LIFE CYCLE ASSESSMENT (LCA)
OF TOTO SANITARY FITTING PRODUCTS

Status: Draft for third party review

Client: TOTO USA

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Author(s): Gary Soe

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 Assessment (LCA) 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, we are more informed on how to reduce impacts on a broader scale. TOTO is the first company in the U.S. plumbing industry to conduct a cradle-to-gave LCA.

TOTO is interested in having Life Cycle Assessment data available for the most important products to be able to obtain SM Transparceny Reports™, Type III environmental declarations that can be used for communication with and amongst other companies, architects and consumer communication, and can also be utilized in whole building LCA tools.

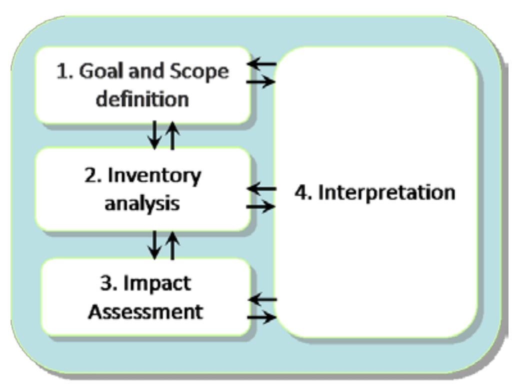
TOTO commissioned Sustainable Minds to help develop LCAs for the most important fitting products. However, TOTO works to develop the internal capacity to conduct LCAs. This means that an effort has been made to gather data and, when necessary, to train TOTO staff to model LCAs and how to report on them. TOTO wants to learn from the results and is looking forward to having guidance for future product improvements that can be deduced from the results.

1.2 Life Cycle Assessment

Performing a life cycle assessment (LCA) follows the Sustainable Minds Transparency Report / EPD Framework which is based on ISO 14040-44 & 14025 standards. 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; therefore, a critical review is not required. An ISO 14044 third party review and a third party Transparency Report verification for product information are options in the Framework to be able to use it as a Type III Environmental Declaration. Both of these reviews will be completed in this project.

1.3 Status

All information in the report reflects the best possible inventory by TOTO at the time it was collected and best-practice of Sustainable Minds to transform this information into this LCA report was conducted. The data covers annual manufacturing data for the time period between the years 2015 and 2017. 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. TOTO relies on vendors for the components and assembly of some of the fittings 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 the WAP Director, who was contracted on behalf of NSF. The review concluded that the report is in conformance with ISO 14040-44. Several comments have been made and responses to them were provided by the LCA specialist. A review statement is included in the appendices of this report.

TOTO has also chosen to have the Transparency Reports undergo third party verification against Parts A and B of the SM Transparency Report / EPD Framework v2017. A third party review has been performed by the WAP Director who was contracted on behalf of NSF. The review concluded that the reports are in conformance with the Sustainable Minds Transparency Report / EPD Framework. Several comments have been made and responses to them were provided by the LCA specialist. A review statement is included in the appendices of this report.

1.4 Team

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

- Gary Soe, Project Manager and Senior Product Engineer

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

From Sustainable Minds:

- Kim Lewis, LCA Practitioner

1.5 Structure

This report follows the structure of the life cycle assessment methodology defined in the Framework as well as the Product Group Definitions (Part Bs) 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 lays down 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.

2.1 Intended application and audience

This report intends to define the specific application of the LCA methodology to the life cycle of TOTO fittings. It is intended for both internal and external purposes. A Sustainable Minds Transparency Report, a Type III Environmental Declaration per ISO 14025, will report the results of this study which is focused on products that are available in the US market.

2.2 TOTO products

TOTO USA is one of the world's largest plumbing products manufacturers and offers a complete line of commercial and decorative plumbing fixtures and fittings, faucets, accessories, shower and flush valves, as well as lavatories, toilets, air baths and urinals. Their 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 are listed in Table 2.1a include three fittings products. The categories of Transparency Reports and manufacturing location are presented in Table 2.1b. Table 2.1c lists the 2016 production volumes of the modeled products which are used in the declaration of the corresponding average product.

Table 2.1a Product codes and SM project concepts

Product code(s)	SM project concept
TET2LA	LCA of a TOTO flushometer valve in combination with a toilet
TEU2UA & TEU2LA	LCA of two TOTO flushometer valves in combination with a urinal

Table 2.1b Categories of declarations, vendors and manufacturing locations

Product code(s)	Category	Vendor(s) Name(s)	Production Location(s)
TET2LA	A declaration of a specific product from a manufacturer's plant	TOTO Shanghai	China
TEU2UA & TEU2LA	A declaration of an average product from a manufacturer's plant	TOTO Shanghai	China

Table 2.1c 2016 production volumes of the modeled products (confidential)

Product code	Production volume (pieces)
TET2LA	
TEU2UA	
TEU2LA	

Below are some pictures and descriptions of selected products.

Table 2.2 Descriptions of the modeled products

TET/U 2LA 	▪ EcoPower® toilet and/or urinal flushometer valve only ▪ Revolutionary self-generating hydropower system ▪ Automatic sensor activated piston toilet flush valve ▪ Superior Piston Valve ▪ ADA Compliant ▪ Watersense EcoPower® toilet and urinal flushometer valve only, concealed model, 1.28 gpf for toilet, TET2LA, and 0.5 gpf for urinal, TEU2LA. Neutral rough-in. Stainless Steel Finish.
TEU2UA 	▪ EcoPower® urinal flushometer valve only ▪ Revolutionary self-generating hydropower system ▪ Automatic sensor activated piston toilet flush valve ▪ Superior Piston Valve ▪ ADA Compliant ▪ Watersense EcoPower® urinal flushometer valve only, concealed model, 0.125 gpf. Neutral rough-in. Stainless Steel Finish.

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 products (Table 2.3). The Transparency Reports of the corresponding products listed in Table 2.1 are expressed in terms of one respective piece of product as well as all life cycle modules which are presented later in this report. The 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. The list of functional units and their corresponding products is presented in Table 2.3. The functional units are taken from the product group definition (Part B) for Commercial Flushometer Valves [7]. TOTO products comply with the functional performance specifications laid down in the aforementioned Part B.

Table 2.3 Functional units of the modeled products

Product code(s)	Functional Unit
TET2LA	10 years of use of a flush valve for toilets and urinals in an average U.S. commercial environment.
TEU2LA & TEU2UA	10 years of use of a flush valve for toilets and urinals in an average U.S. commercial environment.

2.4 System boundaries

To define what is and what is not included in an LCA, the so-called system boundaries are drafted. In general, the system boundaries as laid down in Part A [6] are followed. This section details some of the aspects to assist the reader to understand what is inlcuded 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 a 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
- Use
- End of life
- Recovery

These boundaries apply to all the modeled products and can be referred to as "cradle-to-grave" which means that it includes all life cycle stages and modules as indentified in Part A [6].

The system boundaries for TOTO fitting products are detailed below. Figure 2.1 represents a process flow diagram 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 fitting 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 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

Table 2.4 Fitting products' weights

Product Code	TET/U 2LA	TEU2UA
Total weight (kg, excluding packaging)	3.25	3.03

The metal components make up the largest portion of the body of a fitting. Inputs to the production system of the modeled fitting products are comprised of the following, showing all the parts that have a contribution > 0.15% weight of the total bill of materials:

Table 2.5 Fitting products' raw materials (confidential)

Constituent / Material type	Mater-ials (%)	Recycled content %	Mater-ials (%)	Recycled content %
	TET/U 2LA		TEU2UA	
AA Li-ion battery				
ABS				
Brass				
Brass (C360000)				
Brass (crovalent coating)				
Bronze				
Bronze (C836000)				
Copper				
Copper alloy				
Double wall				
EPDM				
Epoxy resin				
Magnet				
NBR				
Paper				
Surface mount, Pb containing				
Polyacetal				
polyethylene				
PP				
PPO				
PPS				
PU rigid				
PE				
Steel				
Surfacemount				
Stainless steel, SUS303				
Stainless steel, SUS304				
Stainless steel, SUS316				
PE				

The recycled content is particularly relevant for the metal components. The values of the recycled content provided by the vendors is presented. A more detailed raw materials definition of the products as required by Part A is presented in appendix A (Tables A.1 through A.5).

Included are all materials that together contribute over 99% of the weight of all fitting parts, excluding packaging materials. The specific numbers of completeness are listed below (Table 2.6).

Table 2.6 Completeness of the parts with 0.15% weight cut-off

Product code	%wt covered
TET/U 2LA	99.35
TEU2UA	99.58

2.4.1.2. Packaging

The finished product is packaged and ready for transportation to the US market. The specific numbers of the packaging materials' weights are listed below (Table 2.7).

Table 2.7 Packaging information for fittings

Product code	Total weight (g)	Cardboard (g)	Others* (g)
TET/U 2LA	832.72	681.07	151.64
TEU2UA	832.72	681.07	151.64

*Others are manuals (paper) and bags (PE) and stickers (aluminum)

2.4.1.3. Transportation

The transportation of the materials to the manufacturing sites and/or to the warehouse (FAP[1]) were either provided by vendors or estimated. The totals per product are presented below (Table 2.8).

Table 2.8 Transportation of materials to manufacturing sites and/or to FAP (confidential)

Means	tkm	
	TET/U 2LA	TEU2UA
Truck		
Rail		
Ocean freighter		
UPS Truck		

2.4.1.4. Manufacturing

The process flow for fittings products is as follows:

- Raw materials, such as ores petroleum byproducts, are purchased and utilized in the manufacturing of intermediates (materials with certain engineering properties). Intermediates include metal alloys such as brass, steel, bronze, etc. Others include non-metals such as rubbers and thermoplastics.
- Often, the intermediates are manufactured in the same facility in which the fitting's sub-assemblies are manufactured. If not, the intermediates are purchased and transported to the facility.
- The intermediates are manufactured into various fittings' sub-assemblies, each designated for a specific function. The primary methods used for shaping sub-assemblies include, but are not limited to:
  - Sheet rolling
  - Turning
  - Injection molding
  - Wire drawing
  - Tempering
  - Extrusion
  - Potting
  - Soldering
- Depending on their function, some components undergo the following secondary and tertiary processes to alter aesthetics which include but are not limited to:
  - Polishing, brushing and etching
  - Electroplating and PVD plating

[1] FAP = TOTO Fairburn Assembly Plant

- TOTO purchases fittings products from the manufacturer as either finished goods or as sub-assemblies and components. These purchases are shipped to the TOTO Fairburn Assembly Plant (FAP).
  - Finished goods: Finished Goods are visually and dimensionally inspected and water tested by the manufacturer to ensure that they meet TOTO's aesthetic and performance criteria. Electrical components are tested for proper function as well. The materials in the pieces that fail inspection are reworked, recycled as scrap metals, or sent to landfill. Pieces that pass are assembled and packaged as finished goods. Finished goods are shipped to FAP and go directly into inventory.
  - Sub-assemblies: Sub-assemblies and components undergo various levels of inspection by the manufacturer. They are packaged and shipped for further inspection, testing, and assembly by FAP.
- Further assembly by FAP may be required to the purchased sub-assemblies.
- Sub-Assemblies are visually and dimensionally inspected and water tested in FAP to ensure that they meet TOTO's aesthetic and performance criteria. The materials in the pieces that fail inspection are reworked, recycled as scrap metals, or sent to landfill. Pieces that pass are assembled and packaged as a finished good and placed into inventory.

To model the manufacturing, the processes involved and the yield percentages of the primary processes were provided by the vendors and modeled. Secondary and tertiary processes were also provided by the vendors and are modeled. An overview of these processes for each corresponding product are included in the tables below (2.9 (a) through 2.9 (c)). The tables list the types of processes, the materials and the average yield percentages for primary processes. The combination of the processes and the materials is used as the basis for the manufacturing model.

Table 2.9 (a): Primary processes, materials and yield for TET2LA and TEU2LA (confidential)

TET2LAand TEU2LA		
Primary Process	**Material(s)**	**Average Yield (%)**
Bronze Die Casting		
Extrusion		
Injection Molding		
Sheet Rolling, Steel		
Tempering		
Turning, Brass, CNC		
Turning, Bronze, CNC		
Turning, Steel, CNC		
Wire Drawing		

Table 2.9 (b): Primary processes, materials and yield for TEU2UA (confidential)

TEU2UA		
Primary Process	**Material(s)**	**Average Yield (%)**
Bronze Die Casting		
Extrusion		
Injection Molding		
Sheet Rolling, Steel		
Tempering		
Turning, Brass, CNC		
Turning, Bronze, CNC		
Turning, Steel, CNC		
Wire Drawing		

Table 2.9 (c): Secondary and tertiary processes and materials for TET2LA, TEU2LA and TEU2UA (confidential)

TET2LA, TEU2LA and TEU2UA	
Secondary and Tertiary Process	**Material(s)**
Polishing	
Electroplating	
Potting	
Soldering	

2.4.2. Construction 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

After products are purchased by distributers, dealers, and showrooms for purchase by the end users, they are transported f om the FAP warehouse to these purchasers. Transportation and distance would vary and are dependent on the locations of the purchasers and their choice of shipping mode. Transportation of finished packaged products to the warehouse from vendors is done by diesel trucks (average of 30mi). Outbound shipments to customers from FAP are transported by both diesel truck (average of (confidential)) and rail (average of (confidential)). These numbers are estimated based on actual 2016 shipment averages.

2.4.2.2. Construction / Installation

After customers purchase the fitting products from distribution centers, fittings are installed with other toilets, urinals or sinks. Other than packaging cartons, bags and manual becoming waste, nothing else is required or removed at this stage. Waste processing of the waste from product packaging up to the end-of-waste state or disposal of final residues is included in this module.

2.4.3. Use stage [B1-B5]

The use stage includes the following information modules:

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

2.4.3.1. Use or application of the installed product

There are no additional activities or construction work needed or associated with the installation of the product during the use phase. Therefore, this is not included in the model.

2.4.3.2. Maintenance

The service life is defined in such as way that for a typical installation, no regular maintenance activities other than cleaning of the sanitary facilities as a whole is required. There is no maintenance as such included in the model.

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 as way that for a typical installation, no refurbuishment 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 fitting products modeled in this report follow the declared default life cycle use phase scenario in the approved Part B for Commercial Flushometer Valves referenced herein [7]. The water usage of the products is calculated and a summary of the same is listed in Table 2.10.

Table 2.10 Water usage of the products

Product(s) code(s)	Total number of uses during modeled life	Water consumption (gal/use)	Total consumption during modeled life (gal)

TET2LA	260 days/year x 10 years x 51 uses/day = 132,600 uses	1.28	169,728
TEU2LA	260 days/year x 10 years x 18 uses/day = 46,800 uses	0.5	23,400
TEU2UA	260 days/year x 10 years x 18 uses/day = 46,800 uses	0.125	5,850

Water usage in a residential or commercial environment would also include electricity usage for acquisition, treatment and distribution of water to households and collection, conveyance and wastewater treatment of domestic wastewater. Heating for hot water use was not included in the model. Electric Power Research Institute (EPRI) published this type of data in a study on water and sustainability. U.S. EPA data were used to establish weighted average composite factors, to obtain an electricity usage per gallon of water consumed. The foregoing is summarized in Table 2.11 below.

Table 2.11 Average national electricity usage per gallon of water consumed

Activity	***EPRI factors: kWh / MMgal*** [Note 1]	***Weighted avg composite factors: kWh / MMgal***
Acquisition, treatment and distribution of surface water by a Public Water System (PWS)	1,406	1,540 [Note 2]
Acquisition, treatment and distribution of ground water by a PWS	1,824	
Self-supply of drinking water (typically pumping from private wells)	700	700
Collection, conveyance and < secondary treatment of domestic wastewater	661	1,399 [Note 3]
Collection, conveyance and secondary treatment of domestic wastewater	1,212	
Collection, conveyance and advanced treatment of domestic wastewater	1,726	
Collection, conveyance and zero discharge/other treatment of domestic wastewater	400	
	Total electricity per million gallons →	3,639
	Total kWh electricity per 1 gallon →	**0.0036**

Note 1: Source: EPRI, Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment -- The Next Half Century, March 2002.
Note 2: 63% of population served by PWSs relies on surface water, 37% on ground water. Calculated from http://www.epa.gov/safewater/pws/factoids.html.
Note 3: 1.5% of POTW-served population receives < secondary treatment, 43.3% receives secondary treatment, 48.7% receives advanced treatment, and 6.5% receives zero discharge or other treatment. Source: EPA, 2004 Clean Watersheds Needs Survey.

The summary of the use phase data for the fittings over their respective reference service lives is provided in Table 2.12 below.

Table 2.12 Fitting Use Phase Data Summarized

Product code	**Water usage (gallon)**	**Electricity usage (kWh)**
TET2LA	169,728	611.02
TEU2LA	23,400	84.24
TEU2UA	5,850	21.06

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

At their end of life, it is assumed that the fittings and most of their components are going to follow the percentages published in the U.S. EPA's Municipal Solid Waste Generation, Recycling, and Disposal in the United States Report for 2012[2]. According to the report, 64.6% of paper and paperboard, 33.0% of the steel, 19.8% of aluminium, 68.0% of other non-ferrous metals, 17.9% of rubber, 8.8% of plastics and 27.7% of glass in municipal wastes are recycled. These percentages were used to define the waste scenarios of the fittings and their components at their end of life.

Table 2.13 List of modeled waste scenarios

Material	Waste scenario	
	Recycling	**Landfill**
Brass, copper, copper alloy, bronze	68.0%	32.0%
Double wall, paper	64.6%	35.4%
Plastics	8.8%	91.2%
NBR, chloroprene rubber	17.9%	82.1%
AA Li-ion battery, magnet, surface mount	0.0%	100.0%
Stainless steel, ateel alloy	33.0%	67.0%
Aluminium alloy	19.8%	80.2%
Coated glass	27.7%	72.3%

2.4.4.1. De-construction / demolition stage

At the end of of life, de-construction of the fittings products which include the dismantling of the fittings products as well as the initial on-site sorting is assumed to be manual. Therefore, no deconstruction activities was 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 as listed in Table 2.13 were assumed to be intended for recycling and were included in the model. All processing including pre-sorting, crushing, and shredding were modeled.

[2] United States Environmental Protection Agency, Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2012. http://www.epa.gov/osw/nonhaz/municipal/pubs/2012_msw_fs.pdf

2.4.4.4. Disposal stage

The disposal of material flows transported to a landfill following the waste scenarios of materials as listed in Table 2.13 were included in the model.

2.4.5. Recovery stage [D]

Module D reports the environmental benefits or loads resulting from net flows of reusable products, recyclable materials and/or useful energy carriers leaving a product system (e.g. as secondary materials or fuels). It includes recycling potentials of materials expressed as net impacts and benefits. All recycled materials as shown in Table 2.13 is processed in the waste processing stage (i.e. Module [C3]). The transportation (500 miles) as well as the recycling processing of all recycled materials into new materials are included in this stage. It was assumed that on average a yield of 90-95% subsitutes that amount of primary material. There is no thermal recovery modeled for end of life as is defined in the scenarios in Table 2.13.

Table 2.14 Substitution in recovery stage

Material	% of substitution	Material substituted with
ABS, epoxy resin, polyacetal, PP, POM, PE	90%	HDPE
Brass	95%	Brass, secondary
Bronze	95%	Bronze, secondary
Cardboard	95%	Sulphate pulp
Copper	95%	Copper, secondary
Paper	95%	Sulphate pulp
Steel & Stainless steel	95%	Steel

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

Primary manufacturing data related to plant operations and processes along with product-level data, such as material, process used, recycled content, and yield was provided by TOTO's supplier in Shanghai, China. The data provided represents the fittings' production for the calendar year 2015. Data collections were done by manufacturing engineers and collected by using electric bills, purchasing orders, TOTO USA's order volume, info on damaged goods, and production yield and efficiency. Data was provided to TOTO USA by the supplier who calculated and compiled data required per TOTO's consumption during the time period. TOTO USA Senior Product Engineer, Gary Soe has visited this manufacturing plant. Communications between TOTO USA and TOTO Shanghai was done for all data required, and the data validation process was done by both TOTO Shanghai and Gary Soe. Verification/validation of this data was done by both Sustainable Minds and TOTO USA. Sustainable Minds has provided questionnaires and feedback to warrant completeness and consistency. Some data was confidential and is therefore not included in this report, but has been part of a review by Sustainable Minds.

Product-level manufacturing data, such as material, process used, recycled content and yield was validated. Verification/validation was done by TOTO Development Engineering Department of TOTO USA using know-how and information on sites' conditions and labor force, yield and production efficiency information, and product consumption rate at TOTO USA. Plant data related to plant-wide manufacturing operations and processes was not used, as it was not verifiable; instead, datasets from Ecoinvent, US-Ecoinvent or a modification of both was used to model materials and processes.

No materials, components, emissions or energy flows have been left out. 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. 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 mixes based on ecoinvent definitions. This relates to the country of the vendors 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.

Scenarios have been used to model the use stage, as defined in the Part Bs, and end-of-life phase. Details are provided in the description of the life cycle stages earlier in this report.

All used primary data reflects data for the calendar year 2015, with regionally specific data. All background data used to model the LCA is reported in appendices 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 technological 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 datasets. 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 criteria for data selection were 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:

- All vendors have responded to the request for data in great detail. While the vendors have been contacted with LCA related questions for these products before, it is recommended that the vendors will be contacted for future LCA work again and focus on some more details for the most important processes.
- Recycled content for the metal parts as provided by vendors were used. No assumption of virgin material was made even when no information was provided by the vendors. This is likely a worst-case scenario. These numbers need to be validated in future LCA projects. There is a significant improvement potential for using more recycled content.
- Scenarios have been used to model the use phase as defined by the Part Bs.
- 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.

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 TOTO and the vendors have been reported, therefore these criteria have been met. The completeness of the bill of materials is reported in the previous chapter (Table 2.6) and satisfies the above defined cut-off criteria.

3.5 Allocation

Whenever a system boundary is crossed environmental inputs and outputs have to be assigned to the different products. Where multi-inputs are considered or where multi-outputs are considered the same applies. Part A prescribes to report where and how allocation occurs in the modeling of the LCA. In this LCA the following rules have been applied:

The preferred way to avoid allocation when a system boundary is crossed is to expand the system boundaries, e.g. including the cut-off parts. In this LCA, system boundaries are crossed for the manufacturing processes and reuse or reclaiming components after use. Multi-input, multi-output and recycling allocations are described below.

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

<u>Manufacturing processes:</u>
Allocation for the manufacturing processes is done on a process to process level, with different processes assigned to different parts. Allocation for upstream processes follows the ecoinvent assumptions, most notably the co-product allocation is either based on value or, if not available, on mass.

Multi-input processes:
The preferred way to deal with assigning impacts to multi-inputs is to reflect the physical properties of the incoming flows. If a relationship can be established that is more suitable than mass, it should be used.

Waste treatment at the end-of-life:
Waste treatment is typically a multi-input process. Several waste streams come together and are processed. Where specific data are available the composition of the waste flows has been used to model the contribution to the impacts from the waste treatment, this includes substitution benefits for energy utilization for combustion processes where relevant. Where no specific data are at hand average values are used.

Multi-output processes:
Where multiple products are produced allocation is needed. Usually allocation is done by mass, unless another relation is more relevant. Allocation of the manufacturing data in this LCA includes the weight of the finished product and the yield of the specific product.

Reuse and recycling:
Recycled content is used in some of the metal parts and the cardboard for the boxes. All processes needed to be able to utilize recycled content in the used materials after collecting and sorting are assigned to the product utilizing the recycled content. However, the previous use is cut off.

Some process waste and parts of the finished product after use ares also recycled. An example are the metal parts after the use of the product. Life cycle stage end-of-life includes transportation to sorting facilities and processing is included up to the point of material that is ready for recycling, such as shredded metal or granulated plastic.

All processes and transportation needed to actually recycle the materials are assigned to the recovery stage. This includes a credit given for the manufacturing of the primary material that is prevented by doing so. The credit varies for the different materials and is typically the scrap material that is used to make new product consistent with any other scenario for waste processing and is based on current average technology or practice. An example would be recycled fiber for cardboard. This is refered to as “up to the point of functional equivalence where the secondary material or fuel substitutes primary production and subtracting the impacts resulting from the substituted production of the product or substituted generation of energy from primary sources”.

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[3] factors, where relevant, as defined by TRACI 2.1 classification and characterization[4]. 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	$SO_{2\ eq}$ (sulphur 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)

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. SimaPro was used to perform the impact assessment.

4.2 Normalization and weighting

To arrive to the single score indicator, normalization[5] and weighting[6] conforming to Part A of the Framework was applied.

Table 4.2 Normalization and Weighting factors

[3] The 100 year period relates to the period in which the environmental impacts are modeled. This is different from the time period of the functional unit. The two periods are related as follows: all environmental impacts that are created in the period of the functional unit, are modeled through life cycle impact assessment using a 100 year time horizon to understand the impacts that take place.
[4] J. Bare (2011) TRACI 2.0: the tool for the reduction and assessment of chemical and other environmental impacts 2.0. 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.
[5] 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.
[6] 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

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

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 TET2LA

Cradle-to-gate

Figure 5.1 shows the results for the finished product. It shows that the brass parts, together with the printed wiring board have significant material contribution and that other manufacturing processes such as polishing and potting have a significant processing contribution to the results.

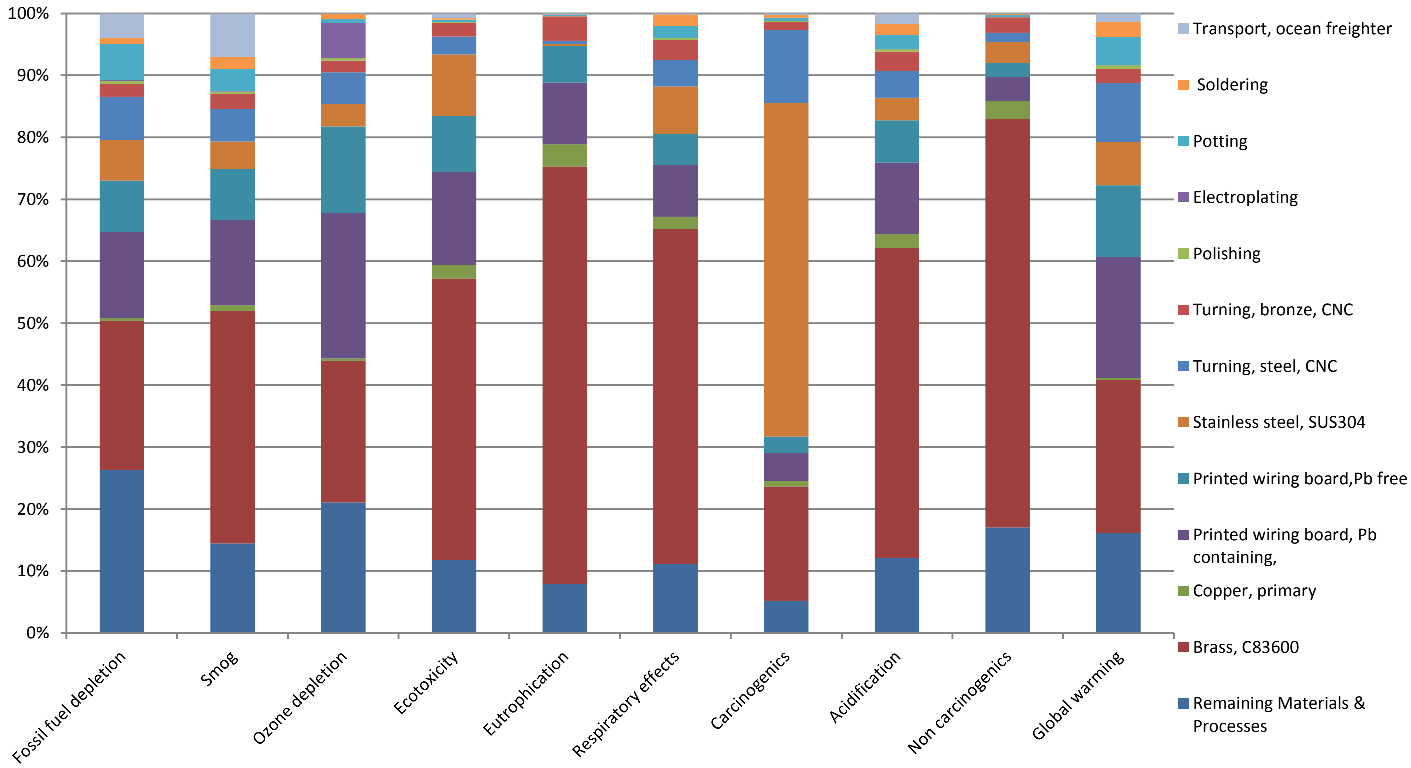


Figure 5.1 Cradle-to-gate impacts for TET2LA – relative results

Variations

Not relevant.

Full life cycle

Figure 5.2 and Table 5.1 show the results for the full life cycle of the product. It shows that the use phase [B1-B7] is dominating the results for all impact categories. This is mostly due to the electricity used for the water supply and operation of the product (60-90%) [B1-B7] and the remainder is related to the water used. The product itself [A1-A3] has a significant contribution to eutrophication (mostly defined by emissions from copper mining), non carcinogens (emissions from the production of coal, copper and zinc) and ecotoxicity (mostly from disposal of steel slags and bottom ashes from coal fired power plants and barium emissions to water from the extraction process of natural gas). The impacts for the product itself [A1-A3] are discussed above in the cradle-to-gate section. The end-of-life scenario [D] includes recycling and benefits from this by preventing the need to primary materials. It shows up as a relevant factor for some of the impact categories offsetting part of the impacts caused by making the parts of the product. Transportation to site [A4] for the delivery, [A5] for the construction and the processes for dismantling and final waste treatment [C1-C4] of the product do not have a significant impact.

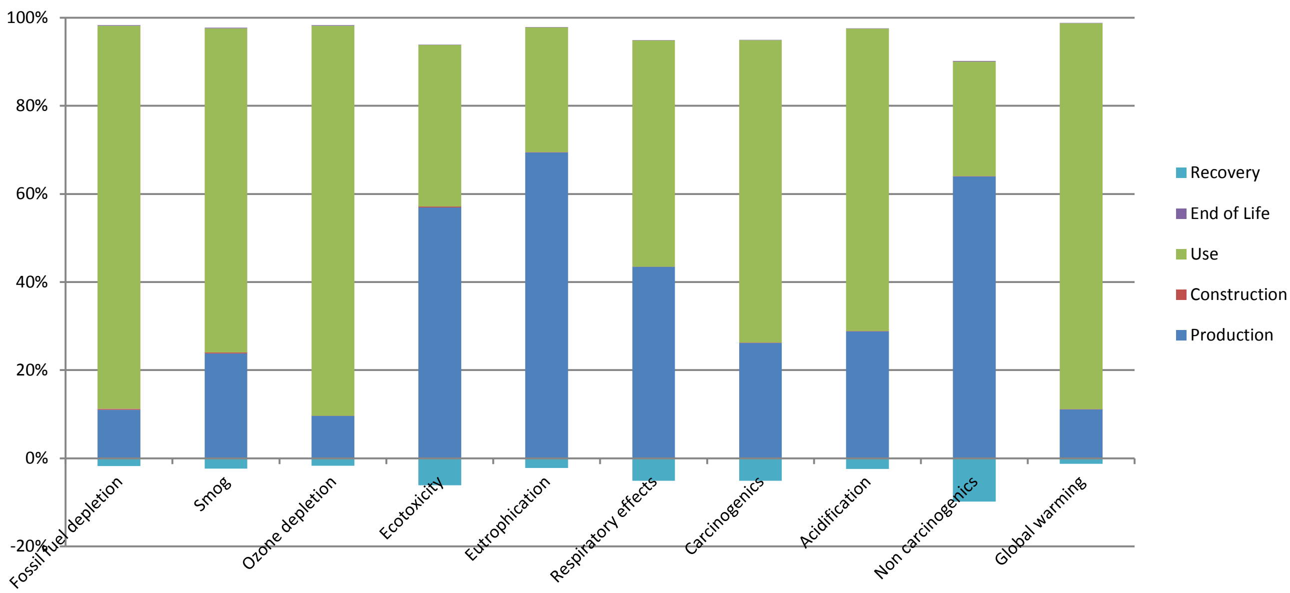


Figure 5.2 Life cycle impacts for TET2LA – relative results

Impact category	**Unit**	**total**	**Production** [A1-A3]	**Construction** [A4-A5]	**Use** [B1-B7]	**End of Life** [C1-C4]	**Recovery** [D]
				Resource Depletion			
Fossil fuel depletion	MJ surplus	3.84E+02	4.39E+01	9.02E-01	3.46E+02	4.49E-01	-6.84E+00
				Human health damage			
Smog	kg O3 eq	3.55E+01	8.85E+00	9.42E-02	2.74E+01	4.69E-02	-8.60E-01
Respiratory effects	kg PM2.5 eq	3.53E-01	1.71E-01	5.69E-05	2.02E-01	2.57E-04	-2.01E-02
Carcinogenics	CTUh	1.55E-05	4.51E-06	7.11E-09	1.18E-05	5.75E-09	-8.77E-07
Non carcinogenics	CTUh	1.50E-04	1.20E-04	6.65E-08	4.87E-05	2.61E-07	-1.84E-05
				Ecological Damage			
Ozone depletion	kg CFC-11 eq	2.84E-05	2.84E-06	2.05E-09	2.60E-05	3.49E-08	-5.00E-07
Ecotoxicity	CTUe	4.74E+02	3.08E+02	1.25E+00	1.98E+02	5.02E-01	-3.32E+01
Eutrophication	kg N eq	1.11E+00	8.08E-01	6.84E-04	3.29E-01	3.42E-04	-2.56E-02
Acidification	kg SO2 eq	4.15E+00	1.26E+00	3.24E-03	2.99E+00	2.25E-03	-1.06E-01
Global warming	kg CO2 eq	6.40E+02	7.27E+01	8.14E-01	5.74E+02	3.40E-01	-8.01E+00

Table 5.1 Life cycle impacts for TET2LA – absolute results

Variations

Not relevant.

SM results

The SM millipoint score 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 5.2 SM millipoint scores for TET2LA by life cycle phase – absolute results

Impact category	Unit	Total	Production	Construction	Use	End of life	Recovery
SM single figure	mPts	61.50	23.33	0.052	41.45	0.04	-3.37

5.2 TEU2LA

Cradle-to-gate

Figure 5.3 shows the results for the finished product. It shows that the brass parts, together with the printed wiring board have significant material contribution and that other manufacturing processes such as polishing and potting have a significant processing contribution to the results.

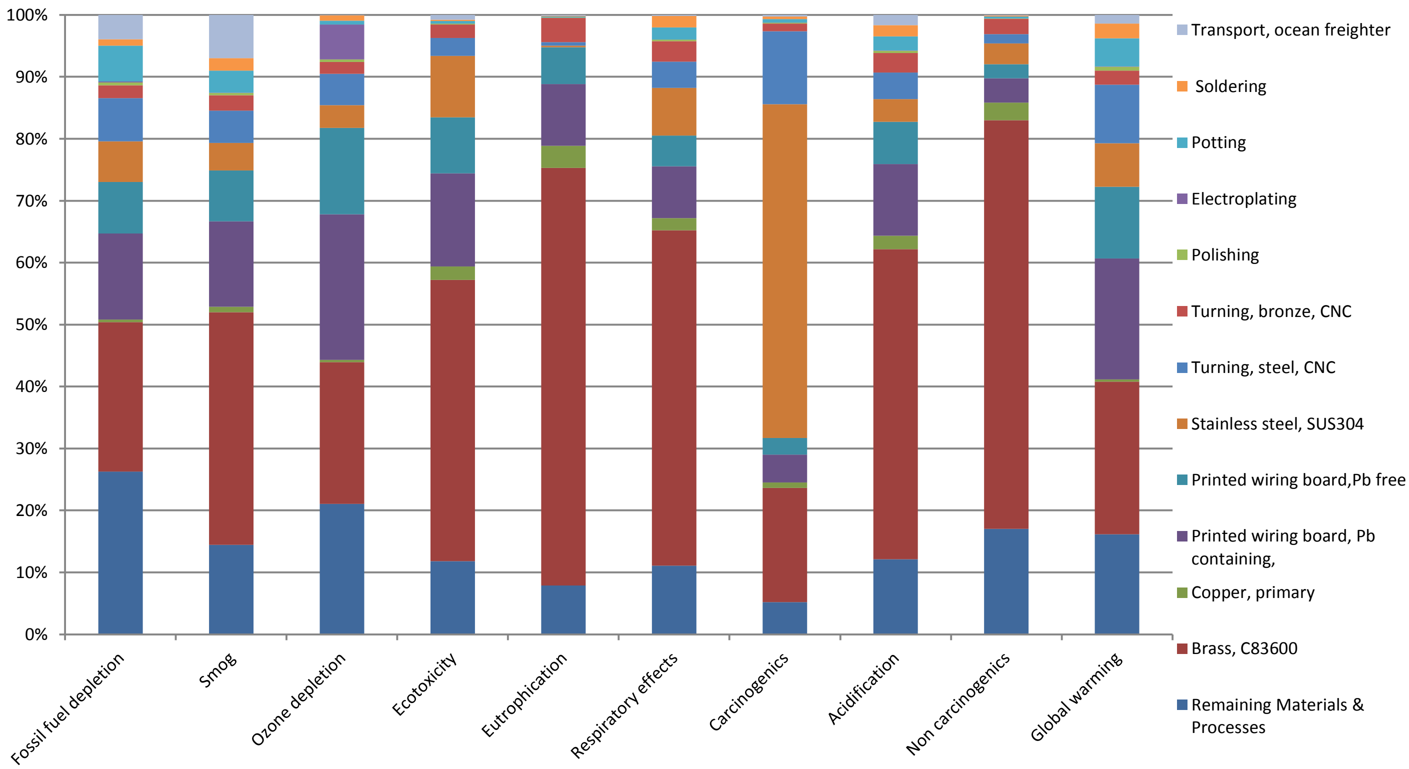


Figure 5.3 Cradle-to-gate impacts for TEU2LA – relative results

Variations

Not relevant.

Full life cycle

Figure 5.4 and Table 5.3 show the results for the full life cycle of the product. It shows that the use phase [B1-B7] is dominating the results for all impact categories. This is mostly due to the electricity used for the water supply and operation of the product (60-90%) [B1-B7] and the remainder is related to the water used. The product itself [A1-A3] has a significant contribution to eutrophication (mostly defined by emissions from copper mining), non carcinogens (emissions from the production of coal, copper and zinc) and ecotoxicity (mostly from disposal of steel slags and bottom ashes from coal fired power plants and barium emissions to water from the extraction process of natural gas). The impacts for the product itself [A1-A3] are discussed above in the cradle-to-gate section. The end-of-life scenario [D] includes recycling and benefits from this by preventing the need to primary materials. It shows up as a relevant factor for some of the impact categories offsetting part of the impacts caused by making the parts of the product. Transportation to site [A4] for the delivery, [A5] for the construction and the processes for dismantling and final waste treatment [C1-C4] of the product do not have a significant impact.

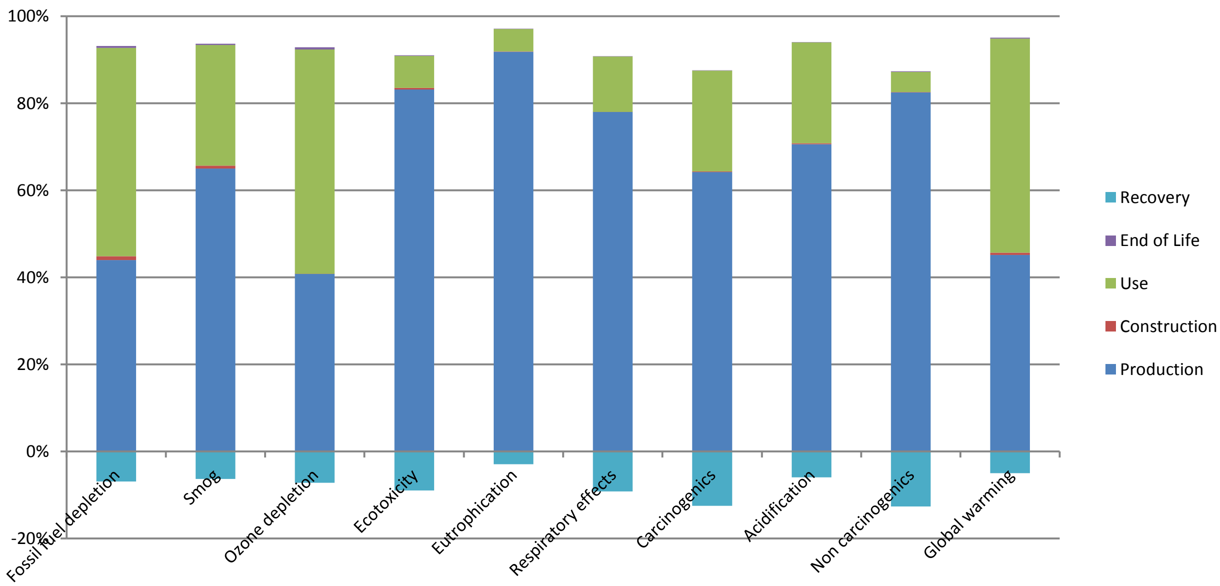


Figure 5.4 Life cycle impacts for TEU2LA – relative results

Impact category	Unit	total	Production [A1-A3]	Construction [A4-A5]	Use [B1-B7]	End of Life [C1-C4]	Recovery [D]
Resource Depletion							
Fossil fuel depletion	MJ surplus	8.61E+01	4.39E+01	9.02E-01	4.77E+01	4.49E-01	-6.84E+00
Human health damage							
Smog	kg O3 eq	1.19E+01	8.85E+00	9.42E-02	3.77E+00	4.69E-02	-8.60E-01
Respiratory effects	kg PM2.5 eq	1.79E-01	1.71E-01	5.69E-05	2.78E-02	2.57E-04	-2.01E-02
Carcinogenics	CTUh	5.28E-06	4.51E-06	7.11E-09	1.63E-06	5.75E-09	-8.77E-07
Non carcinogenics	CTUh	1.08E-04	1.20E-04	6.65E-08	6.71E-06	2.61E-07	-1.84E-05
Ecological Damage							
Ozone depletion	kg CFC-11 eq	5.97E-06	2.84E-06	2.05E-09	3.59E-06	3.49E-08	-5.00E-07
Ecotoxicity	CTUe	3.04E+02	3.08E+02	1.25E+00	2.73E+01	5.02E-01	-3.32E+01
Eutrophication	kg N eq	8.29E-01	8.08E-01	6.84E-04	4.54E-02	3.42E-04	-2.56E-02

Acidification	kg SO2 eq	1.57E+00	1.26E+00	3.24E-03	4.12E-01	2.25E-03	-1.06E-01
Global warming	kg CO2 eq	1.45E+02	7.27E+01	8.14E-01	7.91E+01	3.40E-01	-8.01E+00

Table 5.3 Life cycle impacts for TEU2LA – absolute results

Variations

Not relevant.

SM results

The SM millipoint score 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 5.4 SM millipoint scores for TEU2LA by life cycle phase – absolute results

Impact category	Unit	Total	Production	Construction	Use	End of life	Recovery
SM single figure	mPts	25.77	23.33	0.052	5.71	0.042	-3.37

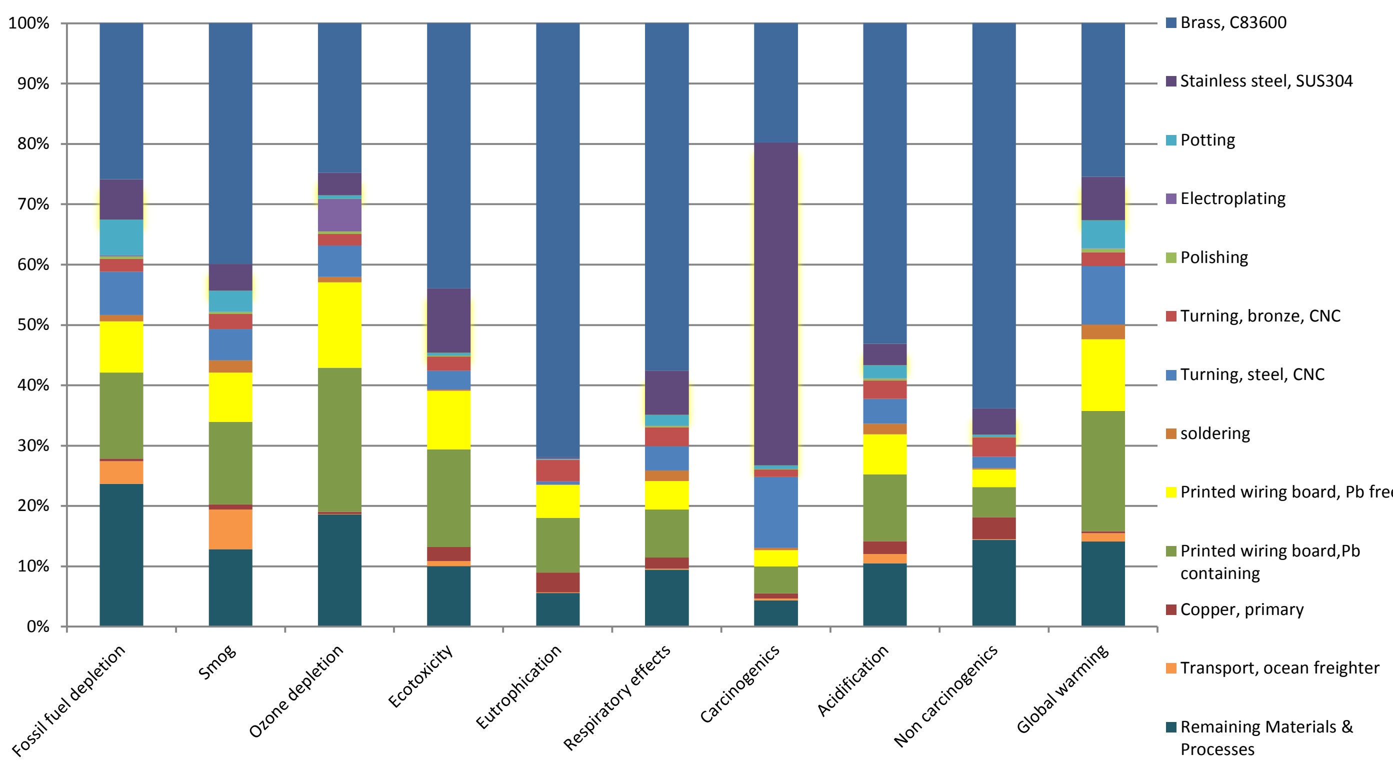
5.3 TEU2UA

This section includes the weighted averaged results based on production volumes.

Cradle-to-gate

Figure 5.5 shows the results for the finished product. It shows that the brass and stainless steel, SUS304, parts, together with the printed wiring board have significant material contributions and that other manufacturing processes such as polishing and potting have significant processing contributions to the results.

Figure 5.5 Cradle-to-gate impacts for the average of TEU2UA – relative results



Variations

The variation in the bill of materials is presented in the Table 5.5 below. It shows many similarities, but also many differences. However, the variations in the results due to averaging are less than 10% in any category.

Table 5.5 Variations in the bill of materials for TEU2LA & TEU2UA (confidential)

Average		%dev TEU2LA	%dev TEU2UA	TEU2LA-TEU2UA Difference
Bronze (C836000)				
Double Wall				
Paper				
Brass				
Cu				
Polyacetal				
PP				
ABS				
Bronze				
Steel				
Pb w/ surface mount				
Brass (covalent coating)				
SUS304				
PPO				
Epoxy Resin				
Surfacemount				
AA Li-ion battery				

Full life cycle

Figure 5.6 and Table 5.6 show the results for the full life cycle of the product. It shows that the use phase [B1-B7] is less dominant than for the TET2LA, but it is still significant for most of the impact categories. This is mostly due to the electricity used for the water supply and operation of the product (60-90%) [B6-B7] and the remainder is related to the water used. The product itself [A1-A3] is more important than that for TET2LA. It shows the same major contributions though. It has the most significant contributions to eutrophication (mostly defined by emissions from copper and gold mining), non carcinogens (emissions from the production of copper, zinc and lead) and ecotoxicity (mostly from emissions during mning of copper, ferrochromium (steel) and gold). The impacts for the product itself [A1-A3] are discussed above in the cradle-to-gate section. The end-of-life scenario [D] includes recycling and benefits from this by preventing the need to primary materials. It shows up as a relevant factor for some of the impact categories offsetting part of the impact caused by making the parts of the product. Transportation to site [A4] for the delivery, [A5] for the construction and the processes for dismantling and final waste treatment [C1-C4] of the product do not have a significant impact.

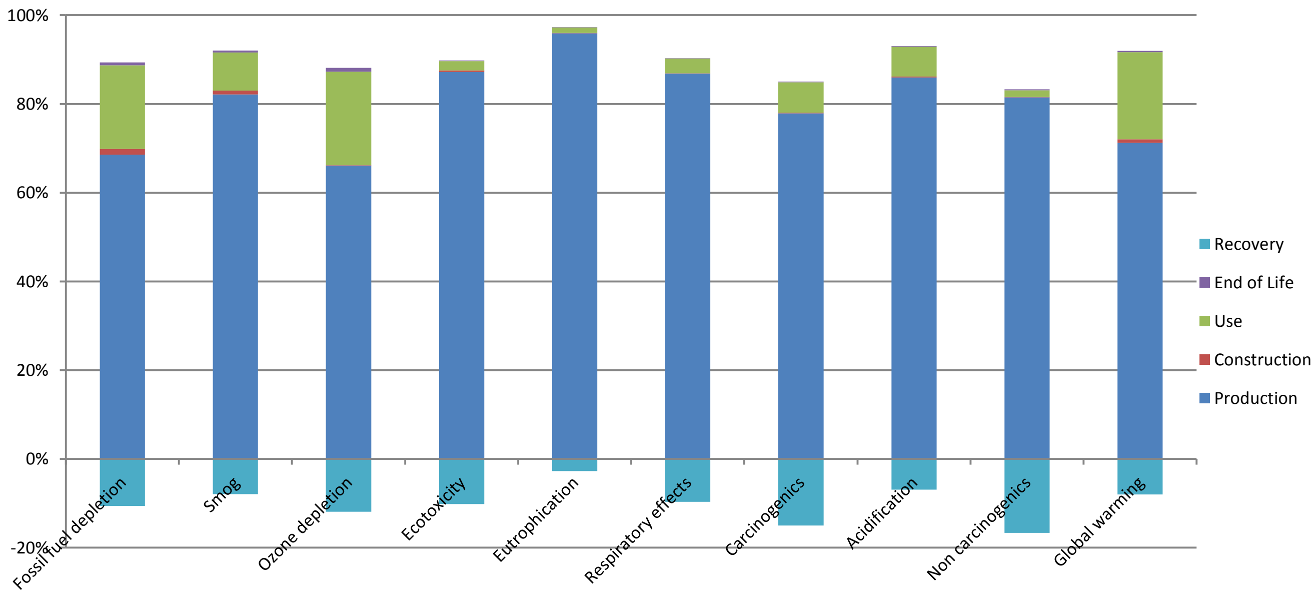


Figure 5.6 Life cycle impacts for TEU2UA – relative results

Impact category	Unit	total	Production [A1-A3]	Construction [A4-A5]	Use [B1-B7]	End of Life [C1-C4]	Recovery [D]
Resource Depletion							
Fossil fuel depletion	MJ surplus	5.00E+01	4.35E+01	8.54E-01	1.19E+01	4.52E-01	-6.74E+00
Human health damage							
Smog	kg O3 eq	9.20E+00	8.99E+00	8.92E-02	9.44E-01	4.86E-02	-8.71E-01
Respiratory effects	kg PM2.5 eq	1.70E-01	1.83E-01	5.42E-05	6.95E-03	2.68E-04	-2.04E-02
Carcinogenics	CTUh	4.11E-06	4.57E-06	6.74E-09	4.07E-07	5.66E-09	-8.81E-07
Non carcinogenics	CTUh	7.45E-05	9.12E-05	6.31E-08	1.68E-06	2.60E-07	-1.87E-05
Ecological Damage							
Ozone depletion	kg CFC-11 eq	3.24E-06	2.81E-06	2.00E-09	8.97E-07	3.60E-08	-5.07E-07
Ecotoxicity	CTUe	2.62E+02	2.87E+02	1.18E+00	6.82E+00	4.93E-01	-3.36E+01
Eutrophication	kg N eq	8.88E-01	9.02E-01	6.73E-04	1.14E-02	3.42E-04	-2.60E-02
Acidification	kg SO2 eq	1.33E+00	1.32E+00	3.07E-03	1.03E-01	2.31E-03	-1.07E-01
Global warming	kg CO2 eq	8.46E+01	7.18E+01	7.87E-01	1.98E+01	3.37E-01	-8.08E+00

Table 5.6 Life cycle impacts of TEU2UA – absolute results

Variations

The only deviation above 10% is in the use phase. The product TEU2LA consumes four times more water than TEU2UA over the same use phase (23,400 gallons vs. 5,850 gallons). The life cycle impacts for the average of TEU2LA & TEU2UA excluding use phase are not reported as the only variation is in the use phase only.

SM results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.7). They confirm the trends in the results using the impact assessment results before normalization and weighting.

Table 5.7 Averaged SM millipoint scores for TEU2UA by life cycle phase – absolute results

Impact category	Unit	Total	Production	Construction	Use	End of life	Recovery
SM single figure	mPts	20.15	22.04	0.049	1.43	0.042	-3.40

5.4 Sensitivity analysis

Fittings and allocation for recycling and recycled content
Metals are an important part of the fitting products and recycled content is a relevant factor in many LCA studies. Recycled content is modeled using scrap that is processed to make new materials in this study. After use, recycling is credited to the offset of virgin metals up to the point of intermediate metals before they are finished into products. This is a substitution based approach and it complies with Part A.

Another approach could be to model a full cut off and not to include the substitution at the end of use and only model the recycling benefits at the manufacturing stage by means of using recycling content and hence less virgin content. The impact of this allocation choice can be seen by looking at the graphs in the previous section. In essence this would eliminate the benefits that show up in the recovery stage. The impact is in the order of 1-10% for most products and most impact categories.

The only instances where the impact is greater than 10% are:
- TEU2LA & TEU2UA 10.4% difference for non-carcinogenics

A note will be included on the Transparency Report as outlined in Part A of the Framework.

5.5 Discussion on data quality

Discussion of the role of excluded elements
This study followed the completeness criteria stated in Section 3.2 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 most are deemed to have a very small impact in the results of the LCA.

Discussion of the precision, completeness and representativeness of data
Not all vendors have responded to the same level of detail as the request for data entailed. It is recommended that important vendors shall be contacted for future LCA work as TOTO moves towards a more integrated People, Planet, Profit strategy. This study 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.

The study used scenarios for the use phase and end of life. Since the use phase is important for the results of the LCA, it is recommended to discuss and validate the approach with industry stakeholders to establish a common practice. This has been established by use of the Part Bs.

Discussion related to the impact of value judgments
The Sustainable Minds indicator expressed in millipoints is a part of the reporting requirements. However, it is important to note 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 3 years validity of a Transparency Report, any changes in these value judgments will be reflected in future updates.

5.6 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:

- There is a need for better data 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 metals.
- Continue the reduction of the use of water for the products during the use phase.
- 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] J. Bare (2011) TRACI 2.0: the tool for the reduction and assessment of chemical and other environmental impacts 2.0. 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] 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.

[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™ / EPD Framework, Part A: LCA calculation rules and report requirements. January 2017.

[7] Part B, Commercial Flushometer Valves. December 13, 2016.

ACRONYMS

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
FAP	TOTO Fairburn Assembly Plant

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 FITTINGS MANUFACTURING PROCESS

The LCI for the fittings are reported in a separate spreadsheet "Fittings BOM". 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. In addition to that, summary tables of the LCI data for the processing at the TOTO vendors for manufacturing is included.

Table A.1 Raw materials definition of TET2LA (confidential)

			Availability					
Component	**Material**	**Mass %**	**Renewable**	**Non-renewable**	**Recycled post-industrial**	**Recycled post-consumer**	**Origin of raw materials**	**Supply Distance (miles)**
coverplate and frame	Stainless Steel		No	Yes	0%	0%		
	ABS		No	Yes	0%	0%		
	Remaining materials		No	Yes	0%	0%		
Valve Metal Body	Bronze (C836000)		No	Yes	15%	0%		
	Brass		No	Yes	10%	0%		
	Bronze (C836000)		No	Yes	15%	0%		
	Bronze (C836000)		No	Yes	15%	0%		
	Remaining materials		No	Yes	0%	0%		
Piston assembly	Miscellaneous materials		No	Yes	0%	0%		
Solenoid Assembly	Miscellaneous materials		No	Yes	0%	0%		
Push manual Button	Miscellaneous materials		No	Yes	0%	0%		
Generator	Copper		No	Yes	0%	0%		
	Remaining materials		No	Yes	0%	0%		
Controller	Miscellaneous materials		No	Yes	0%	0%		
Sensor	Miscellaneous materials		No	Yes	0%	0%		
Battery	AA Li-ion battery		No	Yes	0%	0%		
Other parts	Miscellaneous materials		No	Yes	0%	0%		
	TOTAL	**100**						

Table A.2 Raw materials definition of TEU2LA (confidential)

			Availability					
Component	**Material**	**Mass %**	**Renewable**	**Non-renewable**	**Recycled post-industrial**	**Recycled post-consumer**	**Origin of raw materials**	**Supply Distance (miles)**
coverplate and frame	Stainless Steel		No	Yes	0%	0%		
	ABS		No	Yes	0%	0%		
	Remaining materials		No	Yes	0%	0%		
Valve Metal Body	Bronze (C836000)		No	Yes	15%	0%		
	Brass		No	Yes	10%	0%		
	Bronze (C836000)		No	Yes	15%	0%		
	Bronze (C836000)		No	Yes	15%	0%		
	Remaining materials		No	Yes	0%	0%		
Piston assembly	Miscellaneous materials		No	Yes	0%	0%		
Solenoid Assembly	Miscellaneous materials		No	Yes	0%	0%		
Push manual Button	Miscellaneous materials		No	Yes	0%	0%		
Generator	Copper		No	Yes	0%	0%		
	Remaining materials		No	Yes	0%	0%		
Controller	Miscellaneous materials		No	Yes	0%	0%		
Sensor	Miscellaneous materials		No	Yes	0%	0%		
Battery	AA Li-ion battery		No	Yes	0%	0%		
Other parts	Miscellaneous materials		No	Yes	0%	0%		
	TOTAL	**100**						

Table A.3 Raw materials definition of TEU2UA (confidential)

			Availability					
Component	**Material**	**Mass %**	**Renewable**	**Non-renewable**	**Recycled post-industrial**	**Recycled post-consumer**	**Origin of raw materials**	**Supply Distance (miles)**
coverplate and frame	Stainless Steel		No	Yes	0%	0%		
	ABS frame		No	Yes	0%	0%		
	Remaining materials		No	Yes	0%	0%		
Valve Metal Body	Bronze (C836000)		No	Yes	15%	0%		
	Brass		No	Yes	10%	0%		
	Remaining materials		No	Yes	30%	0%		
Solenoid Assembly	Miscellaneous materials		No	Yes	0%	0%		
Push manual Button	Miscellaneous materials		No	Yes	0%	0%		
Generator	Copper		No	Yes	0%	0%		
	Remaining materials		No	Yes	0%	0%		
Controller	Miscellaneous materials		No	Yes	0%	0%		
Sensor	Miscellaneous materials		No	Yes	0%	0%		
Battery	AA Li-ion battery		No	Yes	0%	0%		
Other parts	Miscellaneous materials		No	Yes	0%	0%		
	TOTAL	**100**%						

Table A.4 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.5 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.6 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.7 LCI data for M&K potting process

M&K Potting	0.5	g
This dataset models an M&K Potting Machine with typical production volume of 150 circuit board per 1 kWh. A circuit board is estimated to consume 0.5g of Epoxy resin. Source: TOTO Shanghai		
Materials/fuels		
Electricity, medium voltage, production	0.006667	kWh
Epoxy resin, liquid, at plant	0.5	g
Emissions to air		
Heat, waste	0.10374	MJ

Table A.8 LCI data for turning bronze CNC process

Turning, bronze, 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
Bronze, at plant	1	kg
Electricity/heat		
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.9 LCI data for polishing process

Polishing	1	kg
This dataset includes the materials, energies and emissions related to the polishing machines used for polishing metal products. This is mainly electricity, compressed air and solvents. Process heat is from average sources. The consumables are polishing discs and abrasive paste. Source: TOTO Shanghai		
Materials/fuels		
Solvents, organic, unspecified, at plant	0.0014	kg
Lubricating oil, at plant	0.000867	kg
Compressed air, average installation, >30kW, 7 bar gauge, at supply network	0.291	m3
Light fuel oil, burned in industrial furnace 1MW, non-modulating	2.6	MJ
Heavy fuel oil, burned in industrial furnace 1MW, non-modulating	0.0328	MJ
Natural gas, burned in boiler modulating >100kW	2.03	MJ
Electricity, low voltage, production	1.15	kWh
Textile, woven cotton, at plant	0.0272	kg
Ethylene glycol, at plant	0.002	kg
Emissions to air		
Hydrocarbons, aliphatic, alkanes, unspecified	0.000558	kg

Polishing	1	kg
Ethene, tetrachloro-	7.51E-05	kg
Water	1.12	kg
Heat, waste	4.13	MJ
Waste to treatment		
Disposal, used mineral oil, 10% water, to hazardous waste incineration	0.000867	kg

Table A.10 LCI data for TAMURA wave soldering process

TAMURA Wave Soldering	0.1	kg
This dataset models a TAMURA wave soldering machine with typical production volume of 100 circuit board per 1kWh. A circuit board is estimated to consume 100g of lead-free wave bars. Source: TOTO Shanghai		
Materials/fuels		
Electricity, medium voltage, production	4.323	kWh
Soft solder, Sn97Cu3, at plant	0.1	kg
Emissions to air		
Heat, waste	15.561	MJ

Table A.11 LCI data for electroplating process

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

APPENDIX B. ADDITIONAL RESULTS

No additional results 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, 2011].

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 fittings LCI-LCA modeling data and results 04-2017.xlsx”.

APPENDIX E. LCI

The LCI results per functional unit for all products are included in a separate “LCA of TOTO fittings LCI-LCA modeling data and results 04-2017.xlsx”.

APPENDIX F. LCIA METHOD

The LCIA characterization factors are included in a separate spreadsheet “LCA of TOTO fittings LCI-LCA modeling data and results 04-2017.xlsx”.

APPENDIX G. PROCESS FLOW DIAGRAMS

A process flow diagram per functional unit of product is included in a separate spreadsheet “LCA of TOTO fittings LCI-LCA modeling data and results 04-2017.xlsx”. It shows the modeled materials and energy flows.