

During the process of compiling this report with the help of many TOTO employees, an insight into the environmental performance of a selection of TOTO products was gained. Additionally, the major contributions and differences were also learned.

Based on these insights we make the following recommendations to TOTO subsidiaries and team members:

- Create a process for LCI data collection for the manufacturing processes onsite and at other manufacturing facilities. This should streamline the data collection for all TOTO facilities, defining the primary sources for the data, and alignment of the reported data. There is a need for better processing data, like energy consumption and yield. One topic within this is the amount of recycled content which provides an opportunity for environmental performance improvement.
- Evaluate improvement options for the major contributions against required investments to drive down in the impact. Good candidates are the recycled content of the material input, the energy efficiency of the firing kiln, electricity use, sourcing for the manufacturing processes, and product yield.
- Evaluate the use of on-site sourced water or 100% water recycling process. A review of technologies, validated with LCA, can help TOTO USA and her sister subsidiaries have a better positioning in the local and global market as being socially and environmentally responsible beyond using less water to actually eliminate its water sourcing.
- Plan the use of more renewable energy or 100% renewable energy, including, but not limited to, on-site solar panels. Environmental impacts from using coal-based electricity are rather significant, and the use of renewable energy can help reduce the carbon footprints.
- As a general approach, evaluate changes in the manufacturing process or supply chain using LCA technologies to choose the best alternative before making a purchasing or investment decision. This will inform the decision-making process with upfront insight into how it will impact the LCA.

6 SOURCES

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

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

[3] Sustainable Minds Transparency Report™ Framework, Part A: LCA calculation rules and report requirements. Version 2023.

[4] Sustainable Minds Transparency Report™ / EPD Framework, Part B: Product group definition | Commercial lavatories | Part B #24-001, version October 7, 2024.

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

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

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

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

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

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

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

ACRONYMS

EPD	Environmental Product Declaration
ISO	International Standardization Organization
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact analysis
LHV	Low Heating Value
PCR	Product Category Rule document
TMX	TOTO Mexico

GLOSSARY

For the purposes of this report, the terms and definitions given in ISO 14020, ISO 14025, ISO 14040, ISO 14041, ISO 14042, ISO 14043, ISO 14044 and ISO 21930 apply. The most important ones are included here:

aggregation	aggregation of data
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
ancillary input	material input that is used by the unit process producing the product, but does not constitute part of the product
capital good	Means, for instance ancillary input needed for activities, and all handling equipment during the life cycle that can be characterized by a relative long lifespan and can be (re)used many times
category endpoint	attribute or aspect of natural environment, human health, or resources, identifying an environmental issue giving cause for concern
characterization factor	factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator
comparative assertion	environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function
completeness check	process of verifying whether information from the phases of a life cycle assessment is sufficient for reaching conclusions in accordance with the goal and scope definition
consistency check	process of verifying that the assumptions, methods and data are consistently applied throughout the study and are in accordance with the goal and scope definition performed before conclusions are reached
co-product	any of two or more products coming from the same unit process or product system
critical review	process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment
cut-off criteria	specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study
data quality	characteristics of data that relate to their ability to satisfy stated requirements

elementary flow	material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation
energy flow	input to or output from a unit process or product system, quantified in energy units
environmental aspect	element of an organization's activities, products or services that can interact with the environment
environmental measure	series of certain quantities, based on economic flows and weighing of environmental effects.
environmental mechanism	system of physical, chemical and biological processes for a given impact category, linking the life cycle inventory analysis results to category indicators and to category endpoints
environmental profile	a series of environmental effects
evaluation	element within the life cycle interpretation phase intended to establish confidence in the results of the life cycle assessment
feedstock energy	heat of combustion of a raw material input that is not used as an energy source to a product system, expressed in terms of higher heating value or lower heating value
functional lifespan	the period or time during which a building or a building element fulfils the performance requirements
functional unit	quantified performance of a product system for use as a reference unit
impact category	class representing environmental issues of concern to which life cycle inventory analysis results may be assigned
impact category indicator	quantifiable representation of an impact category
Input	product, material or energy flow that enters a unit process
interested party	individual or group concerned with or affected by the environmental performance of a product system, or by the results of the life cycle assessment
intermediate flow	product, material or energy flow occurring between unit processes of the product system being studied
intermediate product	output from a unit process that is input to other unit processes that require further transformation within the system
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 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
life cycle inventory analysis LCI	phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle
life cycle inventory analysis result LCI result	outcome of a life cycle inventory analysis that catalogues the flows crossing the system boundary and provides the starting point for life cycle impact assessment
multi-input process	a unit process where more than one flow enters from different product systems for combined processing
multi-output process	a unit process that results in more than one flow used in different product systems
output	product, material or energy flow that leaves a unit process
performance	behavior based on use

primary material	a material produced from raw materials
primary production	a production process that produces primary material
process	set of interrelated or interacting activities that transforms inputs into outputs
process energy	energy input required for operating the process or equipment within a unit process, excluding energy inputs for production and delivery of the energy itself
product	any goods or service
product flow	products entering from or leaving to another product system
product system	collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product
raw material	primary or secondary material that is used to produce a product
recycling	all processes needed to recycle a material, product or element as a material input
reference flow	measure of the outputs from processes in a given product system required to fulfill the function expressed by the functional unit
releases	emissions to air and discharges to water and soil
return system	a system to collect waste material from the market for the purpose of recycling or reuse
reuse	all processes needed to reuse a material, product or element in the same function
secondary material	material input produced from recycled materials
secondary production	production process that produces secondary material
sensitivity analysis	systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study
system boundary	set of criteria specifying which unit processes are part of a product system
third party	person or body that is independent of the involved parties, and as such recognized
transparency	open, comprehensive and understandable presentation of information
type -III-environmental declaration	quantified environmental data of a product with a predefined set of categories based on the ISO 14040 standards, without excluding the presentation of supplementing relevant environmental data, provided within the scope of a type-III-environmental declaration framework
type -III-environmental declaration framework	voluntary process of an industrial sector or independent body to develop a type- III-environmental declaration, including a framework that defines the essential requirements, the selection of categories or parameters, the level of involvement of third parties and a template for external communication
uncertainty analysis	systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty and data variability
unit process	smallest element considered in the life cycle inventory analysis for which input and output data are quantified
waste	substances or objects which the holder intends or is required to dispose of

APPENDIX A. LCI AND OTHER STARTING POINTS FOR THE MANUFACTURING PROCESS

The LCI for the parts are reported in a separate spreadsheet. It includes all parts, processes and other LCI collected to model the products. An overview of the material list for the products as required by Part A is included herein. Also included is an LCI data summary table for the manufacturing processes at the TOTO Mexico.

Table A.1 Raw materials

Table A.1.1 TOTO Mexico ceramic body slip materials; total purchased in 2023.

Constituents	% of materials	Ocean	Truck	Train
Kaolin	2%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Silica	11%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Feldspar	33%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Ball clay	9%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
China Clay_Old Mine	12%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
China Clay_Martin 5	16%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
China Clay_Kaolin KT Cast	18%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier

Table A.1.2 TOTO Mexico ceramic glaze materials purchased in 2023.

Constituents	% of materials	Ocean	Truck	Train
Silica	2%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Feldspar	8%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Aluminum Oxide	1%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Clay-Cellulose blend	2%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Calcium Carbonate	5%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Calcium Sulfate	75%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Zirconium Silicate	4%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Dolomite	1%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier
Zinc Oxide	1%	Submitted to the verifier	Submitted to the verifier	Submitted to the verifier

Table A.2 Products BOMs

Table A.2.1 Wall-Mount Lavatory (LT307R(A))

	Part Listing	Part #	Materials	Q'ty	Weight per part or material (kg)	% of Wt. overall	DATA Source	Type	Year	Truck & Trailer (miles)	Rail (miles)	Freighter (miles)	Mfrg. process
1	LAVATORY	LT307R(A)	China	1	16.600	88.82%	F	M	2023	1.05E+00	0.00E+00	0.00E+00	casting
2*	LAVATORY CARTON	0BU221	Corrugated board	1	1.200	6.42%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	rolling
3*	TOP PAD (INNER - PAK)	083140	Corrugated board	1	0.212	1.13%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	rolling
4*	BOTTOM PAD (INNER - PAK)	083139	Corrugated board	1	0.295	1.58%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	rolling
5*	WALL BRACKETS	8BU002	Stainless Steel	1	0.346	1.85%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	stamping
6*	c-UPC/ASME LABEL STICKER	0EU039-1	Paper	1	0.001	0.01%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	printing
7	INSTALLATION INSTRUCTION	0GU043-1	Paper	1	0.031	0.17%	F	M	2023	1.05E+00	0.00E+00	0.00E+00	printing
8	PRODUCT LABEL	0EU007	Paper	2	0.004	0.02%	F	M	2023	1.05E+00	0.00E+00	0.00E+00	printing
9*	Vinyl Bag (THU077)	0KU013	PE	1	0.001	0.01%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	Injection molding

*Secondary data
F = Factory, M = Measured at factory

Table A.2.2 Undercounter Lavatory (LT569)

	Part Listing	Part #	Materials	Q'ty	Weight per part or material (kg)	% of Wt. overall	DATA Source	Type	Year	Truck & Trailer (miles)	Rail (miles)	Freighter (miles)	Mfrg. process
1	LAVATORY	LT307R(A)	China	1	7.000	86.34%	F	M	2023	1.05E+00	0.00E+00	0.00E+00	casting
2*	c-UPC Sticker (1" x 2")	0BU221	paper	1	0.001	0.01%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	rolling
3*	CARTON BOX	083140	corrugated board	1	0.837	10.32%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	rolling
4*	CIRCULAR INSERT	083139	corrugated board	1	0.178	2.20%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	rolling
5*	MOUNTING CLIP (THU077)	8BU002	Stainless Steel	4	0.019	0.23%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	stamping
6*	MACHINE SCREW (THU077)	0EU039-1	Stainless Steel	4	0.004	0.04%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	threading
7*	WOOD SCREW (THU077)	0GU043-1	Stainless Steel	4	0.004	0.04%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	threading
8*	LEAD ANCHOR (THU077)	0EU007	Stainless Steel	4	0.007	0.09%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	threading
9*	Vinyl Bag (THU077)	0KU013	PE	1	0.001	0.01%	F	M	2023	1.00E+01	0.00E+00	0.00E+00	inj molding
10	TEMPLATE		paper	1	0.023	0.28%	F	M	2023	1.05E+00	0.00E+00	0.00E+00	printing
11	INSTALLATION INSTRUCTIONS		paper	1	0.031	0.38%	F	M	2023	1.05E+00	0.00E+00	0.00E+00	printing
12	PRODUCT LABEL		paper	2	0.004	0.04%	F	M	2023	1.05E+00	0.00E+00	0.00E+00	printing

*Secondary data
F = Factory, M = Measured at factory

Table A.3 LCI data for turning steel CNC process

Turning, steel, CNC, average	1	kg
This dataset encompasses the direct electricity consumption of the machine as well as compressed air and lubricant oil. Furthermore, the metal removed is included. Machine as well as factory infrastructure and operation are considered as well. The disposal of the lubricant oil is also included while the metal removed is assumed to be recycled. Geographical coverage encompasses the industrialized countries based on 2007 LCI data using industry average technology.		
Materials/fuels		
Electricity, low voltage, production	1.78	kWh
Compressed air, average installation, >30kW, 7 bar gauge, at supply network	1.28	m3
Lubricating oil, at plant	0.00382	kg
Metal working machine, unspecified, at plant	0.000174	kg
Metal working factory	2.02E-09	p
Metal working factory operation, average heat energy	4.41	kg
Steel, low-alloyed, at plant	1	kg
Emissions to air		
Heat, waste	6.39	MJ
Waste to treatment		
Disposal, used mineral oil, 10% water, to hazardous waste incineration	0.00382	kg

Table A.4 LCI data for injection molding process

Injection molding	1	kg
This process contains the auxiliaries and energy demand for the mentioned conversion process of plastics. The converted amount of plastics is NOT included into the dataset. Geographical coverage encompasses difference European and Swiss converting companies based on 2003 LCI data using present technologies.		
Resources		
Water, cooling, unspecified natural origin/m3	0.011	m3
Materials/fuels		
Lubricating oil, at plant	0.00303	kg
Solvents, organic, unspecified, at plant	0.0447	kg
Chemicals organic, at plant	0.0128	kg
Titanium dioxide, production mix, at plant	0.00199	kg
Pigments, paper production, unspecified, at plant	0.00756	kg
EUR-flat pallet	0.00146	p
Solid bleached board, SBB, at plant	9.94E-05	kg
Polyethylene, LDPE, granulate, at plant	0.00169	kg
Polypropylene, granulate, at plant	0.00358	kg
Electricity, medium voltage, production	1.48	kWh
Heat, natural gas, at industrial furnace >100kW	4.21	MJ
Heat, heavy fuel oil, at industrial furnace 1MW	0.229	MJ
Packaging box production unit	1.43E-09	p
Transport, lorry 3.5-16t, fleet average	0.142	tkm
Emissions to air		
Heat, waste	5.33	MJ
Emissions to water		
COD, Chemical Oxygen Demand	9.28E-06	kg
Suspended solids, unspecified	6.63E-06	kg
Waste to treatment		
Disposal, plastics, mixture, 15.3% water, to municipal incineration	0.00567	kg
Disposal, hazardous waste, 0% water, to underground deposit	3.31E-05	kg
Disposal, municipal solid waste, 22.9% water, to sanitary landfill	0.000895	kg

Table A.5 LCI data for polishing process

Polishing	1	kg
This dataset includes the materials, energies and emissions related to the polishing machines used for polishing metal products. This is mainly electricity, compressed air and solvents. Process heat is from average sources. The consumables are polishing discs and abrasive paste. Geographical coverage encompasses the industrialized countries based on 2007 LCI data using industry average technology.		
Materials/fuels		
Solvents, organic, unspecified, at plant	0.0014	kg
Lubricating oil, at plant	0.000867	kg
Compressed air, average installation, >30kW, 7 bar gauge, at supply network	0.291	m3
Light fuel oil, burned in industrial furnace 1MW, non-modulating	2.6	MJ
Heavy fuel oil, burned in industrial furnace 1MW, non-modulating	0.0328	MJ
Natural gas, burned in boiler modulating >100kW	2.03	MJ
Electricity, low voltage, production	1.15	kWh
Textile, woven cotton, at plant	0.0272	kg
Ethylene glycol, at plant	0.002	kg
Emissions to air		
Hydrocarbons, aliphatic, alkanes, unspecified	0.000558	kg
Ethene, tetrachloro-	7.51E-05	kg
Water	1.12	kg
Heat, waste	4.13	MJ
Waste to treatment		
Disposal, used mineral oil, 10% water, to hazardous waste incineration	0.000867	kg

Table A.6 LCI data for electroplating process

Electroplating	1	kg
This dataset models an electroplating machine with typical production volume of 90 metal parts per 1 kWh. The consumable are mainly degreasing solvents, activator substances and additive substances. Source: TOTO Shanghai; Data sourced from Shanghai, China; 2013		
Materials/fuels		
Electricity, low voltage, production	0.011	kWh
Natural gas, burned in industrial furnace low-NOx >100kW	0.00863	MJ
Degreasing Solvent (8% Ammonium Metatungstate, 7% Trichloroethylene, 5% DTPA Pentasodium Solution, 3% Sodium Mono Floro Phosphate)	0.089	kg
Additive Substance (6% Ammonium Metatungstate, 5% Trichloroethylene, 3% Fluoboric acid, 5% Sodium Mono Floro Phosphate)	0.342	kg
Activator Substance (5% Nickel Sulfate NiSO4.6H2O, 5% Sodium Acetate, 7% Trichloroethylene, 3% DTPA Pentasodium Solution)	0.089	kg

Table A.7 LCI data for plastic film extrusion process

Extrusion, Plastic Film	1	kg
This process contains the auxiliaries and energy demand for the mentioned conversion process of plastics. The converted amount of plastics is NOT included in the dataset. Geographical coverage encompasses difference European and Swiss converting companies based on 2005 LCI data using present technologies.		
Resources		
Water, cooling, unspecified natural origin/m3	0.0437	m3
Materials/fuels		
Lubricating oil, at plant	0.000105	kg
EUR-flat pallet	0.00144	p
Particle board, outdoor use, at plant	0.0000215	m3
Solid bleached board, SBB, at plant	0.000976	kg
Core board, at plant	0.00732	kg
Polyvinylchloride, suspension polymerised, at plant	0.0000488	kg
Polyethylene, LDPE, granulate, at plant	0.00215	kg
Polypropylene, granulate, at plant	0.000683	kg
Electricity, medium voltage, production	0.66	kWh
Heat, at hard coal industrial furnace 1-10MW	0.0751	MJ
Heat, natural gas, at industrial furnace >100kW	0.601	MJ
Heat, heavy fuel oil, at industrial furnace 1MW	0.134	MJ
Steam, for chemical processes, at plant	0.058	kg
Packaging box production unit	1.4E-09	p
Transport, lorry 3.5-16t, fleet average	0.0118	tkm
Emissions to air		
Heat, waste	2.38	MJ
Waste to treatment		
Disposal, plastics, mixture, 15.3% water, to municipal incineration	0.0241	kg

Table A.8 LCI for sheet rolling steel

Sheet Rolling, Steel	1	kg
This dataset includes the process steps continuous pickling line, cold rolling, annealing, tempering, inspecting and finishing, packing coils or sheets, roll maintenance. Does not include the material being rolled. This process is to be used only for un- and low-alloyed steel. Data-set is representative for European Union based on 2003 LCI data using industry average technology.		
Resources		
Water, cooling, unspecified natural origin/m3	0.027	m3
Materials/fuels		
Chemicals inorganic, at plant	1.58E-08	kg
Electricity, medium voltage, production	0.223	kWh
Heat, unspecified, in chemical plant	0.171	MJ
Hydrochloric acid, 30% in H2O, at plant	0.000397	kg
Kraft paper, bleached, at plant	1.6E-06	kg
Kraft paper, unbleached, at plant	2.68E-05	kg
Lime, hydrated, loose, at plant	5.42E-05	kg
Lubricating oil, at plant	0.00459	kg
Natural gas, burned in industrial furnace >100kW	0.912	MJ
Packaging film, LDPE, at plant	8.49E-05	kg
Kraft paper, bleached, at plant	1.62E-09	p

Rolling mill	1.85E-06	m3
Sawn timber, softwood, raw, air dried, u=20%, at plant	4.47E-05	kg
Silicon carbide, at plant	0.00015	kg
Sodium dichromate, at plant	0.0855	kg
Steel, converter, unalloyed, at plant	0.000236	kg
Steel, electric, un- and low-alloyed, at plant	0.00418	kg
Sulphuric acid, liquid, at plant	0.0298	tkm
Transport, lorry >16t, fleet average	0.135	kg
Water, deionised, at plant	1.58E-08	kg
Emissions to air		
Aluminium	1.42E-06	kg
BOD5, Biological Oxygen Demand	4.13E-05	kg
Cadmium	1.5E-07	kg
Chloride	1.34E-06	kg
Chromium VI	3E-08	kg
Chromium	5.4E-07	kg
COD, Chemical Oxygen Demand	4.13E-05	kg
Copper	2.9E-07	kg
DOC, Dissolved Organic Carbon	1.33E-05	kg
Hydrocarbons, unspecified	1.89E-06	kg
Iron	4.65E-06	kg
Lead	3E-07	kg
Manganese	6.12E-07	kg
Mercury	3E-08	kg
Nickel	8.49E-07	kg
Suspended solids, unspecified	0.000159	kg
TOC, Total Organic Carbon	1.33E-05	kg
Zinc	2.24E-07	kg
Emissions to soil		
Iron	4.52E-05	kg
Oils, unspecified	3.85E-05	kg
Waste to treatment		
Disposal, basic oxygen furnace wastes, 0% water, to residual material landfill	0.000193	kg
Disposal, municipal solid waste, 22.9% water, to municipal incineration	0.000358	kg
Disposal, sludge from steel rolling, 20% water, to residual material landfill	0.0201	kg
Disposal, steel in car shredder residue, 0% water, to municipal incineration	0.0079	kg
Disposal, used mineral oil, 10% water, to hazardous waste incineration	0.000888	kg

Table A.9 LCI data for injection molding process

Injection molding	1	kg
This process contains the auxiliaries and energy demand for the mentioned conversion process of plastics. The converted amount of plastics is NOT included into the dataset.		
Resources		
Water, cooling, unspecified natural origin/m3	0.011	m3
Materials/fuels		
Lubricating oil, at plant	0.00303	kg
Solvents, organic, unspecified, at plant	0.0447	kg
Chemicals organic, at plant	0.0128	kg
Titanium dioxide, production mix, at plant	0.00199	kg
Pigments, paper production, unspecified, at plant	0.00756	kg
EUR-flat pallet	0.00146	p
Solid bleached board, SBB, at plant	9.94E-05	kg
Polyethylene, LDPE, granulate, at plant	0.00169	kg
Polypropylene, granulate, at plant	0.00358	kg
Electricity, medium voltage, production	1.48	kWh
Heat, natural gas, at industrial furnace >100kW	4.21	MJ
Heat, heavy fuel oil, at industrial furnace 1MW	0.229	MJ
Packaging box production unit	1.43E-09	p
Transport, lorry 3.5-16t, fleet average	0.142	tkm
Emissions to air		
Heat, waste	5.33	MJ
Emissions to water		
COD, Chemical Oxygen Demand	9.28E-06	kg
Suspended solids, unspecified	6.63E-06	kg
Waste to treatment		
Disposal, plastics, mixture, 15.3% water, to municipal incineration	0.00567	kg
Disposal, hazardous waste, 0% water, to underground deposit	3.31E-05	kg
Disposal, municipal solid waste, 22.9% water, to sanitary landfill	0.000895	kg

Table A.10 LCI data for cold impact extrusion, steel

Cold impact extrusion, steel	1	kg
This dataset encompasses the electricity consumption of the machine as well as common pre- and post-treatments. Furthermore, machine as well as factory infrastructure and operation are considered as well. Degreasing is not included and has to be added if necessary.		
Materials/fuel	-	-
Deformation stroke, cold impact extrusion, steel	1	kg
Surface treatment, cold impact extrusion, steel	1	kg
Heat treatment, cold impact extrusion, steel	1	kg
Compressed air, average installation, >30kW, 7 bar gauge, at supply network	0.291	m3
Metal working machine, unspecified, at plant	0.0000395	kg
Metal working factory	4.58E-10	p
Metal working factory operation, average heat energy	1	kg

APPENDIX B. ADDITIONAL RESULTS

No additional result views have been reported at this point.

APPENDIX C. IMPACT CATEGORIES

The impact assessment is based on the TRACI 2.1 methodology [6]. The contents of this publication are presented in this appendix. A definition of the impact categories within TRACI 2.1 is available in section 4.1.

APPENDIX D. USED DATASHEETS

To model the LCA different data sources have been used. This appendix includes a list of all datasheets that have been used. The list is included in the separate spreadsheets:

- LCA of TOTO Ceramic Products – Commercial Lavatories Modeling Data and Results 10-2024.xlsx

APPENDIX E. LCI

The LCI results per functional unit for all products are included in the separate spreadsheets:

- LCA of TOTO Ceramic Products – Commercial Lavatories Modeling Data and Results 10-2024.xlsx

APPENDIX F. LCIA METHOD

The LCIA characterization factors are included in the separate spreadsheets below:

- LCA of TOTO Ceramic Products – Commercial Lavatories Modeling Data and Results 10-2024.xlsx

APPENDIX G. PROCESS FLOW DIAGRAMS

Process flow diagrams per functional unit of product are included in the separate spreadsheets mentioned above. The modeled materials and energy flows are presented.