TOTO®

LIFE CYCLE ASSESSMENT (LCA) OF TOTO SANITARY CERAMIC PRODUCTS

Status | Public Version

Client | TOTO USA

TOTO®

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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 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.

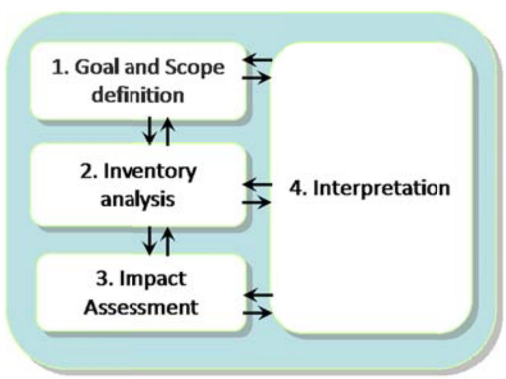
TOTO is continuing to have Life Cycle Assessment (LCA) data available for the most important products to be able to obtain a SM Transparency Report, a type III environmental declaration that can be used for communication with and amongst other companies, architects and consumer communication, and can 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 Framework, which is based on ISO 14040-44 & 14025 standards. 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 certification for transparency reports are required in the Framework in order to be able to use

Transparency Reports as Type III environmental declarations. Both of these reviews 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 a commercial toilet in an average US commercial environment 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. A third-party review has been performed by NSF and verified that the report is in conformance with ISO 14040-44.

TOTO has also chosen to have the Transparency Reports™ undergo third-party verification against Parts A and Part B: Product group definition | Commercial toilets | Part B #23-003 of the SM Transparency Report™ / EPD Framework v2024. A third-party review has been performed by NSF. The review concluded that the reports are in conformance with the Sustainable Minds Transparency Report™ / EPD Framework.

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 TOTOT 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 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 and get the serious conversations going 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 market place 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 ceramics. 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 two ceramic toilets manufactured in Indonesia and India. These are listed in Table 2.1a. The categories of Transparency Reports and manufacturing locations as well as other products' information are presented in Tables 2.1b, 2.1c and 2.1d.

Table 2.1a Product codes, names and SM project concepts

Product Code	Product Name Description	Project concept
CT725CU(F)(G)(X)	Ultra-High Efficiency 1G/1.28gpf toilet	LCA of a TOTO toilet
CT728CU(V)(G)(X)	Ultra-High Efficiency 1G/1.28gpf toilet	LCA of a TOTO toilet

Table 2.1b Vendors and manufacturing locations

Product code	Production plant/vendors	Production Location
CT725CU(F)(G)(X)	STI and TVN (TOTO)	Indonesia and Vietnam
CT728CU(V)(G)(X)	TOTO India	India

Table 2.1c Categories of declarations

Product	Category
CT725CU(F)(G)(X)	a declaration of a specific product from a manufacturer's plant
CT728CU(V)(G)(X)	

Table 2.1d Product information

Product code	CSI master format classification	ASTM or ANSI product specification	Physical properties and technical information or any other market identification
CT725CU(F)(G)(X)	22 42 13.13	ASME A112.19.2/CSA B45.1 Certifications: IAPMO(cUPC)	Vitreous China Plumbing Fixture
CT728CU(V)(G)(X)			

Table 2.2 Ceramic and part weights as sold

Product code	Weight of finished ceramic parts (kg)	Packaging weight (kg)	Parts: fittings (kg)
CT725CU(F)(G)(X)	23.72	1.43	0.25
CT728CU(V)(G)(X)	24.15	1.43	0.25

Manufacturing data has been collected and compiled for the TOTO Vietnam (TVN), STI (TOTO) and TOTO India (TIN) facilities.

Presented below are images and descriptions of the modeled products.

Table 2.3 Description of the modeled products

CT725CU(F)(G)(X) 	• Siphon Jet Flush Action • Elongated Front Rim • Floor-Mounted • Designed to work with EcoPower Flush Valves • Rough-in 10-12in • CeFiONtect Ceramic Glaze See more at: https://www.totousa.com/commercial-flushometer-tornado-flush-top-spud-floor-mounted-toilet-universal-height-cefiontect-reclaimed-water
CT728CU(V)(G)(X) 	• Siphon Jet Flush Action • Elongated Front Rim • Wall-Mounted • Designed to work with EcoPower Flush Valves • Rough-in 10-12in • CeFiONtect Ceramic Glaze See more at: https://www.totousa.com/commercial-flushometer-tornado-flush-top-spud-wall-hung-toilet-cefiontect

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 Transparency Reports of the corresponding products listed in Table 2.1a 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 unit in Table 2.4 serve as the reference unit for the product's LCA. Reference units express the amount of a product and its function as it is applied and/or used in the United States of America and it includes the lifespan of the product. These functional units are taken from Part B of the SM Transparency Report Framework [7]. TOTO products comply with the functional performance specifications defined in the aforementioned Part B.

Table 2.4 Functional unit of the modeled product

Product	**Functional Unit**
CT725CU(F)(G)(X)	One commercial toilet in an average commercial environment
CT728CU(V)(G)(X)	

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 30 years is an industry accepted average lifespan that is based on the economic lifespan of a product. Electrical and other hardware components, especially related to rubbers for watertight connections and moving parts, will require replacement earlier than the 30-year RSL.

2.4 System boundaries

To define what is included and what is excluded in an LCA, the system boundaries are drafted. In general, the system boundaries as defined in Part A [6] 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 LCA's system boundaries include the following life cycle phases:

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

These boundaries apply to the modeled product 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 [6].

The system boundaries for TOTO ceramic products are detailed below. Figure 2.1 represents the life cycle phases and stages for the entire life cycle of these products.

	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	X

X = a declared module

Figure 2.1 Applied system boundaries for the modeled ceramic products

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

Toilet bowls are mostly made of ceramic, which is then coated with body slip and glaze. The recipe of raw materials for the body slip and glaze for ceramic products in TOTO STI, TOTO Vietnam and TIN including the transportation mode and distances when purchased are listed in the appendix table A1. BOM of each product is as follows:

Table 2.5 Ceramic production raw materials

Table 2.5a: Raw materials definition of CT725CU(F)(G)(X)

Component	Material	Mass %	Renewable	Non-renewable	Recycled post-industrial	Recycled post-consumer	Origin of raw materials
China body	Ceramic	91.45%	No	Yes	0%	0%	Miscellaneous
Carton Box	Corrugated Board	3.2%	No	Yes	0%	0%	Indonesia
Right side pad	Corrugated Board	3.86%	No	Yes	0%	0%	Indonesia
-	Remaining materials	1.49%	No	Yes	0%	0%	Miscellaneous
	TOTAL	**100%**					

Table 2.5b Raw materials definition of CT725CU(F)(G)(X)

Component	Material	Mass %	Renewable	Non-renewable	Recycled post-industrial	Recycled post-consumer	Origin of raw materials
China body	Ceramic	91.45%	No	Yes	0%	0%	Miscellaneous
Carton Box	Corrugated Board	3.2%	No	Yes	0%	0%	Vietnam
Right side pad	Corrugated Board	3.86%	No	Yes	0%	0%	Vietnam
-	Remaining materials	1.49%	No	Yes	0%	0%	Miscellaneous
	TOTAL	**100%**					

Table 2.5c Raw materials definition of CT728CU(V)(G)(X)

Component	Material	Mass %	Renewable	Non-renewable	Recycled post-industrial	Recycled post-consumer	Origin of raw materials
China body	Ceramic	91.45%	No	Yes	0%	0%	Miscellaneous
Carton Box	Corrugated Board	3.2%	No	Yes	0%	0%	India
Right side pad	Corrugated Board	3.86%	No	Yes	0%	0%	India
-	Remaining materials	1.49%	No	Yes	0%	0%	Miscellaneous
	TOTAL	**100%**					

Non-ceramic parts that make a toilet are spud nut and washer. 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. We assumed a yield loss for metals of 10% and 2% for plastics. Table 2.5 shows an aggregation of materials that make up the non-ceramic parts of the product that are > 1%. The products have no materials considered hazardous.

Table 2.6 Spud nut and washers product constituent

Constituent	CT725CU(F)(G)(X)	CT728CU(V)(G)(X)
Brass	0.98%	0.96%
Corrugated	5.47%	5.38%

Because data on recycled content was not provided, it was assumed that 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. Primary data for ceramic manufacturing at TOTO India, TOTO Indonesia (STI) and TOTO Vietnam (TVN) were used. The unit processes used as required by Part A are presented in Appendix A. Default allocations of Ecoinvent datasets are assumed to apply in this model.

The specific numbers of completeness are listed below (Table 2.7).

Table 2.7 Completeness of the parts after 1% weight cut-off of the non-ceramic parts

Product code	%wt covered
CT725CU(F)(G)(X)	99.78%
CT728CU(V)(G)(X)	99.78%

2.4.1.2. Manufacturing

The toilets at the TOTO Indonesia, TOTO Vietnam and TOTO India plant are manufactured as follows:

- Raw materials arrive by ocean freighter, truck and are unloaded / stored into silos or designated area.
- The preparation materials, primarily materials that embody the mass of the toilet, 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 toilet body. 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.

We confirm that manufacturing process and machines used in TVN is similar with that in STI within our scope in the modeling.

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 facilities as well as the yield percent of the plants. Yield is a composite of production losses at different stages in the manufacturing process. Product yield percentage is the percentage of final product compared to raw material input; while total plant yield is the average yield percentage for all the products manufactured in the plant. Differences in yield percentages are due to complexity of the products produced and differences in process, for example, method of casting.

Total energy consumption and emissions in the plant are allocated for different products based on the production efficiency. Production efficiency is the efficiency of energy input embedded in the product and emissions out from the production. Energy input and emission output would firstly be reported in average and plant level, and the product specific data would be reported later for each product. All processes are assigned to the final product based on the yields presented in Table 2.10 a & b using the total yield and production efficiency, with the exception of natural gas use and associated emissions from the kiln. Natural gas usage and associated emissions are allocated by using the last column, the firing yield.

For the most part, the casting materials are process aids. Exceptions are soluble salts majorly within the bonding slip, which are applied to the toilets 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 Figures 2.2a-b.

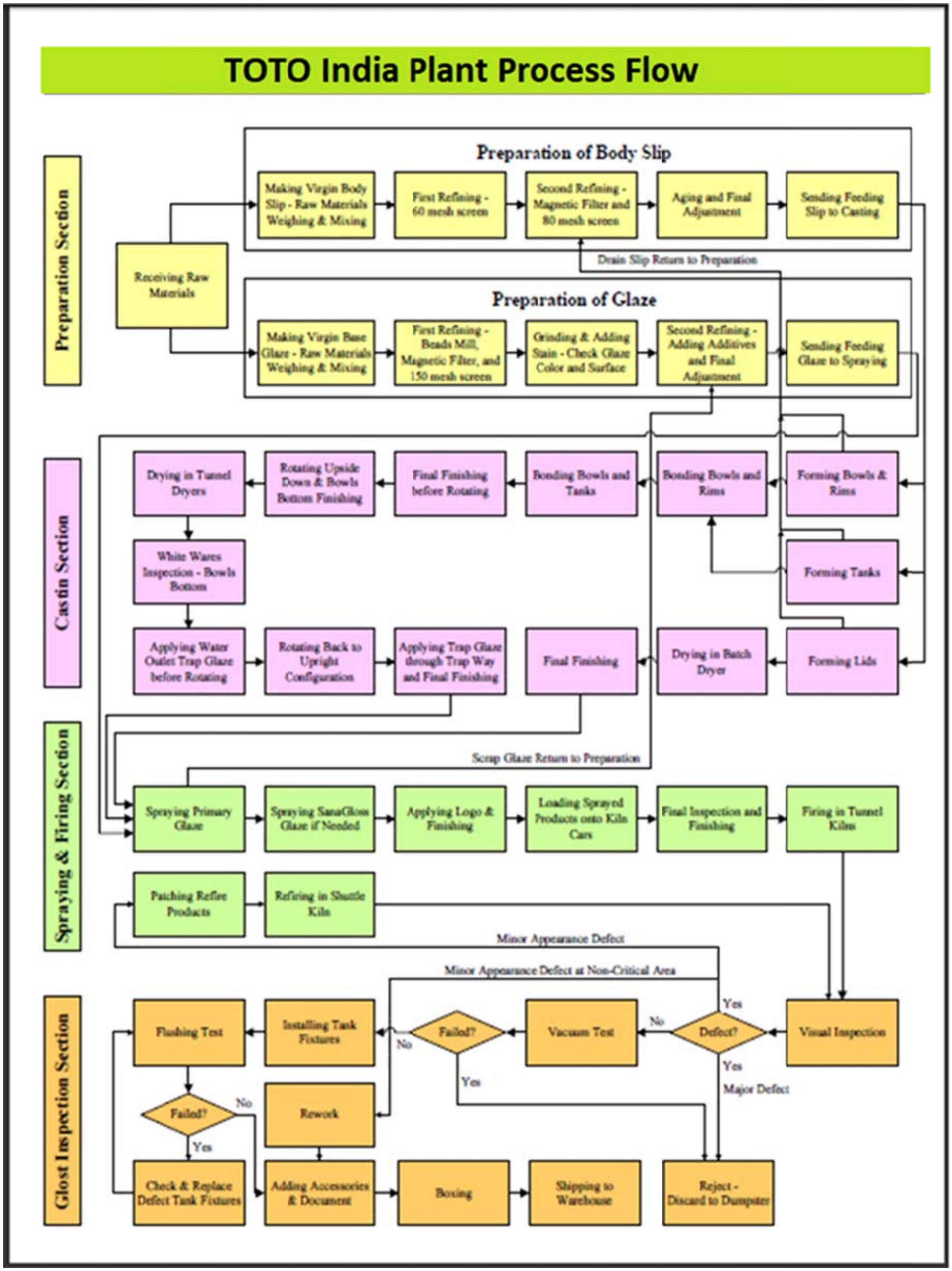


Figure 2.2a TOTO India Manufacturing Process Flow

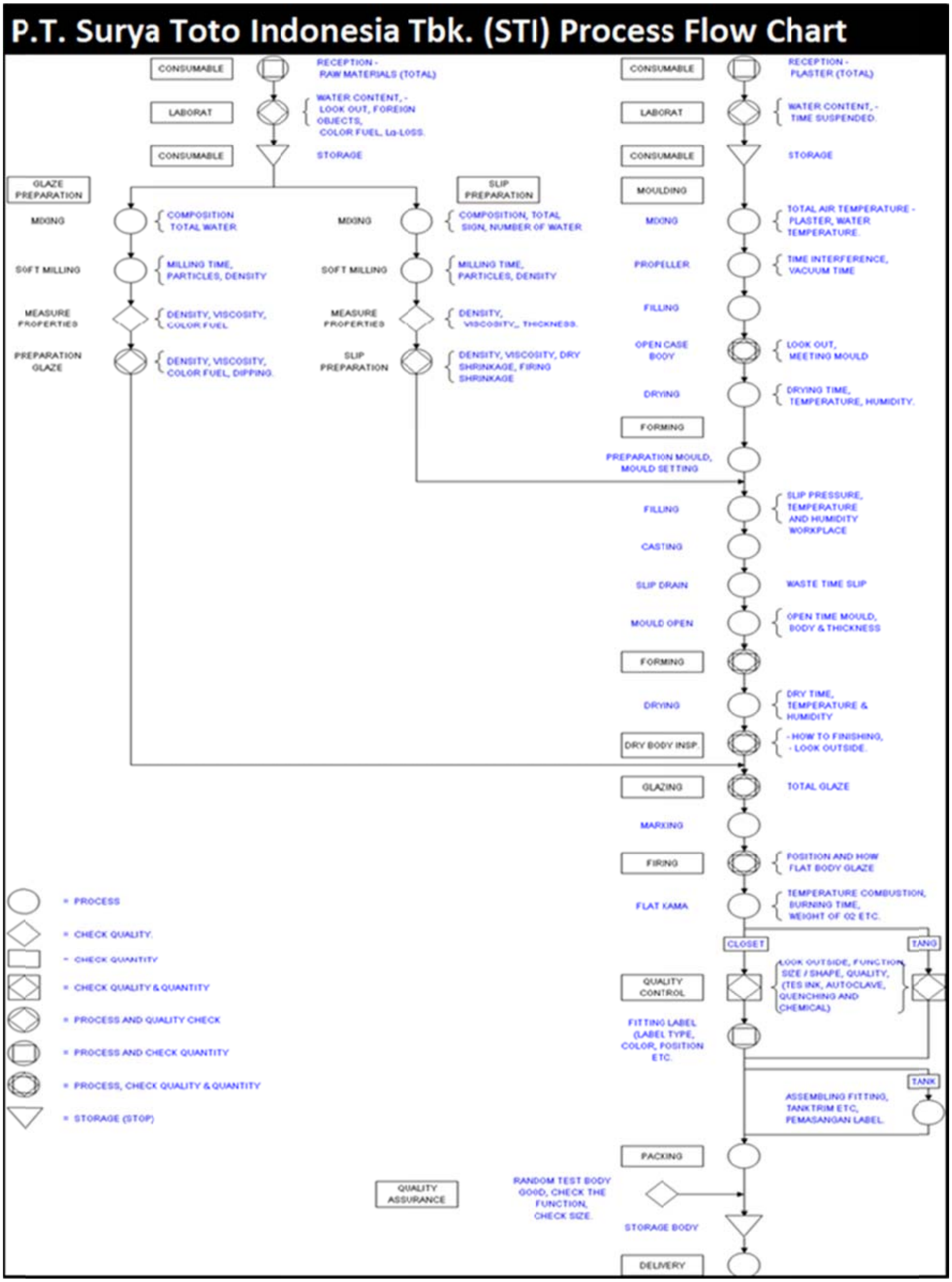


Figure 2.2b TOTO Indonesia and TOTO Vietnam Manufacturing Process Flow

Following discussions with both manufacturing plants, STI and TVN, we determined that their manufacturing process flows are practically the same and that one process chart will be used to represent both plants.

A summary of the mass balance calculations for the TOTO Indonesia, Vietnam and India facilities in 2023 was provided to the verifier. Individual inputs and outputs can be viewed in Appendix A.

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.

In order to assign inputs and outputs to products, all the data reported below are based on data per weight of ceramics.

2.4.1.3. Energy Requirements

The major manufacturing processes were described in section 2.4.1.4. The energy requirement to produce one kg of ceramic in TOTO Indonesia, Vietnam and India was provided to the verifier.

Generation sources in Indonesia is 44% from coal, 19% from oil, 19% from natural gas, 10% from geothermal and 14% from hydro power[1] while sources in India are 53.7% from coal, 11.3% from oil, 3% from nuclear power, 10% from solar and wind and 22% from hydro power[2]. Generation sources in Vietnam is 47% from coal, 33% from hydro power, 10% from natural gas and 10% from geothermal[3] Impact factors for this electricity source were created when modeling in SimaPro.

2.4.1.4. Water consumption

The manufacturing operation requires the consumption of water. Data was provided to the verifier.

Despite the relatively high water usage, TOTO's operations are always evolving in order to find ways to reduce the use of natural resources. For example, programs implemented in 2012 in the TOTO Morrow in the USA casting department (highest water consuming department) resulted in significant reductions in water use. Also,

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1 https://energypedia.info/wiki/Indonesia_Energy_Situation

2 https://www.ibef.org/industry/power-sector-india.aspx
https://www.ibef.org/industry/power-sector-india.aspx

3 https://www.statista.com/topics/8530/energy-sector-in-vietnam/

Morrow utilizes roughly 20,000 gallons of on-site recycled greywater per production day, thereby setting a great example for her sister companies, STI and TVN.

All water waste is processed on-site in the TOTO Morrow in the wastewater treatment plant (WWTP). Treatment utilizes a number of Cationic Polymer, Anionic Polymer, Polymer flocculants and Sodium Hydroxide. Much of the greywater from this process is reused in the plant. The remainder of water is discharged to the respective city and county water systems via the public sewer system. While finding ways to be more efficiency during production and transportation, STI and TVN are having more opportunities to learn from TOTO Morrow plant and to mitigate their environmental impacts.

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. Because the drying and firing temperature is high enough for carbonation, we assume that the worst case scenario that all possible raw materials are carbonated and combusted during the process.

Table 2.8 Air emissions for product manufacturing in 2023

Air emission	Grams per kg of ceramic		
	CT725CU(F)(G)(X) (Indonesia)	**CT725CU(F)(G)(X) (Vietnam)**	**CT728CU(V)(G)(X) (India)**
NO_x	1.41	1.32	0.19
SO_2	0.01	0.09	0.21
CO	0.90	1,23	0.81
CO_2	850.10	1132.55	3521.08

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 2.9 Water effluents for toilet manufacturing in 2023

Water effluents	Grams per kg of ceramics		
	CT725CU(F)(G)(X) (Indonesia)	**CT725CU(F)(G)(X) (Vietnam)**	**CT728CU(V)(G)(X) (India)**
Chemical Oxygen Demand	0.32	0.41	0.19
Total Kjeldahl Nitrogen (TKN)	0.02	0.033	0.000
Phosphorous matter	0.01	0.005	0.000
Aluminum	0.03	0.022	0.000
Copper	0.00035	0.0005	0.000
Zinc	0.0022	0.0031	0.007
NO3-NO2	0.2	0.11	0.000
Total Suspended Solids	0.10	0.21	0.099
Biochemical Oxygen Demand	0.22	0.12	0.078
Chloroform	0.000	0.000	0.000
Bis(2-ethylhexyl)phthalate	0.000	0.000	0.000
Grease & Oil	0.000	0.000	0.000

Antimony	0.000	0.000	0.000
Beryllium	0.000	0.000	0.000
Cadmium	0.000	0.000	0.000
Chromium	0.000	0.000	0.000
Lead	0.000	0.000	0.000

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. The finished product is packaged and ready for transportation to distribution centers and ultimately to the US market. Because all the stickers and paper are less than 0.1kg, which is less than 1% of total weight, we do not include them. The stretch wrap is below the cutoff of 1%wt and impact. The corrugated board that makes up the boxes, pads, and insert are included for each product and are listed below in Table 2.10.

Table 2.10 Packaging information

Product code	Cardboard weight (kg)
CT725CU(F)(G)(X)	1.39
CT728CU(V)(G)(X)	1.39

2.4.1.7. Transportation

Transportation distances of the toilet components and processing aids were provided by TOTO's purchasing, production, and logistics department. Trucks and ocean freighters are assumed to be diesel-powered. No empty returns are accounted for in truck and trailer transportation.

CT725CU(F)(G)(X) is manufactured by two TOTO plants, TOTO Indonesia and TOTO Vietnam while CT728CU(V)(G)(X)) is manufactured by TOTO India alone to meet the demands. The majority of the materials purchased come from manufacturers located in Indonesia and Vietnam for CT725CU(F)(G)(X) for each plant and the same is true for TOTO India's CT728CU(V)(G)(X)). One of the main materials (Kaolin) is sourced from the furthest side of each country as a worst scenario and transportation by ocean freighter, rail and truck and trailer are calculated and included in the model.

2.4.1.8. Solid waste

Solid waste from facilities includes sludge, ceramic/slip scrap, mold scrap, carton boxes, metal scrap and other wastes. Among them, ceramic/slip scrap, mold 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 percent 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 to treat is included in the model. We assumed that all the solid wastes are conveyed by diesel-powered trucks. Where transportation distances were not known, we used 75 miles for commingled, single stream waste recycling, 50 miles for pallet recycle, and 25 miles for metal and oil waste.

Table 2.11 Solid waste from TOTO Indonesia and TOTO India

Solid waste (g per kg of ceramic)	TOTO Indonesia		TOTO Vietnam		TOTO India	
	Weight	Fate	Weight	Fate	Weight	Fate
Sludge	114.9	Landfill	120.95	Landfill	125.76	Landfill
Wasted gypsum	80.06	Reuse	84.27	Reuse	244.63	Reuse
Ceramic scrap	341.89	Reuse	359.88	Reuse	858.16	Reuse
Slip scrap	0.00	Landfill	4.67	Landfill	0.00	Landfill
Pallet scrap	4.44	70.60% recycled, others to landfill	2.51	70.60% recycled, others to landfill	4.01	83% recycled, others to landfill
Carton scrap	2.39	Recycle	0.13	Recycle	1.67	Recycle
Hazardous waste	0.00	Incineration	4.84	Incineration	0.00	Incineration
Wastepaper	0.13	Recycle	1.58	Recycle	0.13	Recycle
Metal scrap	4.59	Recycle	0.32	Recycle	4.42	Recycle
Waste plastic containers	1.50	Recycle	1.50	Recycle	1.46	Recycle
Waste oil	0.30	Hazardous Landfill	0.30	Hazardous Landfill	0.14	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

All toilets and their components are packaged in the manufacturing plants 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). Toilet components from the facilities arrive finished and require no further assembly. The distance from the Port of Savannah to FAP is approximately 252 miles via diesel-powered trucks.

After products are purchased by distributers, 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 from FAP were transported an average of 947 miles by diesel truck and an average of 1114 miles by rail. When factoring the quantity transported by truck and rail (95% and 5% respectively), the weighted average transported distance comes to approximately 949 miles. In 2023, outbound shipments were transported an average of 883 miles by diesel truck and an average of 1269 miles 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 toilet 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.

Materials needed for installation of urinal include a wax ring or wax-free gasket and flange, in which the most common slack wax ring is used as an ancillary product for this study. The weight of these materials may vary in size based on customer needs, and range from 0.1 kg to 0.15 kg; 0.15kg was ring is used for this study. These are necessary for creating a seal between the toilet outlet and drain line to ensure no leakage of sewer gas into the bathroom. The wax ring is generally a high-grade petroleum wax and often includes a polyethylene sleeve. The wax-free gasket and flange consists of a rubber gasket affixed to a plastic flange. These are generally used to install toilets to a recessed floor drain or for a no-mess installation. Supply lines are needed to supply the flushometer valve with water. These supply lines consist of copper pipe and angle stop. The nut connecting to the water supply is normally brass alloy which is a part of flushometer valve. The nut which connects to the toilet bowl will include an inner gasket for proper sealing. The toilet bowl does not include these materials and hence they are not included in the LCA. These materials will have a low additional environmental impact as compared to the the toilet bowls and flushometer valves, in which the latter's environmental impact will be analyzed separately by means of its own Part B.

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 toilets would include regular cleaning. Per Part B, we assume daily cleanings with 1.69 fl oz (50 mL) of a 1% Sodium Lauryl Sulfate solution per event. This is included in the model.

The use of 50mL/day over 260days/year over 75 years gives a total of 975L of solution. Taking a density of 1.01kg/L for a 1% SLS solution, 975kg of solution will be required over the course of 75 years. Hence, 9.75kg of 1% SLS and 975kg of water will be required.

2.4.3.3. Repair

The service life is defined in such a way that for a typical installation, no repair is required. Repair would be incidental. There is no repair as such included in the model.

2.4.3.4. Replacement

The service life is defined in such a way that for a typical installation, replacing a whole product in order to return product to a condition in which it can perform its required functional or technical performance is not required. Replacements are not relevant and therefore no calculation rules need to be defined. The model does not include 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 [7].

The report will include the toilet bowls only with no integrated flushing mechanism, resulting in no water flow and no water use impacts. A flushometer valve, which may be used with these bowls, does have a flushing mechanism and water control and it will be analyzed separately in its own LCA.

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 toilets are assumed to have a useful life of beyond 30 years (RSL). At the end of life, it is assumed that the toilets are landfilled but most of their components follow the waste scenarios as outlined in Table 219. TOTO ceramic materials can be recycled as aggregate in several applications; however this is not a common practice at the moment. According to the data from the U.S. EPA's Municipal Solid Waste Generation, Recycling, and Disposal in the United States Report for 2018[4], 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. We use these rates to define the waste scenario of metal and plastic parts in the toilets. 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, shredded and sorted metal waste, to hold the primary product is valuable good that will lose its waste status after the sorting process and no additional waste processing is needed (e.g. melting) and no credits for material recovery are given.

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 a recycling site.

2.4.4.3. Waste processing stage

The waste processing of material flows transported to a recycling site following the waste scenarios of materials was assumed to be intended for recycling and were included in the model. All processing including pre-sorting, crushing, and shredding were modeled.

2.4.4.4. Disposal stage

The disposal of material flows transported to a landfill.

[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

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 department concerned in TOTO Indonesia, TOTO Vietnam and TOTO India 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 sheet "LCA of TOTO Ceramic Products – CT Modeling Data and Results 03-2023" submitted with the report.

Product composition data have been provided by TOTO subsidiaries. Some data was confidential and is therefore not included in this report. We have used publicly available data on composition and manufacturing for upstream and missing data and have supplemented that 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 have been applied based on scientifically accepted values.

This study includes products in standard cotton finish. Products are offered in several different finishes to meet the customers' demands. The results included in this study represent an average performance for all available options, using a production-weighted average for all models produced in CY2023. These properties are used to calculate the mass reference flow, which was normalized to 1 kg for products with standard cotton finish.

All manufacturing data used is primary data from the calendar year 2023, with regional specific data. All used background data to model the LCA is reported in the appendix A and D. 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 US 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 US EcoInvent data the report follows the data quality in these datasets as it relates 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 close 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 will 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 were 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.
- Literature data has been used 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.
- LCA results are expressed in relative terms and do not predict impacts on category endpoints, threshold exceedances, safety margins, or risks.

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

- Raw materials in all manufacturing plants are from reported use data inventories.
- Casting materials, inspection materials and installation materials are cut off.
- Maintenance and parts replacement of capital equipments, such as CNC machine, injection machine, mold equipment, etc. was not considered.
- Transportation of Kaolin, products from vendors, is estimate based on rail lines, port information. The worst case scenario of the furthest distance from each factory (TVN and STI) to the manufacturing facility to transport kaolin with ocean freight method was considered.
- Water content of sludge was measured and reported; however, this measurement not performed routinely
- Waste from pallets, cartons, wastepaper, metals, and plastics are allocated based on product volume of each plant..
- We use general waste treatment data of EPA to make waste scenarios of products.
- Water and electricity consumption in the use phase is using general person and flush data from EPA.
- Pallet use is assumed based on the average numbers per unit of product and reported pallet quantity of specific models.

Data quality 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 for the primary data for both facilities have been reported, therefore these criteria have been met. The completeness of the bill of materials is reported in the previous chapter (Table 2.9) and satisfies the above defined cut-off criteria.

To reduce possible artificial variation in EPD results across the product group, capital goods and system infrastructure flows are excluded from the system boundary by default, with justification required for alternative assumptions.

The LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

A summary of the life cycle stages included in the report is as follows:

1. Raw Material Supply (upstream processes): Extraction, handling and processing of the raw materials used in production of the product: Kaolin, ball clay, supplementary materials, aggregate (course and fine), water, admixtures and other materials or chemicals used in the mixtures.
2. Transportation: Transportation of these materials from supplier to the ‘gate’ of the factory.
3. Manufacturing: The core processes result from the energy used to store, batch, mix and distribute the the product and operate the facility/ plant.
4. Water use in making the products.

3.5 Allocation

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.

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 not considered due to lack of background data in the LCA model.

Secondary products and material could be part of the intermediary products from the upstream supply chain and background datasets used in the LCA model.

3.5.2 Allocation for reuse, recycling and recovery

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

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

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

3.5.3 Cut-off Criteria

To ensure that all relevant environmental impacts were represented in the study the following cut-off criteria were used.

Mass—If the flow was less than 1% of the cumulative mass of all the inputs and outputs of the model, it was excluded, provided its environmental relevance was not a concern.

Energy—If the flow was less than 1% of the cumulative energy of all the inputs and outputs of the model, it was excluded, provided its environmental relevance was not a concern.

Environmental relevance—If the flow was less than 1% of the cumulative energy of all the inputs and outputs of the model, it was excluded, provided its environmental relevance was not a concern.

In addition, the total of neglected input flows per module shall not exceed 5% of energy usage, mass or environmental impacts.

4 IMPACT ASSESSMENT

4.1 Impact assessment

The environmental indicators (global warming, ozone layer depletion, summer smog, acidification and eutrophication and abiotic depletion for non-fuel and fuel resources) as required by ISO 14025 are included as well as other indicators required by Part A of the Framework (see Table 4.1). The impact indicators are derived by using the 100 year time horizon[5] 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. This follows the approach from Part A of the Framework.

Table 4.1 Selected impact categories and units

Impact category	Unit
Ozone depletion	CFC-11 eq
Smog	O_3 eq (ozone)
Acidification	SO_2 eq (sulfur dioxide)
Fossil fuel depletion	MJ surplus
Eutrophication	N eq (nitrogen)
Respiratory effects	$PM_{2.5}$ eq (fine particulates)
Non carcinogenics	CTU_h
Carcinogenics	CTU_h
Ecotoxicity	CTU_e
Global warming	CO_2 eq (carbon dioxide)

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 not reported.

A definition of these impact categories is included in appendix C. During the impact assessment stage of the modeling, the list of impacts, LCI, for substances that may have not been recognized by the impact assessment method was reviewed. SimaPro was used to perform the impact assessment.

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

[5] The 100 year period relates to the period in which the environmental impacts are modeled. This is different from the time period of the 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.
[6] J. Bare (2012) TRACI 2.1: the tool for the reduction and assessment of chemical and other environmental impacts 2.1. Clean Technologies and Environmental Policy. 13(5); United States Environmental Protection Agency (2012). Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) User's Manual. Document ID: S-10637-OP-1-0.

4.2 Normalization and weighting

To arrive to the single score indicator, normalization[7] and weighting[8] conforming to Part A of the Framework was applied.

Table 4.2 Normalization and Weighting factors

Impact category	Normalization	Weighting (%)
Ozone depletion	6.20	2.4
Smog	7.18E-4	4.8
Acidification	1.10E-2	3.6
Fossil fuel depletion	5.79E-5	12.1
Eutrophication	4.63E-2	7.2
Respiratory effects	4.12E-2	10.8
Non carcinogenics	952	6.0
Carcinogenics	19,706	9.6
Ecotoxicity	9.05E-5	8.4
Global warming	4.13E-5	34.9

4.3 LCI Indicators

Submitted with the report is the LCI indicators file, “Submittal_CT725_CT728_UT445_UT105_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. 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.

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.

[7] A. Lautier, et al. (2010). Development of normalization factors for Canada and the United States and comparison with European factors. Science of the Total Environment. 409: 33-42.
[8] Bare, Jane; Gloria, Tom and Norris, Greg, Development of the Method and U.S. Normalization Database fro Life Cycle Impact Assessment and Sustainability Metrics, Environmental Science and Technology, / VOL. 40, NO. 16, 2006

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 CT725CU(F)(G)(X)

This section includes the results of CT725CU(F)(G)(X)

Cradle-to-gate

Figure 5.1a and 5.1b illustrate the results per functional unit for the finished product in each of both plants, STI and TVN. The results show that the ceramic parts, dominate all impact categories; however, the eutrophication and non-carcinogenic categories are heavily influenced by processing of ceramic, followed by manufacturing of brass. The ozone depletion category is heavily impacted by ceramic parts. The contributions to the smog, carcinogenic, ecotoxicity and fossil fuel depletion categories by oceanic transportation are also relevant. The other parts, such as brass and corrugated packaging board, processes, casting and turning brass, and transportation with trucks contribute between 5% and 14% of the overall impacts in the remaining categories.

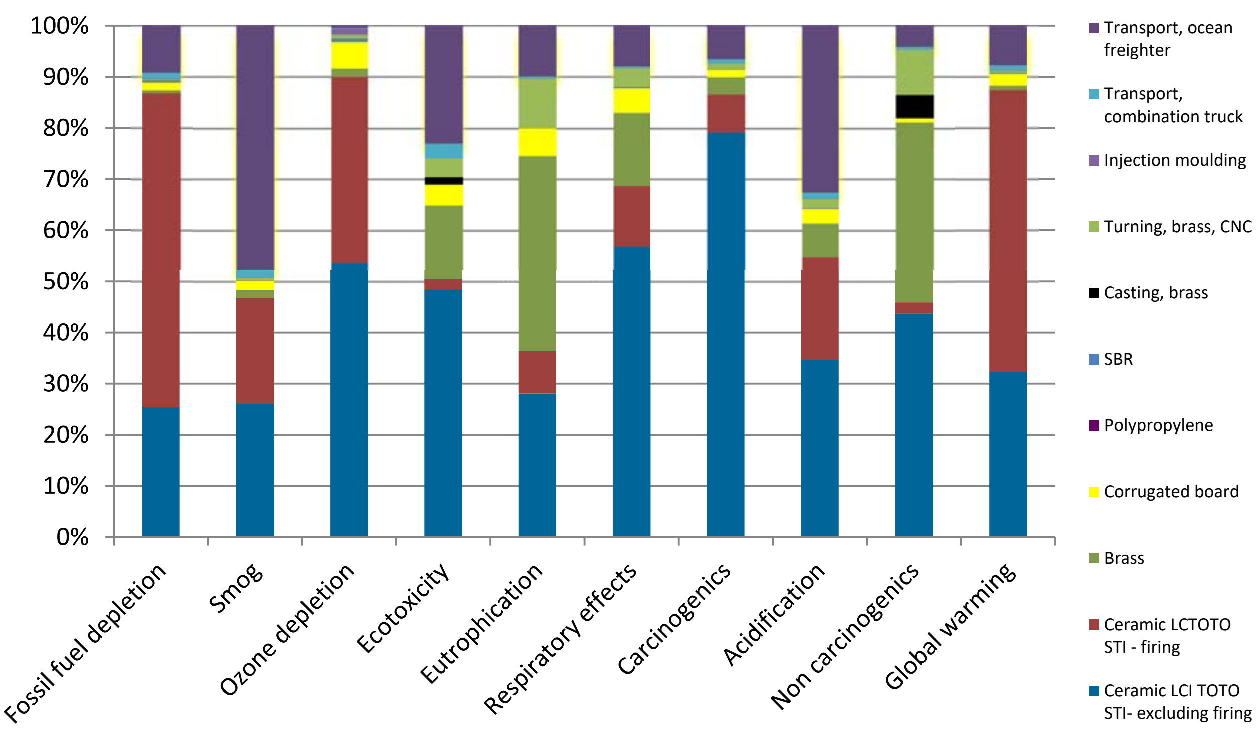

Figure 5.1a Cradle-to-gate impacts for CT725CU(F)(G)(X) – relative results (Indonesia: STI)

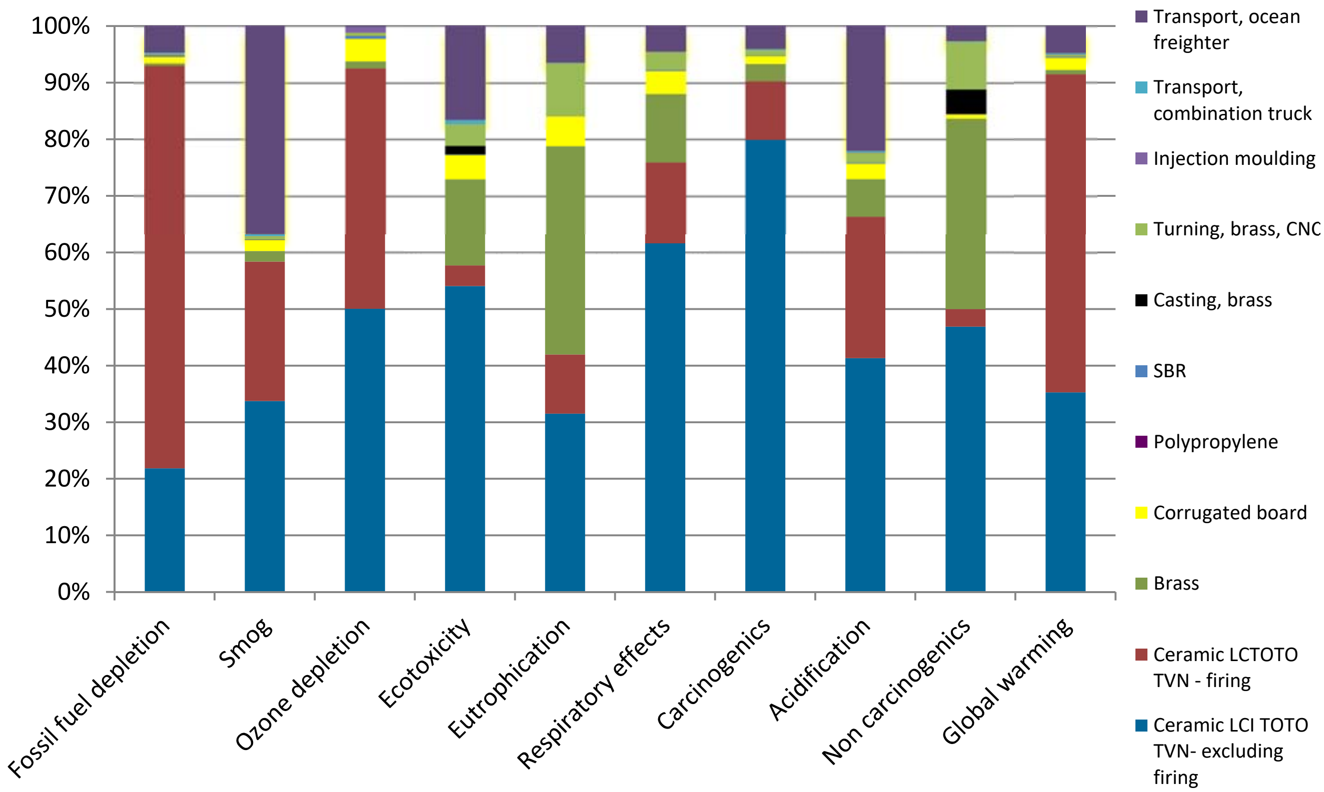

Figure 5.1b Cradle-to-gate impacts for CT725CU(F)(G)(X) – relative results (TVN: Vietnam)

Variations

The figures show similarities between the two plants because of their similar production, manufacturing process, raw materials amount, machines and yields. But, TVN's more use of natural gas and electricity resulted in bigger impacts on fossil fuel depletion and smog categories. With the accuracy of data received from both factories, the numbers in the results deviate to the average case.

Full life cycle

Figure 5.2a&b and Table 5.1 show the results per functional unit for the full life cycle of the product in both plants, STI and TVN. While the product itself [A1-A3] is significant in all impact categories, it is the impacts associated with the use phase which dominate all categories. The magnitude of the use phase impacts primarily result from the contributions of the 1.5 replacement toilets [B4] required to meet the estimated service life of the building (ESL), the reporting of which include all life-cycle impacts associated with the production, transport, use and disposal of the replacements. For the maintenance phase, the contribution is mostly due to the embedded energy use (such as electricity) in the water used during the maintenance phase, together with the cleaning agents required for maintenance. For the product itself [A1-A3] has a significant contribution to ecotoxicity (mainly caused by electricity production using natural gas and crude oil as well as the disposal of slags and hard coal ash and zinc and copper production and processing for brass alloy), fossil fuel depletion (mostly defined by the natural gas at the kiln and its extraction together with crude oil production and the production of polypropylene) and non-carcinogens (mostly from the production of brass and copper and disposal of hard coal ash in landfills). The impacts for the product itself [A1-A3] are discussed above in the cradle-to-gate section. The contribution of the delivery and installation of the product [A4-A5] which are covered

under the construction stage is associated with the transportation by truck for delivery to the market. The impacts are somewhat relevant (0-23%).
The delivery and the processes for dismantling and final waste treatment [C1-C4] of the product show up slightly relevant in the global warming impact category.

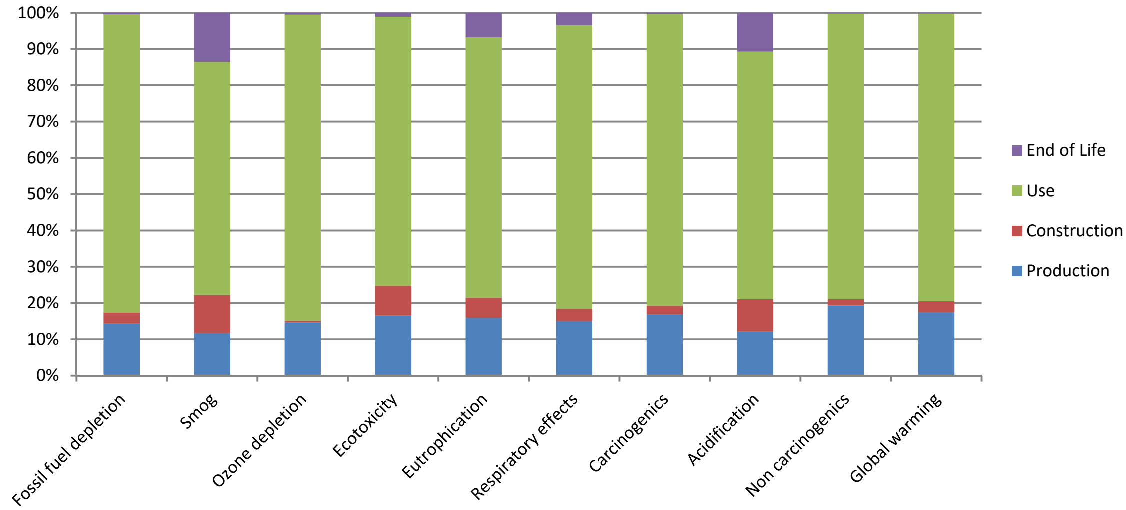

Figure 5.2a Life cycle impacts for CT725CU(F)(G)(X) – relative results (Indonesia)

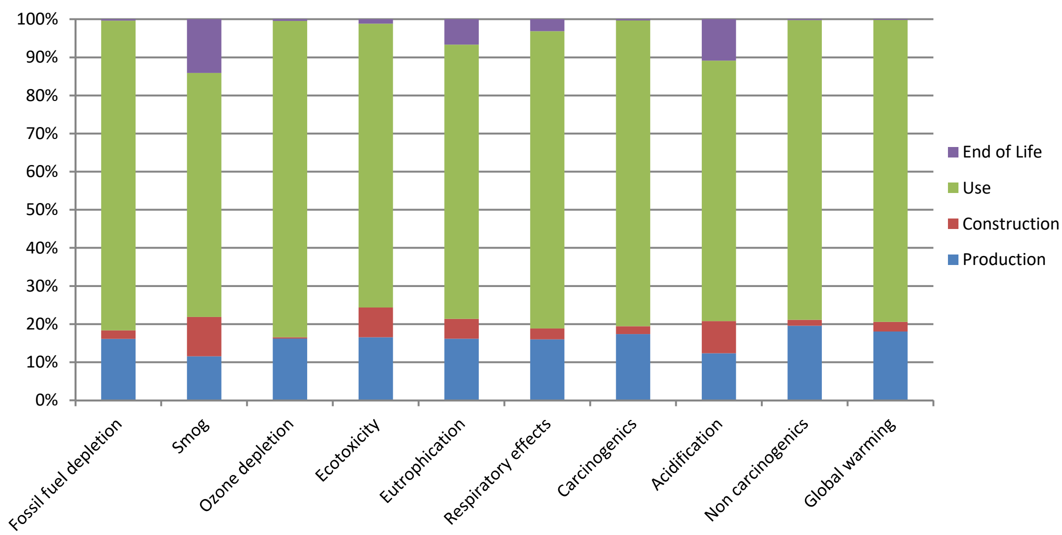

Figure 5.2b Life cycle impacts for CT725CU(F)(G)(X) – relative results (Vietnam)

Table 5.1a Life cycle impacts for average of STI and TVN's CT725CU(F)(G)(X) – absolute results

Impact category	Unit	total	Production	Construction	Use	End of Life	Recovery
Human health damage							
Smog	kg O3 eq	1.46E+02	1.70E+01	1.52E+01	9.37E+01	2.02E+01	x
Respiratory effects	kg PM2.5 eq	1.86E-01	2.91E-02	5.77E-03	1.46E-01	6.12E-03	x
Non carcinogenics	CTUh	9.53E-05	1.88E-05	1.59E-06	7.62E-05	2.25E-07	x
Ecological Damage							
Ozone depletion	kg CFC-11 eq	1.69E-05	2.63E-06	6.34E-08	1.42E-05	8.53E-08	x
Eutrophication	kg N eq	5.39E-01	8.70E-02	2.90E-02	3.90E-01	3.63E-02	x
Acidification	kg SO2 eq	5.28E+00	6.49E-01	4.58E-01	3.61E+00	5.71E-01	x
Global warming	kg CO2 eq	4.53E+02	8.07E+01	1.25E+01	3.60E+02	9.44E-01	x

Numbers shown in orange have a variation of 3 to 10%
Numbers shown in red have a variation between 10-15%

The results above shall reflect a weighted average production data in both plants and weighted average transportation distance from the multiple suppliers for each mode of transport used.

Table 5.1b Life cycle impacts for average of STI and TVN's CT725CU(F)(G)(X)

Parameter	Fossil fuel depletion	Smog	Ozone depletion	Eutrophication	Acidification	Non carcinogenics	Global warming
Unit	MJ surplus	kg O3 eq	kg CFC-11 eq	kg N eq	kg SO2 eq	CTUh	kg CO2 eq
A1-A3	1.32E+02	6.97E+00	2.63E-06	6.90E-02	3.66E-01	1.88E-05	8.06E+01
A4	2.07E+01	5.15E+00	3.48E-08	1.00E-02	1.74E-01	1.51E-06	1.18E+01
A5	1.32E+00	1.01E+01	2.86E-08	1.89E-02	2.84E-01	8.51E-08	7.59E-01
B1	x	x	x	x	x	x	x
B2	1.09E+02	1.94E+00	2.48E-06	2.49E-02	2.24E-01	7.73E-06	3.96E+01
B3	x	x	x	x	x	x	x
B4	5.97E+02	9.18E+01	1.17E-05	3.65E-01	3.39E+00	6.85E-05	3.20E+02
B5-B7	x	x	x	x	x	x	x
C1	x	x	x	x	x	x	x
C2	6.35E-01	5.73E-02	6.34E-10	1.29E-04	1.99E-03	4.64E-08	3.60E-01
C3	1.10E+00	1.01E+01	5.75E-09	1.80E-02	2.84E-01	8.72E-08	1.05E-01
C4	1.78E+00	1.01E+01	7.89E-08	1.82E-02	2.85E-01	9.17E-08	4.79E-01
Total	8.62E+02	1.36E+02	1.70E-05	5.24E-01	5.01E+00	9.67E-05	4.54E+02

Variations

The deviations at the production phase are not due to the variation in yields and the different amount of natural gas and electricity used for production. The firing yield and production yield as can be seen in Table 2.10a &b. The deviation at the construction phase is mainly due to different distance from each factory in Indonesia and Vietnam to the port of Savannah, Georgia. As shown in the table 2.13, TVN's water usage per kilogram of ceramic is higher than STI, the effect of which shows in the figure 5.2a&b and variations in table 5.1 with more impacts in different category. With the accuracy of factory data received, the numbers in the results deviate to the average case.

SM results

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

Table 5.1c Averaged SM millipoint scores for STI and TVN's CT725CU(F)(G)(X) by life cycle phase – absolute results

Impact category	Unit	TOTAL	Production A1-A3 & A1-A3 EOL	Construction A4, A5	Use B1-B7	End of Life C1-C4
SM single figure	mPts	45.03	7.38	1.81	34.84	1.2

Numbers shown in orange have a variation of 3 to 10%

LCI Indicators

It is provided in the separate excel sheet, Submittal_CT725_CT728_UT445_UT105_LCI indicators"

Table 5.1d: Additional Environmental Information

Parameter	Fossil fuel depletion	Ecotoxicity	Carcinogenics	Non carcinogenics
Unit	MJ surplus	CTUe	CTUh	CTUh
A1-A3	1.29E+02	1.08E+02	3.00E-06	2.82E-05
A4	2.21E+01	3.07E+01	1.72E-07	1.61E-06
A5	1.32E+00	1.56E+00	9.16E-09	8.51E-08
B1	x	x	x	x
B2	1.09E+02	1.89E+01	7.87E-07	7.73E-06
B3	x	x	x	x
B4	5.92E+02	4.06E+02	1.05E-05	9.70E-05
B5-B7	x	x	x	x
C1	x	x	x	x
C2	6.47E-01	9.00E-01	5.06E-09	4.72E-08
C3	1.10E+00	1.55E+00	9.85E-09	8.72E-08
C4	1.79E+00	1.83E+00	1.02E-08	9.19E-08
Total	8.58E+02	5.70E+02	1.45E-05	1.35E-04

5.2 CT728CU(V)(G)(X)

This section includes the results of CT728CU(V)(G)(X)

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Cradle-to-gate

Figure 5.1 illustrates the results per functional unit for the finished product. The results show that the ceramic parts, dominate all impact categories; however, the eutrophication and non-carcinogenic categories are heavily influenced by manufacturing of brass. The ozone depletion category is heavily impacted by ceramic parts. The contributions to the smog, carcinogenic, ecotoxicity and fossil fuel depletion categories by oceanic transportation are also relevant. The other parts, such as brass and corrugated packaging board, processes, casting and turning brass, and transportation with trucks contribute between 5% and 14% of the overall impacts in the remaining categories.

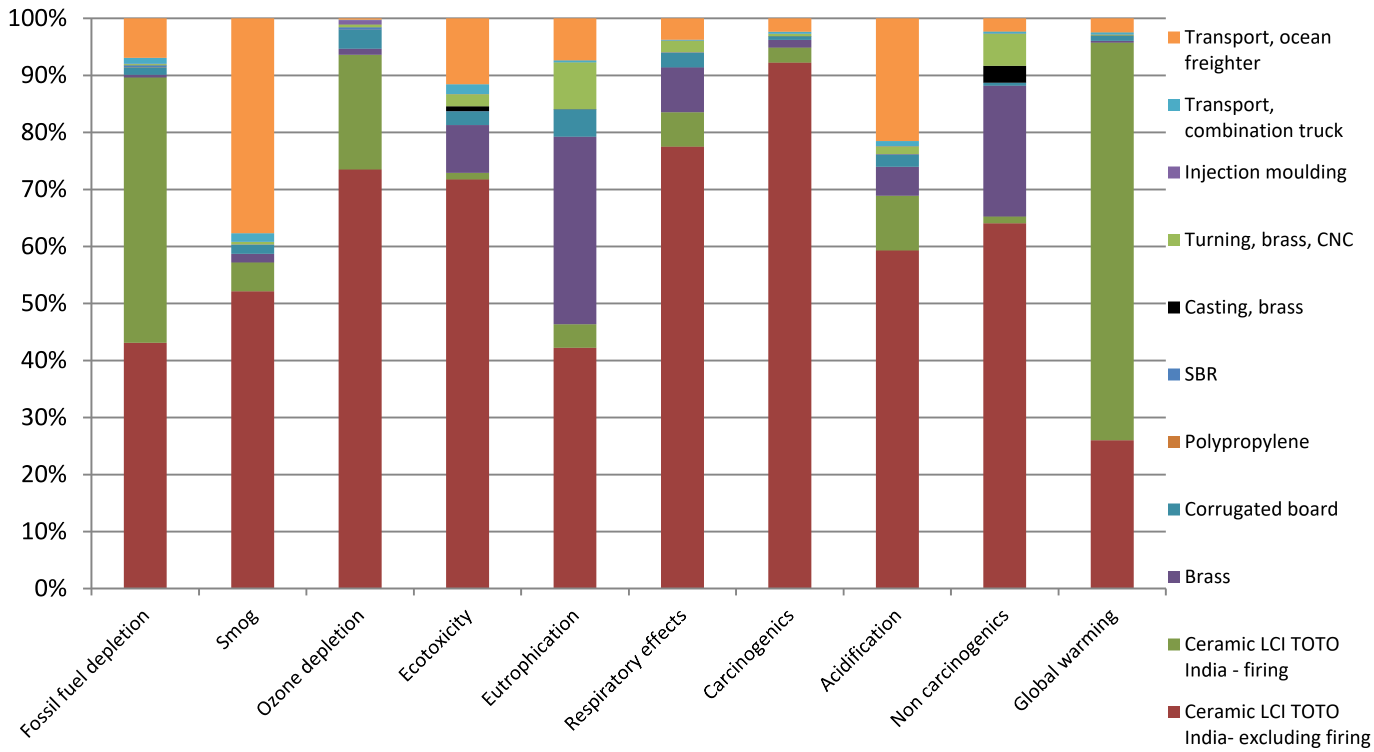
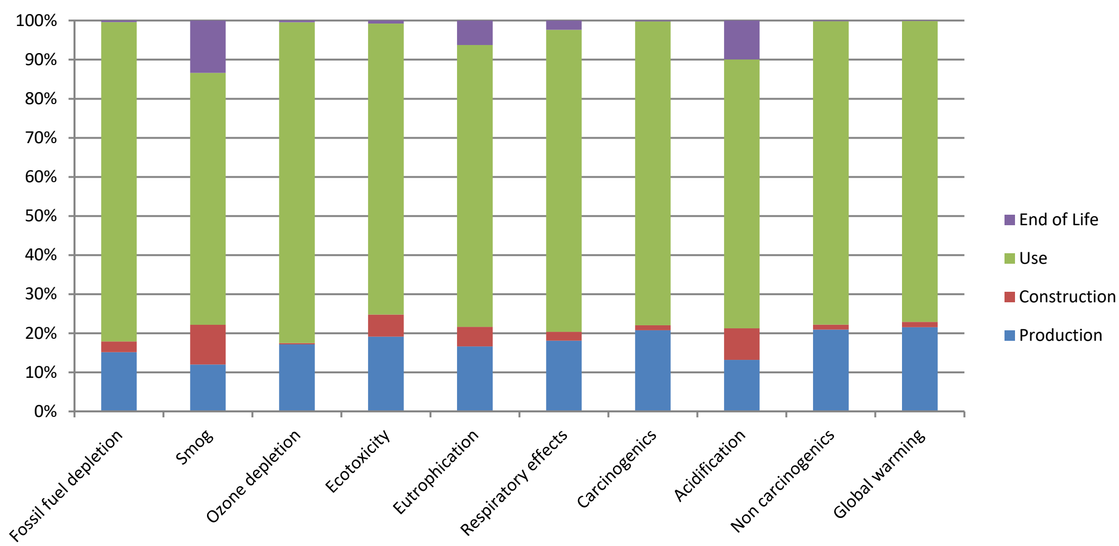


Figure 5.3 Cradle-to-gate impacts CT728CU(V)(G)(X) – relative results

Full life cycle

Figure 5.4 and Table 5.3 show 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 1.5 replacements [B4] to meet the 75 year estimated service life (ESL) , is highly dominating in all categories. For the maintenance phase [B2], the contribution is mostly due to the embedded energy use (such as electricity) in the water used during the maintenance phase, together with the cleaning agents required for maintenance. For the product itself [A1-A3] has a significant contribution to ecotoxicity (mainly caused by electricity production using natural gas and crude oil as well as the disposal of slags and hard coal ash and brass production and processing), fossil fuel depletion (mostly defined by the natural gas at the kiln and its extraction together with crude oil production and the production of polypropylene) and non-carcinogens (mostly from the production of brass and copper and disposal of hard coal ash in landfills). The impacts for the product itself [A1-A3] are discussed above in the cradle-to-gate section. The contribution of the delivery and installation of the product [A4-A5] which are covered under the construction stage is associated with the transportation by truck for delivery to the market. The impacts on all categories, especially fossil fuel depletion, smog, ecotoxity and acidification, are very significant (10-37%).

Figure 5.4 Life cycle impacts for CT728CU(V)(G)(X)-- relative results



Variations

With the accuracy of data received from TOTO factory, the numbers in the results deviate to the average case.

Table 5.2a Life cycle impacts for CT728CU(V)(G)(X) – absolute results

Impact category	Unit	total	Production	Construction	Use	End of Life	Recovery
Human health damage							
Smog	kg O3 eq	1.51E+02	1.81E+01	1.53E+01	9.72E+01	2.02E+01	x
Respiratory effects	kg PM2.5 eq	2.57E-01	4.68E-02	5.84E-03	2.00E-01	6.12E-03	x
Non carcinogenics	CTUh	1.33E-04	2.83E-05	1.70E-06	1.05E-04	2.26E-07	x
Ecological Damage							
Ozone depletion	kg CFC-11 eq	2.06E-05	3.55E-06	6.51E-08	1.70E-05	8.65E-08	x
Eutrophication	kg N eq	5.78E-01	9.66E-02	2.92E-02	4.19E-01	3.64E-02	x
Acidification	kg SO2 eq	5.73E+00	7.59E-01	4.62E-01	3.95E+00	5.71E-01	x
Global warming	kg CO2 eq	9.65E+02	2.08E+02	1.33E+01	7.43E+02	9.54E-01	x

SM results

The SM millipoint scores per functional unit by life cycle phase for this product is presented below (Table 5.4). They confirm the trends in the results using the impact assessment results prior to normalization and weighting.

Table 5.2b Life cycle impacts for CT728CU(V)(G)(X)

Parameter	Fossil fuel depletion	Smog	Ozone depletion	Eutrophication	Acidification	Non carcinogenics	Global warming
Unit	MJ surplus	kg O3 eq	kg CFC-11 eq	kg N eq	kg SO2 eq	CTUh	kg CO2 eq
A1-A3	1.29E+02	8.06E+00	3.55E-06	7.86E-02	4.76E-01	2.82E-05	2.08E+02
A4	2.21E+01	5.26E+00	3.64E-08	1.03E-02	1.78E-01	1.61E-06	1.26E+01
A5	1.32E+00	1.01E+01	2.86E-08	1.89E-02	2.84E-01	8.51E-08	7.59E-01
B1	x	x	x	x	x	x	x
B2	1.09E+02	1.94E+00	2.48E-06	2.49E-02	2.24E-01	7.73E-06	3.96E+01
B3	x	x	x	x	x	x	x
B4	5.92E+02	9.52E+01	1.45E-05	3.94E-01	3.73E+00	9.70E-05	7.04E+02
B5-B7	x	x	x	x	x	x	x
C1	x	x	x	x	x	x	x
C2	6.47E-01	5.83E-02	6.46E-10	1.32E-04	2.03E-03	4.72E-08	3.66E-01
C3	1.10E+00	1.01E+01	5.75E-09	1.80E-02	2.84E-01	8.72E-08	1.05E-01
C4	1.79E+00	1.01E+01	8.01E-08	1.82E-02	2.85E-01	9.19E-08	4.83E-01
Total	8.58E+02	1.41E+02	2.07E-05	5.63E-01	5.46E+00	1.35E-04	9.66E+02

Table 5.2c SM millipoint scores for CT728CU(V)(G)(X) by life cycle phase – absolute results

Impact category	**Unit**	**Total**	**Production A1-A3 & A1-A3 EOL**	**Construction A4, A5**	**Use B1-B7**	**End of Life C1-C4**
SM single figure	mPts	69.74	13.51	1.88	53.34	1.2

LCI Indicators

It is provided in the separate excel sheet, Submittal_CT725_CT728_UT445_UT105_LCI indicators"

Table 5.2d Additional Environmental Information

Parameter	Fossil fuel depletion	Ecotoxicity	Carcinogenics	Non carcinogenics
Unit	MJ surplus	CTUe	CTUh	CTUh
A1-A3	1.29E+02	1.08E+02	3.00E-06	2.82E-05
A4	2.21E+01	3.07E+01	1.72E-07	1.61E-06
A5	1.32E+00	1.56E+00	9.16E-09	8.51E-08
B1	x	x	x	x
B2	1.09E+02	1.89E+01	7.87E-07	7.73E-06
B3	x	x	x	x
B4	5.92E+02	4.06E+02	1.05E-05	9.70E-05
B5-B7	x	x	x	x

C1	x	x	x	x
C2	6.47E-01	9.00E-01	5.06E-09	4.72E-08
C3	1.10E+00	1.55E+00	9.85E-09	8.72E-08
C4	1.79E+00	1.83E+00	1.02E-08	9.19E-08
Total	8.58E+02	5.70E+02	1.45E-05	1.35E-04

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 Indonesia and Vietnam, and India, for CT725 and CT728 respectively. All primary data were 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 were provided by the manufacturer and represent all information for calendar year 2023. 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 V9.5 LCI datasets. Time coverage of the datasets varies from approximately 2022 to present. One exception is a dataset from 2016, but the overall contribution of that dataset to results is negligible. All datasets rely on at least one 1-year average data. Overall time coverage of the datasets is considered good and meets the requirement of the PCR that all data be updated within a 10- year period. The specific time coverage of secondary datasets can be found in Table 5.4.

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 of 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 LCI datasets. 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.. Any proxies used for raw materials have also been detailed in Table 5.4..

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 manufacturing facilities. The raw material transportation distances were calculated based on the raw material manufacturers' addresses, extracted from the relevant SDS's. Proxy datasets were utilized in the LCA model when secondary data were not available, as shown in Appendix A. Precision can be increased via sub-metering individual manufacturing processes to better account for manufacturing processes rather than including overhead utility information.

Completeness
The data included is consider 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. 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: Key datasets used in inventory analysis

Dataset	Source	Year of Last Update	Time Coverage	Geographical Coverage	Technological Coverage	Overall Representatives	Relevant Module	Description
Slack wax, at plant, US SE NREL/US U	Ecoinvent	2021	within 10-year period	US	Appropriate technology	very good	A5	Ancillary materials
China clay, Kaolin KTcast A/F US-EI 2.2	Ecoinvent	2021	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Brass, at plant/US* US-EI U	Ecoinvent	2021	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Synthetic rubber, at plant/US- US-EI U	Ecoinvent	2021	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Silica sand, at plant/US** US-EI U	Ecoinvent	2022	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Feldspar, at plant/RER S	Eocinvent	2022	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials

Limestone, milled, packed, at plant/US* US-EI U	Ecoinvent	2022	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	Ecoinvent	2012	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Dolomite, milled, loose US-EI 2.2	USLCI	2012	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Tap water, at user/US- US-EI U	Ecoinvent	2022	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 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Rubber sealing compound (EN15804 A1-A3)	Ecoinvent	2022	within 10-year period	US	Appropriate technology	very good	A1-A3	Raw materials
Electricity, low voltage, at grid, India FY2016 US-EI 2.2	USLCI	2022	within 10-year period	India	Appropriate technology	good	A1-A3	Energy
Heat, natural gas, at boiler condensing modulating >100kW/RER U	USLCI	2020	within 10-year period	India	Appropriate technology	good	A1-A3	Energy
Electricity, low voltage, at grid, Indonesia FY2016 US-EI 2.2	USLCI	2016	within 10-year period	Indonesia	Appropriate technology	good	A1-A3	Energy
Heat, natural gas, at boiler condensing modulating >100kW/RER U	USLCI	2020	within 10-year period	Indonesia	Appropriate technology	good	A1-A3	Energy
Electricity, low voltage, at grid, Vietnam FY2016 US-EI 2.2	USLCI	2016	within 10-year period	Vietnam	Appropriate technology	good	A1-A3	Energy
Heat, natural gas, at boiler modulating <100kW/RER S	USLCI	2020	within 10-year period	Vietnam	Appropriate technology	good	A1-A3	Energy
Transport, combination truck, average fuel mix NREL/US U	Ecoinvent	2021	within 10-year period	Vietnam	Appropriate technology	good	A4	Transport

Transport, train, diesel powered NREL/US U	Ecoinvent	2021	within 10-year period	Vietnam	Appropriate technology	very good	A4	Transport
Transport, ocean freighter, average fuel mix NREL/US U	Ecoinvent	2021	within 10-year period	US	Appropriate technology	very good; technologic proxy	A4	Transport
Transport, lorry >16t, fleet average/RER S	Ecoinvent	2021	within 10-year period	India	Appropriate technology	good	A4	Transport
Transport, train, diesel powered NREL/US U	Ecoinvent	2021	within 10-year period	India	Appropriate technology	very good	A4	Transport
Transport, passenger car, diesel, fleet average 2010/RER U	Ecoinvent	2021	within 10-year period	Indonesia	Appropriate technology	very good	A4	Transport
Transport, train, diesel powered NREL/US U	Ecoinvent	2021	within 10-year period	Indonesia	Appropriate technology	very good	A4	Transport

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 below.

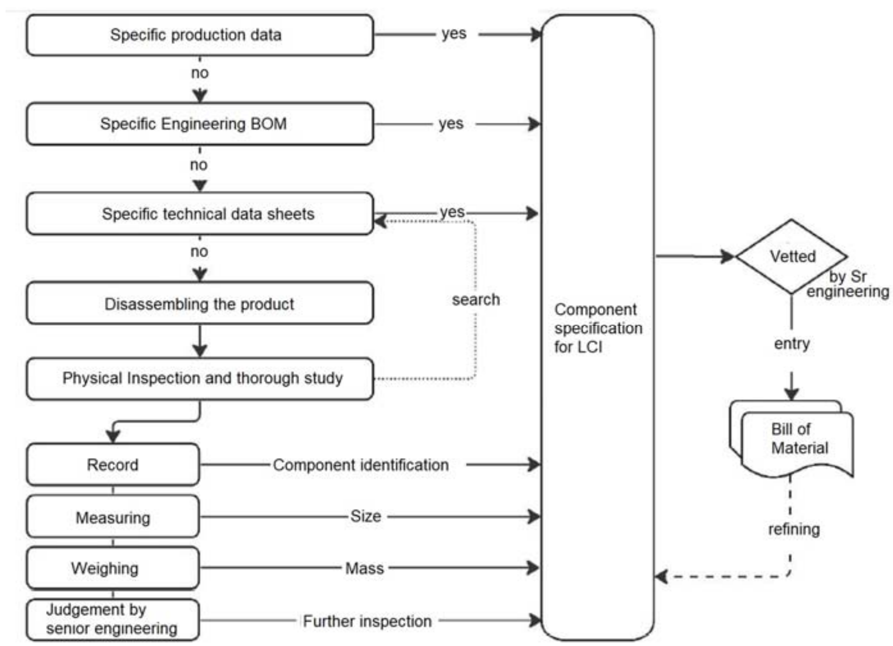


Figure : Data collection procedure

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 as visualized in Figure 4-1, 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 factories and its suppliers and an analysis of the actual components. For some modules, a bill of materials was provided by TOTO factories 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 shall 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 worst-case scenario in that all materials were primary.

The study used scenarios for the end of life. The analysis will include the toilet bowls only-without any flushing mechanism and hence no water flow and no water use impacts. A flushometer valve, which may be used with these bowls, does have a flushing mechanism and water control and it will be analyzed separately with its own LCA. Since the use phase is important for the results of the LCA, it is recommended to discuss and validate the better approach (toilet bowl only vs. Bowl and a flushometer valve combo) with industry stakeholders to establish a common practice. This has been established by Part B.

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 years validity of a Transparency Report, 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 the Morrow facility and others, 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 in 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] Bare JC (2012) Tool for the reduction and assessment of chemical and other environmental impacts (TRACI), Software name and version number: TRACI Version 2.1, User’s Manual. US EPA.

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[5] Bare, Jane; Gloria, Tom and Norris, Greg, Development of the Method and U.S. Normalization Database for Life Cycle Impact Assessment and Sustainability Metrics, Environmental Science and Technology, / VOL. 40, NO. 16, 2006

[6] Sustainable Minds Transparency Report™ Framework, Part A: LCA calculation rules and report requirements. Version 2024.

[7] Sustainable Minds Transparency Report™ / EPD Framework, Part B: Product group definition | Commercial toilets | Part B #23-003, version March 6, 2024.

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
STI	Surya Toto Indonesia (TOTO Indonesia)
TVN	TOTO Vietnam
TIN	TOTO India

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 facilities.

Table A.1 Products BOMs

CT725CU(F)(G)(X) (Indonesia)

			Part Listing	Part #	Materials	Q'ty	Weight per part or material (kg)	DATA Source	DATA TYPE	DATA Year	Processes (casting, injection molding, etc.)	City,Country of the materials (Raw and Finished Goods)
	1		TOILET BOWL	CT725	bowl itself	1	23.72	F	M	2023	molding	Indonesia
Secondary Data Set	2		SPUD	TH****	see below	1		F	M	2023		Indonesia
		1	Spud		Brass	1	0.16	F	M	2023	casting	Indonesia
		2	Gasket		EPDM	1	0.031	F	M	2023	injec mold	Indonesia
		3	Washer		Brass	1	0.0064	F	M	2023	milling	Indonesia
		4	Nut		Brass	1	0.051	F	M	2023	rolling brass	Indonesia
	3		CARTON BOX	0BU061	Corrugated board	1	0.63	F	M	2023	rolling, cutting	Indonesia
	4		SIDE INSERT 1	0DU368	Corrugated board	1	0.38	F	M	2023	rolling, cutting	Indonesia
	5		SIDE INSERT 2	0DU369	Corrugated board	1	0.38	F	M	2023	rolling, cutting	Indonesia
	6		c-UPC LABEL STICKER	0EU036	Paper	1	0.0003	F	M	2023	rolling, cutting	Indonesia
	7		INSTALLATION WARNING		Paper	1	0.02	F	M	2023	rolling, cutting	Indonesia
	8		INSTALLATION MANUAL		Paper	1	0.02	F	M	2023	rolling, cutting	Indonesia
	9		PRODUCT LABEL	0EU082	Paper	1	0.00354	F	M	2023	rolling, cutting	Indonesia

CT725CU(F)(G)(X) (Vietnam)

			Part Listing	Part #	Materials	Q'ty	Weight per part or material (kg)	DATA Source	DATA TYPE	DATA Year	Processes (casting, injection molding, etc.)	City,Country of the materials (Raw and Finished Goods)
	1		TOILET BOWL	CT725	bowl itself	1	23.72	F	M	2023	molding	Vietnam
Secondary Data Set	2		SPUD	TH****	see below	1		F	M	2023		Vietnam
		1	Spud		Brass	1	0.16	F	M	2023	casting	
		2	Gasket		EPDM	1	0.031	F	M	2023	injec mold	
		3	Washer		Brass	1	0.0064	F	M	2023	milling	
		4	Nut		Brass	1	0.051	F	M	2023	rolling brass	
	3		CARTON BOX	0BU061	Corrugated board	1	0.63	F	M	2023	rolling, cutting	Vietnam
	4		SIDE INSERT 1	0DU368	Corrugated board	1	0.38	F	M	2023	rolling, cutting	Vietnam
	5		SIDE INSERT 2	0DU369	Corrugated board	1	0.38	F	M	2023	rolling, cutting	Vietnam
	6		c-UPC LABEL STICKER	0EU036	Paper	1	0.0003	F	M	2023	rolling, cutting	Vietnam
	7		INSTALLATION		Paper	1	0.02	F	M	2023	rolling,	Vietnam

		WARNING								cutting	
	8	INSTALLATION MANUAL		Paper	1	0.02	F	M	2023	rolling, cutting	Vietnam
	9	PRODUCT LABEL	0EU082	Paper	1	0.00354	F	M	2023	rolling, cutting	Vietnam

CT728CU(V)(G)(X)

			Part Listing	Part #	Materials	Q'ty	Weight per part or material (kg)	DATA			Processes (casting, injection molding, etc.)	City, Country of the materials (Raw and Finished Goods)
								Source	TYPE	Year		
	1		TOILET BOWL	CT728	bowl itself	1	24.15	F	M	2023	molding	Gujarat, India.
Secondary Data Set	2		SPUD	TH****	see below	1		F	M	2023		Gujarat, India.
		1	Spud		Brass	1	0.16	F	M	2023	casting	Gujarat, India.
		2	Gasket		EPDM	1	0.031	F	M	2023	injec mold	Gujarat, India.
		3	Washer		Brass	1	0.0064	F	M	2023	milling	Gujarat, India.
		4	Nut		Brass	1	0.051	F	M	2023	rolling brass	Gujarat, India.
	3		CARTON BOX	0BU061	Corrugated board	1	0.63	F	M	2023	rolling, cutting	Gujarat, India.
	4		SIDE INSERT 1	0DU368	Corrugated board	1	0.38	F	M	2023	rolling, cutting	Gujarat, India.
	5		SIDE INSERT 2	0DU369	Corrugated board	1	0.38	F	M	2023	rolling, cutting	Gujarat, India.
	6		c-UPC LABEL STICKER	0EU036	Paper	1	0.0003	F	M	2023	rolling, cutting	Gujarat, India.
	7		INSTALLATION WARNING		Paper	1	0.02	F	M	2023	rolling, cutting	Gujarat, India.
	8		INSTALLATION MANUAL		Paper	1	0.02	F	M	2023	rolling, cutting	Gujarat, India.
	9		PRODUCT LABEL	0EU082	Paper	1	0.00354	F	M	2023	rolling, cutting	Gujarat, India.

Table A.2 LCI data for zinc die casting process

Die casting, zinc	1	kg
Operating temperature is slightly higher than casting of brass and bronze. A small amount of zinc evaporates. The evaporation losses are estimated at 0.1%wt. Adapted from EcoInvent LCI for die casting of bronze.		
Materials/fuels		
Aluminum casting, plant	4.9E-11	p
Electricity, medium voltage, production	0.0205	kWh
Heat, heavy fuel oil, at industrial furnace 1MW	0.2952	MJ
Heat, natural gas, at industrial furnace >100kW	0.369	MJ
Emissions to air		
Heat, waste	0.0708	MJ
Zinc	0.001	kg

Table A.3 LCI data for turning brass CNC process

Turning, brass, 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.		
Materials/fuels		
Electricity, low voltage, production	0.992	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
Brass, at plant	1	kg
Emissions to air		
Heat, waste	3.57	MJ
Waste to treatment		
Disposal, used mineral oil, 10% water, to hazardous waste incineration	0.00382	kg

Table A.4 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.		
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.5 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.6 LCI data for brass die casting process

Die casting, brass	1	kg
Operating temperature is slightly higher than casting of brass. A small amount of Brass evaporates. The evaporation losses are estimated at 0.1%wt. Adapted from EcoInvent LCI for die casting of bronze.		
Materials/fuels		
Aluminum casting, plant	4.9E-11	p
Electricity, medium voltage, production	0.0197	kWh
Heat, heavy fuel oil, at industrial furnace 1MW	0.283	MJ
Heat, natural gas, at industrial furnace >100kW	0.354	MJ
Emissions to air		
Heat, waste	0.0708	MJ
Brass	0.000303	kg

Table A.7 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 methodology and is reported in [Bare, 2012]. The contents of this publication are presented in this appendix. A definition of the impact categories within TRACI is available in the appendices of Part A [6].

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 a separate spreadsheet "LCA of TOTO Ceramic Products – CT Modeling Data and Results 03-2023.xlsx".

APPENDIX E. LCI

The LCI results per functional unit for all products are included in a separate spreadsheet "LCA of TOTO Ceramic Products – CT Modeling Data and Results 03-2023.xlsx".

APPENDIX F. LCIA METHOD

The LCIA characterization factors are included in a separate spreadsheet "LCA of TOTO Ceramic Products – CT Modeling Data and Results 03-2023.xlsx".

APPENDIX G. PROCESS FLOW DIAGRAMS

Process flow diagrams per functional unit of product are included in a separate spreadsheet "LCA of TOTO Ceramic Products – CT Modeling Data and Results 03-2023.xlsx". The modeled materials and energy flows are presented