LIFE CYCLE ASSESSMENT (LCA) OF TOTO SANITARY FITTING PRODUCTS

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Client	TOTO USA
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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 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.

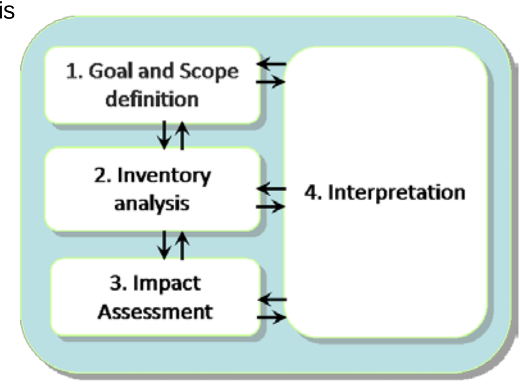
TOTO is interested in having Life Cycle Assessment data available for the most important products to be able to obtain SM Transparceny Reports™, Type III environmental declarations that can be used for communication with and amongst other companies, architects and consumer communication, and can also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



Source: ISO 14040

This report includes all phases.

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 14044-44 third-party review and a third-party verification for Transparency Reports™ are options 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.

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 Sustainable Minds and TOTO employees to transform this information into this LCA report was conducted. The data covers annual manufacturing data during the calendar year 2015. 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 Practitioner. 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 Brad McAllister, WAP Director, who was contracted on behalf of NSF. The review concluded 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 B of the SM Transparency Report™ / EPD Framework v2016. A third-party review has been performed by Brad McAllister, 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.

1.4 Team

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

- Kristen Girts, Project Manager & Associate Quality Engineer
- Gary Soe, Senior Product Engineer

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

From Sustainable Minds:
- Kim Lewis, LCA Practitioner

- Millali Marcano, Project Manager

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 defines 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 and sold 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 include nine commercial fittings products listed in Table 2.1.

Table 2.1 Products studied in this report

Product code	Product name	Description
TET1LA	EcoPower® Toilet Flush Valve	EcoPower® High-Efficiency Toilet Flush Valve, 1.28gpf
TEU1LA	EcoPower® HE Urinal Flush Valve	EcoPower® High-Efficiency Urinal Flush Valve, 0.5gpf
TEU1UA	EcoPower® Ultra-HE Urinal Flush Valve	EcoPower® High-Efficiency Urinal Flush Valve, 0.125gpf
TEL105-D10E	Standard EcoPower® Faucet	Standard EcoPower® Faucet, 10 second, on-demand 0.5gpm/0.09gpc
TEL105-C20E	Standard EcoPower® Faucet	Standard EcoPower® Faucet, 20 second, continuous 0.5gpm/0.19gpc
TEL105-D10ET	Standard EcoPower® Faucet	Standard EcoPower® Faucet, 10 second, on-demand 0.5gpm/0.09gpc w/ thermostatic mixing valve
TEL105-D10EM	Standard EcoPower® Faucet	Standard EcoPower® Faucet, 10 second, on-demand 0.5gpm/0.09gpc w/ mixing tee
TEL105-C20ET	Standard EcoPower® Faucet	Standard EcoPower® Faucet, 20 second, continuous 0.5gpm/0.19gpc w/ thermostatic mixing valve
TEL105-C20EM	Standard EcoPower® Faucet	Standard EcoPower® Faucet, 20 second, continuous 0.5gpm/0.19gpc w/ mixing tee

Note: The faucets discussed in this report are a part of a series of EcoPower® products, the TEL105 series. TEL105-D10E and TEL105-C20E differ only in the use phase, with the “D” version having a 10 second on-demand flow and the “C” version having a 20 second continuous flow. Throughout this report, these units may be collectively refered to as TEL105-C/DE where flow option has no influence. Either of these products can be coupled with either a thermostatic mixing valve or a mixing tee, indicated by the “T” or “M” at the end of the product code. Throughout this report, these units may be collectively refered to as TEL105-D10ET/M or TEL105-C20ET/M where choice of mixing valve has no influence, or as TEL105-C/DET or TEL105C/DEM where a mixing valve is specified but flow rate has no influence. There are six possible products codes that can be obtained by the combination of options. Throughout this report, these units may be collectively refered to as TEL105-D/CEM/T where neither flow option nor choice of mixing valve has influence.

The categories of Transparency Reports™ and manufacturing location are presented in Tables 2.2a and 2.2b. Tables 2.2c lists production volumes during the calendar year 2015 of the modeled products which are used in the declaration of the corresponding average product. Table 2.2d provides other product information.

Table 2.2a Product codes and SM project concepts

Product code(s)	Project concept
TET1LA	LCA of one TOTO flushometer valve in combination with a toilet
TEU1LA	LCA of one TOTO flushometer valve in combination with a urinal
TEU1UA	LCA of one TOTO flushometer valve in combination with a urinal
TEL105-D10E TEL105-C20E	LCA of two TOTO electronic faucets
TEL105-D10ET TEL105-D10EM TEL105-C20ET TEL105-C20EM	LCA of two TOTO electronic faucets with corresponding mixing valve

Table 2.2b Categories of declarations, vendors and manufacturing locations

Product code(s)	Category	Vendor(s) Name(s)	Production Location(s)
TET1LA	A declaration of a specific product from a manufacturer’s plant	TOTO Shanghai	China
TEU1LA	A declaration of a specific product from a manufacturer’s plant	TOTO Shanghai	China
TEU1UA	A declaration of a specific product from a manufacturer’s plant	TOTO Shanghai	China
TEL105-D10E TEL105-C20E	A declaration of an average product from a manufacturer’s plant	TOTO Shanghai	China
TEL105-D10ET TEL105-D10EM TEL105-C20ET TEL105-C20EM	A declaration of an average product from a manufacturer’s plant	TOTO Shanghai	China

Table 2.2c 2015 production volumes of the modeled products (confidential)

Product code	Production volume (pieces)
TEL105-D10E	
TEL105-C20E	
TEL105-D10ET	
TEL105-D10EM	
TEL105-C20ET	
TEL105-C20EM	

Table 2.2d Product information

Product code	CSI MasterFormat® classification	ASTM or ANSI product specification	Physical properties and technical information or any other market identification
TET1LA	22 42 43	ASSE 1037, CSA B125.3 IAPMO(cUPC)	Commercial Flushometer
TEU1LA	22 42 43	ASSE 1037, CSA B125.3 IAPMO(cUPC)	Commercial Flushometer
TEU1UA	22 42 43	ASSE 1037, CSA B125.3 IAPMO(cUPC)	Commercial Flushometer
TEL105-D10E TEL105-C20E	22 49 39	ASME A112.18.1M, CSA B125.1 IAPMO(cUPC)	Commercial Faucet
TEL105-D10ET TEL105-D10EM TEL105-C20ET TEL105-C20EM	22 49 39	ASME A112.18.1M, CSA B125.1 IAPMO(cUPC)	Commercial Faucet

In Table 2.3 below are some pictures and descriptions of selected products.
See more at: http://www.totousa.com/products/commercial

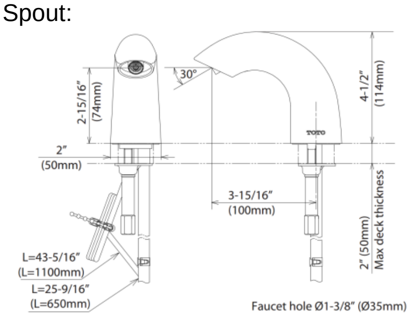
Table 2.3 Descriptions of the modeled products

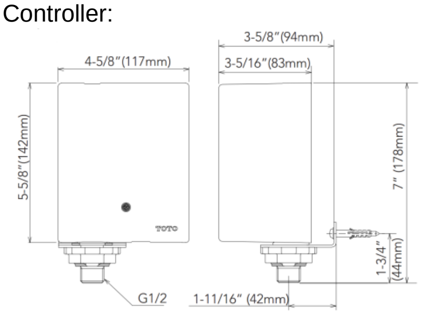
TET1LA 	• 1.28 GPF • Self-powered hydroelectric flush valve system • No minimum daily usage requirement • Durable chrome plated body with tamper-proof screws and solid bronze valve body • Self-cleaning piston valve with 360° filter screen • Neutral rough-in and adjustable tail piece connection • True mechanical flush override • Smart sensor with self-adjusting detection range • 6-second detection time to prevent ghost flushing • For toilet with 1-1/2" top spud inlet • Exposed flush valve with 1" angle stop and 1-1/2" vacuum breaker set • ADA compliant See more at: http://www.totousa.com/ecopower%C2%AE-high-efficiency-toilet-flush-valve-only

<table>
<tr>
<td>TEU1LA
</td>
<td>• 0.5 GPF
• Self-powered hydroelectric flush valve system
• No minimum daily usage requirement
• Durable chrome plated body with tamper-proof screws and solid bronze valve body
• Self-cleaning piston valve with 360° filter screen
• Neutral rough-in and adjustable tail piece connection
• True mechanical flush override
• Smart sensor with self-adjusting detection range
• 6-second detection time to prevent ghost flushing
• ADA compliant

See more at: http://www.totousa.com/ecopower%C2%AE-high-efficiency-urinal-flush-valve-only-05-gpf</td>
</tr>
<tr>
<td>TEU1UA
</td>
<td>• 0.125 GPF
• Self-powered hydroelectric flush valve system
• No minimum daily usage requirement
• Durable chrome plated body with tamper-proof screws and solid bronze valve body
• Neutral rough-in and adjustable tail piece connection
• True mechanical flush override
• Smart sensor with self-adjusting detection range
• 6-second detection time to prevent ghost flushing
• ADA compliant

See more at: http://www.totousa.com/ecopower%C2%AE-ultra-high-efficiency-urinal-flush-valve-only-0125-gpf</td>
</tr>
<tr>
<td>TEL105-D/CE

Spout:


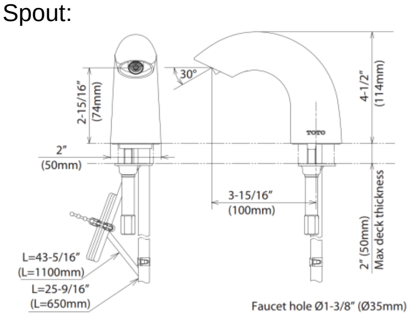
Controller:

</td>
<td>• Operated entirely by hydropower. No external power source needed.
• Strategic location of sensor at tip of spout for instant response time.
• No wiring. Easy installation and low-cost maintenance.
• 0.5 GPM water-saving flow rate
• ADA compliant
• Consists of spout and controller

See more at: http://www.totousa.com/standard-ecopowerfaucet-05-gpm</td>
</tr>
</table>

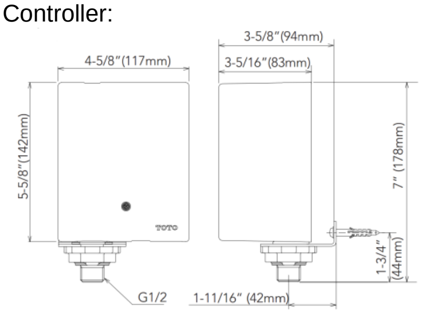
TOTO

TEL105-C/DET

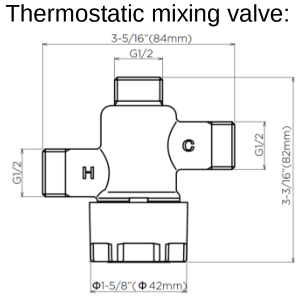
Spout:



Controller:



Thermostatic mixing valve:

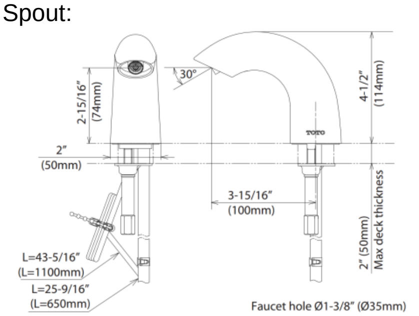


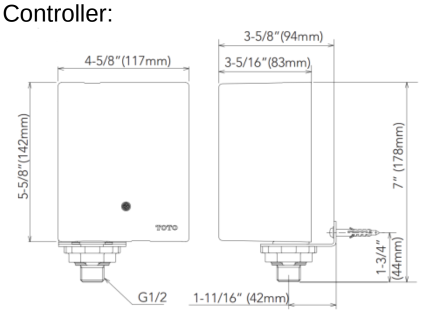
G1/2 compatibel with ½ NPSM

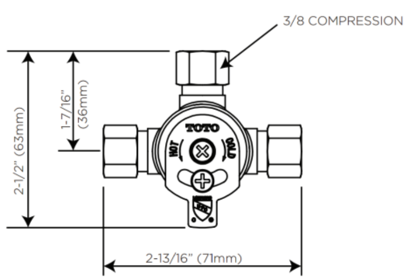
- Operated entirely by hydropower. No external power source needed.
- Strategic location of sensor at tip of spout for instant response time.
- No wiring. Easy installation and low-cost maintenance.
- 0.5 GPM water-saving flow rate.
- ADA compliant
- Consists of spout, controller and thermostatic mixing valve

See more at: http://www.totousa.com/standard-ecopowerfaucet-05-gpm

<table>
<tr>
<td>
TEL105-C/DEM

Spout:


Controller:


Mixing tee:


</td>
<td>

Operated entirely by hydropower. No external power source needed.
Strategic location of sensor at tip of spout for instant response time.
No wiring. Easy installation and low-cost maintenance.
0.5 GPM water-saving flow rate.
ADA compliant
Consists of spout, controller and mixing tee

See more at: http://www.totousa.com/standard-ecopowerfaucet-05-gpm
</td>
</tr>
</table>

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. 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 includes the lifespan of the product. The list of functional units and their corresponding products is presented in Table 2.4. The functional units are taken from the Part B documents pursuant to the SM Transparency Report™ / EPD Framework [7,8]. TOTO products comply with the functional performance specifications defined in the aforementioned Part Bs.

Table 2.4 Functional units of the modeled products

Product code(s)	Functional Unit

TET1LA TEU1LA TEU1UA	10 years of use of a flush valve for toilets and urinals in an average U.S. commercial environment
TEL105-D10E TEL105-C20E TEL105-D10ET TEL105-D10EM TEL105-C20ET TEL105-C20EM	3 years of use of a faucet in an average U.S. commercial environment

2.4 System boundaries

To define what is and what is not included in an LCA, system boundaries are drafted. In general, the system boundaries as specified 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. They define which life cycle phases and processes are included and which are not. The LCA is modeled according to specific system boundaries which are quantified in such a way that they reflect the respective reference units of the modeled products as defined in Section 2.3 herein.

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 of the applied system boundaries for 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.

The process flow for the production stage is presented in Figure 2.2.

Figure 2.2 Fittings manufacturing process flow (confidential)

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

2.4.1.1. Raw Materials

Table 2.5 Fitting products' weights

Product Code	**Total weight (kg, excluding packaging)**
TET1LA & TEU1LA*	4.168
TEU1UA	3.517
TEL105-C/DE	2.131
TEL105-C/DET	2.437
TEL105-C/DEM	2.322

*TET1LA and TEU1LA share the same BOM

The metal components make up the largest portion of the body of a fitting. Other materials, such as plastics and rubbers, are used for smaller parts of the assembly. The recycled content is particularly relevant for the metal components. Material masses and the associated yield and recycled content have been provided by the vendors. The material inputs to the production system of the modeled fitting are provided in Table 2.6. All materials that have a contribution greater than 0.15% weight of the total bill of materials are included. Additional raw materials data of the products as required by Part A is presented in appendix A (Tables A.1 through A.6). The modeling of the material inputs involved the usage of datasets from Ecoinvent, US-Ecoinvent or a modification both to meet geographical boundaries.

Table 2.6 Fitting products' raw materials (confidential)

	Materials (%)	**Recycled content %**	**Materials (%)**	**Recycled content %**	**Materials (%)**	**Recycled content %**	**Materials (%)**	**Recycled content %**	**Materials (%)**	**Recycled content %**
	TET1LA & TEU1LA*		**TEU1UA**		**TEL105-C/DE**		**TEL105-C/DET**		**TEL105-C/DEM**	
Part Materials										
AA Li-ion battery										
ABS										
Brass										
Brass (C360000)										
Brass (covalent coating)										
Brass (Pb free)										
Bronze										

Bronze (C836000)										
Copper										
EPDM										
Epoxy resin										
Magnet										
NBR										
Surface mount, Pb containing										
Polyacetal										
PP										
PPO										
PPS										
PU rigid										
PVC										
Steel										
Surfacemo unt										
Stainless Steel										
Stainless steel, SUS303										
Stainless steel, SUS304										
Stainless steel, SUS316										
Stainless steel, SUS305										
Zinc die cast										
Double wall										
Paper										
Polyethyle ne										

*TET1LA and TEU1LA share the same BOM

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 2.7).

Table 2.7 Completeness of the parts with 0.15% weight cut-off

Product code	**%wt covered**
TET1LA & TEU1LA*	99.68
TEU1UA	99.78
TEL105-C/DE	99.77
TEL105-C/DET	99.82

TEL105-C/DEM	99.72

*TET1LA and TEU1LA share the same BOM

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 2.8).

Table 2.8 Packaging information for fittings

Product code	Total weight (g)	Cardboard (g)	Others (g)*
TET1LA & TEU1LA**	4918.9	681.1	69.6
TEU1UA	4349.1	681.1	151.0
TEL105-C/DE	2472.7	303.1	44.2
TEL105-C/DET	2872.5	360.2	80.6
TEL105-C/DEM	2759.2	370.4	74.2

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

**TET1LA and TEU1LA share the same BOM

2.4.1.3. Transportation

The transportation of the materials to the manufacturing sites and of finished goods to the gate were either provided by vendors or estimated and modeled. The manufacturing gate has been defined as the US port to which products are delived. The totals per product are presented below (Table 2.9).

Table 2.9a Transportation of materials to manufacturing sites (confidential)

Means	tkm				
	TET1LA & TEU1LA*	TEU1UA	TEL105-C/DE	TEL105-C/DET	TEL105-C/DEM
Truck					
Rail					
Ocean freighter					

Table 2.9b Transportation of materials from manufacturing to gate (confidential)

Means	tkm				
	TET1LA & TEU1LA*	TEU1UA	TEL105-C/D105E	TEL105-C/DET	TEL105-C/DEM
Truck					
Rail					
Ocean freighter					

*TET1LA and TEU1LA share the same BOM

2.4.1.4. Manufacturing

The process flow for fittings products is as follows:

- Raw materials, such as ores and 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, zinc, etc. Others include non-metals such as rubbers and thermoplastics.

- Often, the intermediates are manufactured in the same facility in which the fittings' 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:
  - Die casting
  - 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
- 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. This assembly is performed manually, sometimes using power tools in which the energy consumption would be negligible.
- 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 finished goods and placed into inventory.

The combination of the processes and associated production yield, as well as material mass and recycled content of the material (Tables 2.5 and 2.6), is used as the basis for the manufacturing model. The primary processes involved and associated 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 (2.10a through 2.10j). The tables list the types of processes, the materials and the average yield percentages for primary processes. A more detailed description of the modeled processes as required by Part A is presented in appendix A (tables A.7 through A.15). The modeling of primary and secondary processes was conducted via the utilization of datasets from Ecoinvent, US-Ecoinvent or a modification of both to meet geographical boundaries.

Table 2.10a Primary processes, materials and yield for TET1LA & TEU1LA (confidential)

TET1LA & TEU1LA*		
Primary Process	**Material(s)**	**Average Yield (%)**
Bronze Casting		
Zinc Die Casting		
Extrusion		
Injection Molding		
Sheet Rolling, Steel		
Turning, Brass, CNC		
Turning, Bronze, CNC		
Turning, Steel, CNC		
Wire Drawing		

*TET1LA and TEU1LA share the same BOM

Table 2.10b Primary processes, materials and yield for TEU1UA (confidential)

TEU1UA		
Primary Process	**Material(s)**	**Average Yield (%)**
Bronze Casting		
Zinc Die Casting		
Extrusion		
Injection Molding		
Sheet Rolling, Steel		
Turning, Brass, CNC		
Turning, Bronze, CNC		
Turning, Steel, CNC		
Wire Drawing		

Table 2.10c Primary processes, materials and yield for TEL105-C/DE (confidential)

TEL105-C/DE		
Primary Process	**Material(s)**	**Average Yield (%)**
Extrusion		
Injection molding		
Sheet rolling, Steel		
Turning, Brass		
Turning, Steel		
Wire Drawing		

Table 2.10d Primary processes, materials and yield for TEL105-C/DET (confidential)

TEL105-C/DET		
Primary Process	**Material(s)**	**Average Yield (%)**
Casting Brass		
Extrusion		
Injection molding		
Sheet rolling, Steel		
Turning, Brass		
Turning, Steel		
Wire Drawing		

Table 2.10e Primary processes, materials and yield for TEL105-C/D105EM (confidential)

TEL105-C/DEM		
Primary Process	**Material(s)**	**Average Yield (%)**
Casting Brass		
Extrusion		
Injection molding		
Sheet rolling, Steel		
Turning, Brass		
Turning, Steel		
Wire Drawing		

Table 2.10f Secondary and tertiary processes and materials for TET1LA & TEU1LA (confidential)

TET1LA & TEU1LA*	
Secondary and Tertiary Process	**Material(s)**
Electroplating	
Polishing	
Potting	
Soldering	

*TET1LA and TEU1LA share the same BOM

Table 2.10g Secondary and tertiary processes and materials for TEU1UA (confidential)

TEU1UA	
Secondary and Tertiary Process	**Material(s)**
Electroplating	
Polishing	
Potting	
Soldering	

Table 2.10h Secondary and tertiary processes and materials for TEL105-C/DE (confidential)

TEL105-C/DE	
Secondary and Tertiary Process	**Material(s)**
Electroplating	
Polishing	
Potting	
Soldering	

Table 2.10i Secondary and tertiary processes and materials for TEL105-C/DET (confidential)

TEL105-C/DET	
Secondary and Tertiary Process	**Material(s)**
Electroplating	
Polishing	
Potting	

Soldering	

Table 2.10j Secondary and tertiary processes and materials for TEL105-C/DEM (confidential)

TEL105-C/DEM	
Secondary and Tertiary Process	**Material(s)**
Electroplating	
Polishing	
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

From the manufacturing gate, defined in section 2.4.1.3, the products are delived to TOTO USA's east coast distribution center, the Fairburn Assembly Plant. Transportation of finished packaged products and sub-assemblies to the warehouse from vendors is done by diesel trucks (average of 25 mi) and by rail (2184 mi). After products are purchased by distributors, dealers, and showrooms for purchase by the end users, they are transported from the FAP warehouse to these purchasers. Transportation and distance would vary and are dependent on the locations of the purchasers and their choice of shipping mode. Outbound shipments to customers from FAP are transported by both diesel truck (average of 883 mi) and rail (average of 1370 mi). These numbers are estimated based on actual 2015 shipment averages.

Table 2.11a Transportation of products from gate to FAP (confidential)

Means	**tkm**				
	TET1LA & TEU1LA*	TEU1UA	TEL105-C/DE	TEL105-C/DET	TEL105-C/DEM
Truck					
Rail					

Table 2.11b Transportation of products from FAP to site (confidential)

Means	**tkm**				
	TET1LA & TEU1LA*	TEU1UA	TEL105-C/DE	TEL105-C/DET	TEL105-C/DEM
Truck					
Rail					

*TET1LA and TEU1LA share the same BOM

2.4.2.2. Construction / Installation

After customers purchase the fitting products from distribution centers, fittings are installed with toilets, urinals or sinks. Installation of fittings units is manual. Other than packaging cartons, bags and manuals 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 and presented in table 2.12. It is assumed that packaging disposal will follow the percentages published in the U.S. EPA's Municipal Solid Waste Generation, Recycling, and Disposal in the United States Report for 2013[1]. According to the report, 36.7% of paper and paperboard and 90.8% of plastics in municipal wastes are sent to landfill. Additional information on disposal of the fittings components is presented in section 2.4.4.

Table 2.12 Waste materials to landfill

Product	Cardboard (g)	Paper (g)	PE (g)
TET1LA & TEU1LA*	249.95	20.49	12.81
TEU1UA	249.95	50.40	12.69
TEL105-C/DE	111.23	12.85	8.54
TEL105-C/DET	132.19	24.13	13.83
TEL105-C/DEM	135.95	23.34	9.83

*TET1LA and TEU1LA share the same BOM

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, inputs to this module are considered to be zero.

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. Inputs to this module are considered to be zero.

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. Inputs to this module are considered to be zero.

[1] United States Environmental Protection Agency, Advancing Sustainable Materials Management: 2013 Fact Sheet. Assessing Trends in Material Generation, Recycling, and Disposal in the United States. Published June 2015. https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_fs.pdf

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 the 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. Inputs to this module are considered to be zero.

2.4.3.5. Refurbishment

The service life is defined in such as way that for a typical installation, no refurbishment is required. Inputs to this module are considered to be zero.

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 Bs of the Sustainable Minds Transparency Report™ / EPD Framework referenced herein [7,8]. The water usage of the products was calculated as shown in Table 2.13.

Table 2.13 Water usage of the products

Product codes	Total number of uses during modeled life	Water consumption (gal/use)	Total consumption during modeled life (gal)
TET1LA	365 days/year x 10 years x 133 uses/day = 485,450 uses	1.28	621,376.00
TEU1LA	260 days/year x 10 years x 18 uses/day = 46,800 uses	0.50	23,400.00
TEU1UA	260 days/year x 10 years x 18 uses/day = 46,800 uses	0.125	5,850.00
TEL105-D10E	365 days/year x 3 years x 133 uses/day = 145,635 uses	0.09	13,107.15
TEL105-C20E	365 days/year x 3 years x 133 uses/day = 145,635 uses	0.19	27,670.65
TEL105-D10ET	365 days/year x 3 years x 133 uses/day = 145,635 uses	0.09	13,107.15
TEL105-C20ET	365 days/year x 3 years x 133 uses/day = 145,635 uses	0.19	27,670.65
TEL105-D10ET	365 days/year x 3 years x 133 uses/day = 145,635 uses	0.09	13,107.15
TEL105-C20ET	365 days/year x 3 years x 133 uses/day = 145,635 uses	0.19	27,670.65

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 2.14 below.

Table 2.14 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: 68% of population served by PWSs relies on surface water, 32% on ground water. Calculated from http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_treatment_web.pdf.
Note 3: 1.7% of POTW-served population receives < secondary treatment, 40.9% receives secondary treatment, 49.9% receives advanced treatment, and 7.5% receives zero discharge or other treatment. Source: EPA, 2008 Clean Watersheds Needs Survey.

The summary of the use phase data for the fittings over their respective reference service life is provided in Table 2.15 below.

Table 2.15 Fitting use phase data

Product code	**Water usage (gallon)**	**Electricity usage (kWh)**
TET1LA	621,376.00	2236.95
TEU1LA	88,569.00	84.24
TEU1UA	5,850.00	21.06
TEL105-D105E	13,107.15	47.19
TEL105-C205E	27,670.65	99.61
TEL105-D105ET	13,107.15	47.19
TEL105-C205ET	27,670.65	99.61
TEL105-D105ET	13,107.15	47.19
TEL105-C205ET	27,670.65	99.61

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 2013. According to the report, 63.3% of paper and paperboard, 33.0% of the steel, 68.2% of other non-ferrous metals, 16.1% of rubber, and 9.2% of plastics 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 as shown in Table 2.16.

Table 2.16 List of modeled waste scenarios

Material	**Waste scenario**	
	Recycling	**Landfill**
Brass, copper, copper alloy, bronze	68.2%	31.8%
Double wall, paper	63.3%	36.7%
Plastics	9.2%	90.8%
NBR, rubber	16.1%	83.9%
AA Li-ion battery, magnet, surface mount	0.0%	100.0%
Stainless steel, steel alloy	33.0%	67.0%

2.4.4.1. De-construction / demolition stage

At the end of life, de-construction of the fittings products which includes the dismantling of the fittings products, as well as the initial on-site sorting, is assumed to be manual. Therefore, inputs to this module are considered to be zero.

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 2.12 were 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 following the waste scenarios of materials as listed in Table 2.12 was 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 2.12 are processed in the waste processing stage (i.e. Module [C3]). The transportation (100 km) 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% substitutes that amount of primary material (Table 2.17). There is no thermal recovery modeled for end of life as is defined in the scenarios in Table 2.12.

Table 2.17 Substitution in recovery stage

Material	% of substitution	Material substituted with
ABS, epoxy resin, polyacetal, PP, PVC	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
Zinc	95%	Zinc

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:

- The vendor has responded to the request for data in great detail. However, the use industry averages as opposed to plant specific manufacturing data results in greater uncertainty. 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).

All relevant 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 2.7) and satisfies the above defined cut-off criteria. Plant specific manufacturing process data was not used as they were incomplete or hard to verify. The significance of plant specific data on LCA results will show up in future LCA studies as TOTO continues to collect more LCA relevant data.

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 ensures that the sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation. This check was done by identifying the input and output mass for each process and confirming that they are equal. This means that no double counting or omissions of inputs or outputs through allocation is occuring.

When allocations have been made, 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.

Manufacturing processes:
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 that the co-product allocation is either based on value or, if not available, on mass. No plant specific data was allocated to products, as no plant specific data related to manufacturing operations was used in the model.

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, including 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 are also recycled. An example is 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 referred 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 made optional by Part A of the Framework (see Table 4.1). The impact indicators are derived by using the time horizon[2] factors, where relevant, as defined by TRACI 2.1 classification and characterization[3]. 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)

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 8.1.1.16 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.

4.2 Normalization and weighting

To arrive to the single score indicator, normalization[4] and weighting[5] conforming to Part A of the Framework was applied.

[2] 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.
[3] Bare JC (2012) Tool for the reduction and assessment of chemical andother environmental impacts (TRACI), Software name andversion number: TRACI Version 2.1, User's Manual. US EPA.
[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.

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

[5] 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. Where applicable, some sections include the weighted averaged results based on production volumes. This chapter also outlines the sensitivity analyses and concludes with recommendations.

5.1 TET1LA

Cradle-to-gate

Figure 5.1 shows the results for the finished product. Bronze and zinc parts, together with the printed wiring board have significant material contributions to the results. The stainless steel material is relevant to the carcenogenics category. The electroplating process is a major contributor to the ozone depletion catgory while the die casting process is relevant to the ecotoxicity and non-carcinogenics categories. Furthermore, polishing and potting have somewhat significant processing contribution to the results. Because these products are manufactured in China but sold in the US market, the transportation via oceanic freighter appears as a relevant contributor to the fossil fuel depletion and smog categories. The other parts and processes contribute between 3% and 15% of the overall impacts in the remaining categories.

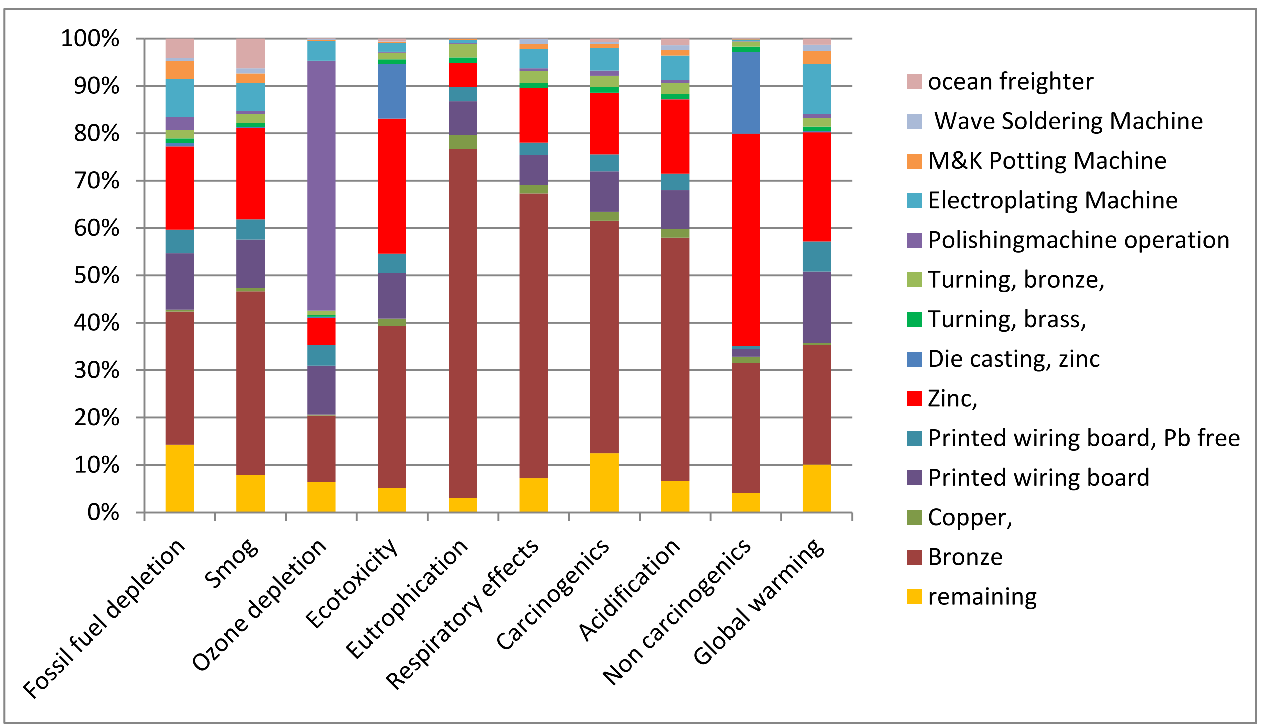


Figure 5.1 Cradle-to-gate impacts for TET1LA – relative results

Full life cycle

Figure 5.2 and Table 5.1 show the results for the full life cycle of the product. Results show that the use phase dominates all impact categories, with the exception of non carcinogenics. The use phase [B1-B7] is highly significant for global warming, fossil fuel depletion, carcinogenics, and ozone depletion. This is mostly due to the embedded electricity used for the water supply and the water consumed during use. The production phase [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 production of the product itself [A1-A3] are discussed above in the cradle-to-gate section. The end-of-life scenario [D] includes recycling, which appears as benefits by preventing the need to generate primary materials. It is a relevant factor for the impact categories, offsetting a portion of the impacts caused by manufacturing the parts of the product. The transportation to the installation site [A4], the construction/installation of the product and the processes for dismantling [A5], and the final waste treatment of the product [C1-C4] do not have a significant impact according to these results.

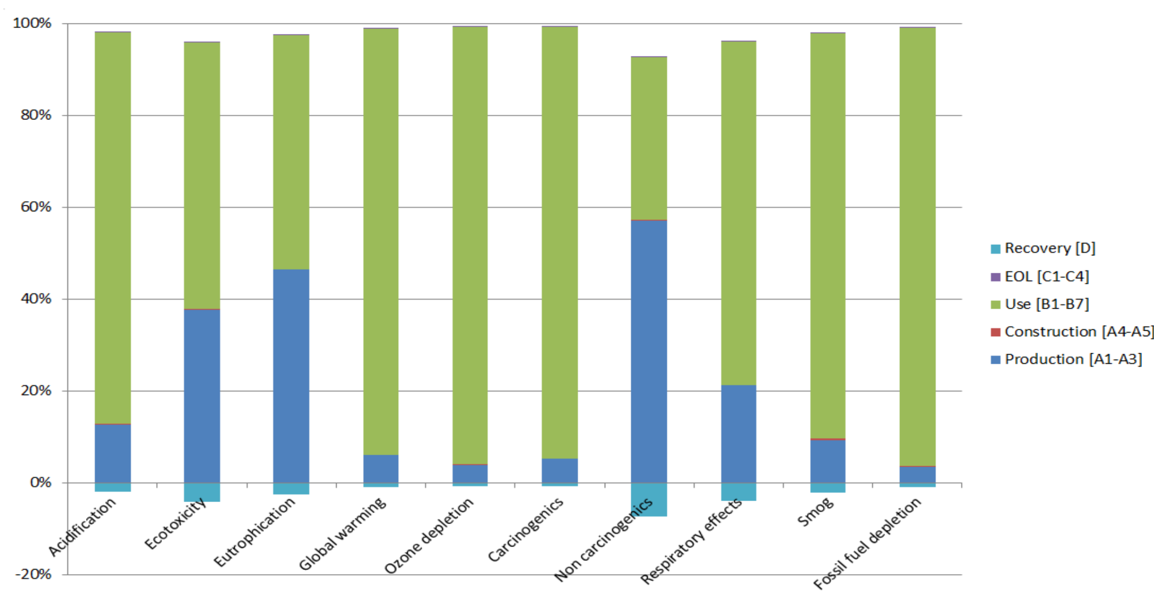


Figure 5.2 Life cycle impacts for TET1LA – relative results

Table 5.1 Life cycle impacts for TET1LA – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
Ecological damage							
Acidification	kg SO_2 eq	1.24E+01	1.65E+00	1.46E-02	1.10E+01	2.17E-03	-2.40E-01
Ecotoxicity	CTUe	1.15E+03	4.73E+02	3.23E+00	7.25E+02	2.18E-01	-5.19E+01
Eutrophication	kg N eq	2.25E+00	1.10E+00	1.45E-03	1.21E+00	2.28E-04	-5.71E-02
Global warming	kg CO_2 eq	1.01E-04	6.34E-06	3.59E-09	9.52E-05	3.22E-08	-1.00E-06
Ozone depletion	kg CFC-11 eq	2.18E+03	8.72E+01	1.63E+00	2.10E+03	2.70E-01	-1.47E+01
Human health damage							

Carcinogenics	CTUh	4.54E-05	2.45E-06	1.83E-08	4.32E-05	2.52E-09	-3.21E-07
Non carcinogenics	CTUh	4.29E-04	2.87E-04	1.71E-07	1.78E-04	1.78E-08	-3.66E-05
Respiratory effects	kg PM2.5 eq	9.12E-01	2.10E-01	2.60E-04	7.39E-01	2.32E-04	-3.75E-02
Smog	kg O_3 eq	1.09E+02	1.05E+01	4.67E-01	1.00E+02	5.82E-02	-2.37E+00
Resource depletion							
Fossil fuel depletion	MJ surplus	1.30E+03	4.67E+01	2.33E+00	1.27E+03	4.52E-01	-1.16E+01

SM results

The SM millipoint scores by life cycle phase for this product are presented below (Table 5.2). They confirm the trends in the results using the impact assessment results before normalization and weighting.

Table 5.2 SM millipoint scores for TET1LA by life cycle phase – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
SM single figure score	mPts	182.20	31.81	0.14	151.73	0.02	-1.50

5.2 TEU1LA

Cradle-to-gate

Figure 5.3 shows the results for the finished product. Bronze and zinc parts, together with the printed wiring board have significant material contributions to the results. The stainless steel material is relevant to the carcenogenics category. The electroplating process is a major contributor to the ozone depletion catgory while the die casting process is relevant to the ecotoxicity and non-carcinogenics categories. Furthermore, polishing and potting have somewhat significant processing contribution to the results. Because these products are manufactured in China but sold in the US market, the transportation via oceanic freighter appears as a relevant contributor to the fossil fuel depletion and smog categories. The other parts and processes contribute between 3% and 15% of the overall impacts in the remaining categories.

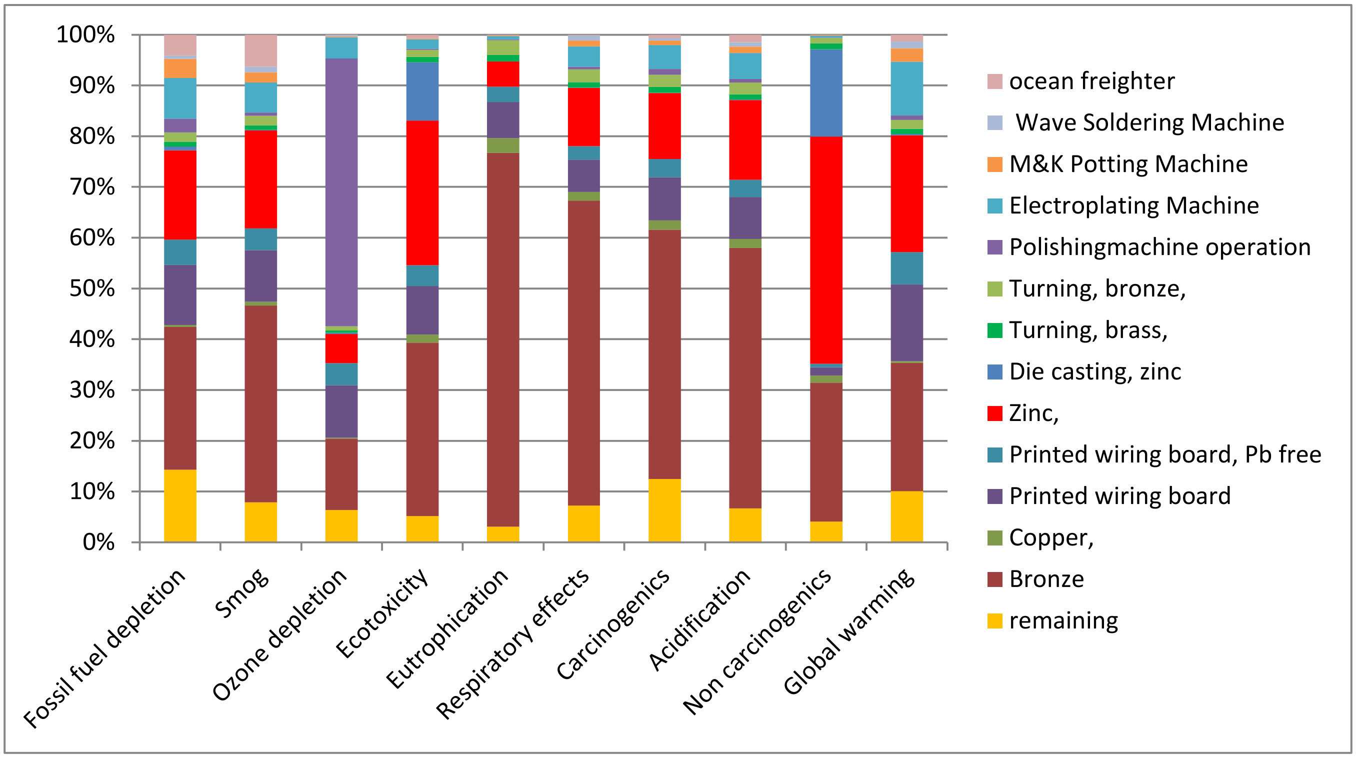


Figure 5.3 Cradle-to-gate impacts for TEU1LA – relative results

Full life cycle

Figure 5.4 and Table 5.3 show the results for the full life cycle of the product. Results show that the production [A1-A3] dominates all impact categories except for global warming and fossil fuel depletion, in which the use phase appears to be as significant. The production [A1-A3] is most significant as a contributor 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 production of the product itself [A1-A3] are discussed above in the cradle-to-gate section. The use phase [B1-B7] is relevant to all impact categories, especially fossil fuel depletion, carcinogens, and glodal warming. This is mostly due to the embedded electricity used for the water supply and the water consumed during use. The end-of-life scenario [D] includes recycling, which appears as benefits by preventing the need to generate primary materials. It is a relevant factor for the impact categories, offsetting a portion of the impacts caused by manufacturing the parts of the product. The transportation to the installation site [A4], the construction/installation of the product and the processes for dismantling [A5], and the final waste treatment of the product [C1-C4] do not have a significant impact according to these results.

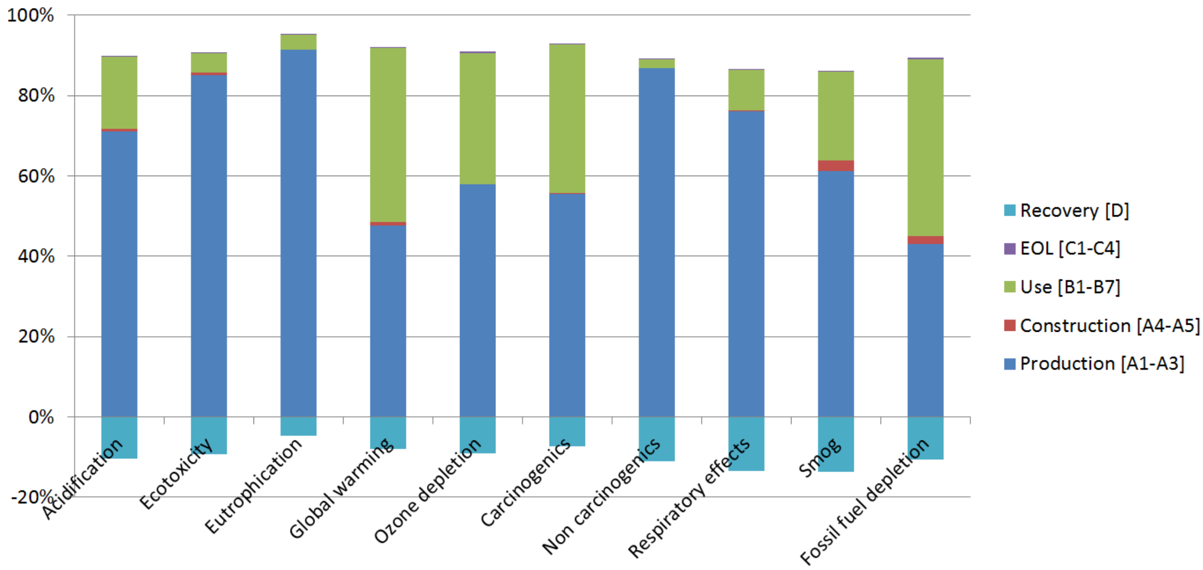


Figure 5.4 Life cycle impacts for TEU1LA – relative results

Table 5.3 Life cycle impacts for TEU1LA – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
Ecological damage							
Acidification	kg SO_2 eq	1.98E+00	1.65E+00	1.46E-02	4.12E-01	2.17E-03	-2.40E-01
Ecotoxicity	CTUe	4.61E+02	4.73E+02	3.23E+00	2.73E+01	2.18E-01	-5.19E+01
Eutrophication	kg N eq	1.10E+00	1.10E+00	1.45E-03	4.54E-02	2.28E-04	-5.71E-02
Global warming	kg CO_2 eq	1.81E+02	8.72E+01	1.63E+00	7.91E+01	2.70E-01	-1.47E+01
Ozone depletion	kg CFC-11 eq	1.02E-05	6.34E-06	3.59E-09	3.59E-06	3.22E-08	-1.00E-06
Human health damage							
Carcinogenics	CTUh	4.34E-06	2.45E-06	1.83E-08	1.63E-06	2.52E-09	-3.21E-07
Non carcinogenics	CTUh	2.60E-04	2.87E-04	1.71E-07	6.71E-06	1.78E-08	-3.66E-05
Respiratory effects	kg PM2.5 eq	2.11E-01	2.10E-01	2.60E-04	2.78E-02	2.32E-04	-3.75E-02
Smog	kg O_3 eq	1.37E+01	1.05E+01	4.67E-01	3.77E+00	5.82E-02	-2.37E+00
Resource depletion							
Fossil fuel depletion	MJ surplus	1.02E+02	4.67E+01	2.33E+00	4.77E+01	4.52E-01	-1.16E+01

SM results

The SM millipoint scores by life cycle phase for this product are presented below (Table 5.4). They confirm the trends in the results using the impact assessment results before normalization and weighting.

Table 5.4 SM millipoint scores for TEU1LA by life cycle phase – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
SM single figure score	mPts	36.18	31.81	0.14	5.71	0.02	-1.50

5.3 TEU1UA

Cradle-to-gate

Figure 5.5 shows the results for the finished product. Bronze and zinc parts, together with the printed wiring board have significant material contributions to the results. The stainless steel material is relevant to the carcenogenics category. The electroplating process is a major contributor to the ozone depletion catgory while the die casting process is relevant to the ecotoxicity and non-carcinogenics categories. Furthermore, polishing and turning have somewhat significant processing contribution to the results. Because these products are manufactured in China but sold in the US market, the transportation via oceanic freighter appears as a relevant contributor to the fossil fuel depletion and smog categories. The other parts and processes contribute between 2% and 13% of the overall impacts in the remaining categories.

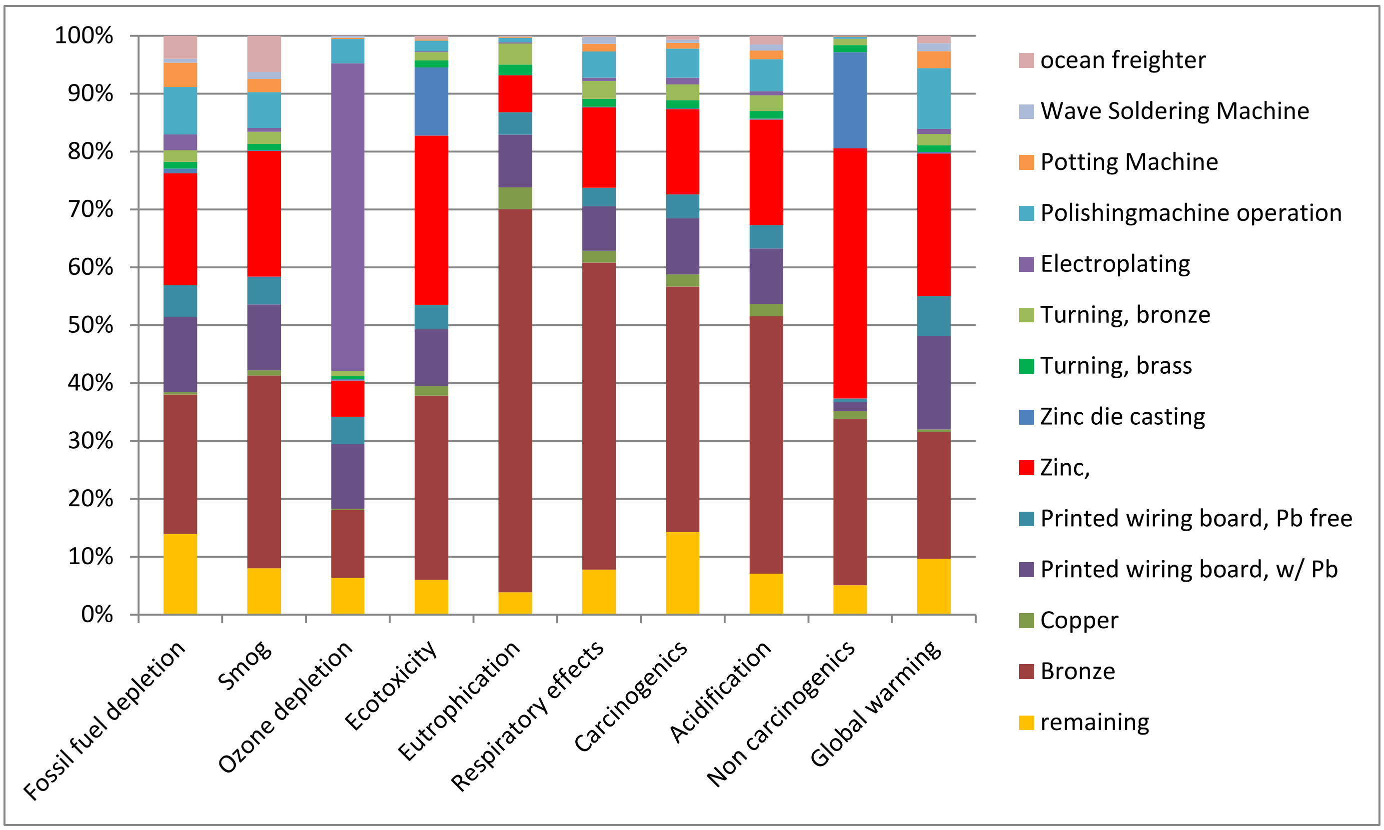


Figure 5.5 Cradle-to-gate impacts for TEU1UA– relative results

Full life cycle

Figure 5.6 and Table 5.5 show the results for the full life cycle of the product. Results show that the production [A1-A3] dominates all impact categories and is most significant as a contributor 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 production of the prouct itself [A1-A3] are discussed above in the cradle-to-gate section. The use phase [B1-B7] is relevant to some impact categories, especially fossil fuel depletion, ozone depletion, carcinogens, and global warming. This is mostly due to the embedded electricity used for the water supply and the water consumed during use. It does not appear that the use phase is significant to ecotoxicity, eutrophication, or non-carcinogens. The end-of-life scenario [D] includes recycling, which appears as benefits by preventing the need to generate primary materials. It is a relevant factor for the impact categories, offsetting a portion of the impacts caused by manufacturing the parts of the product. The transportation to the installation site [A4], the construction/installation of the product and the processes for dismantling [A5], and the final waste treatment of the product [C1-C4] do not have a significant impact according to these results.

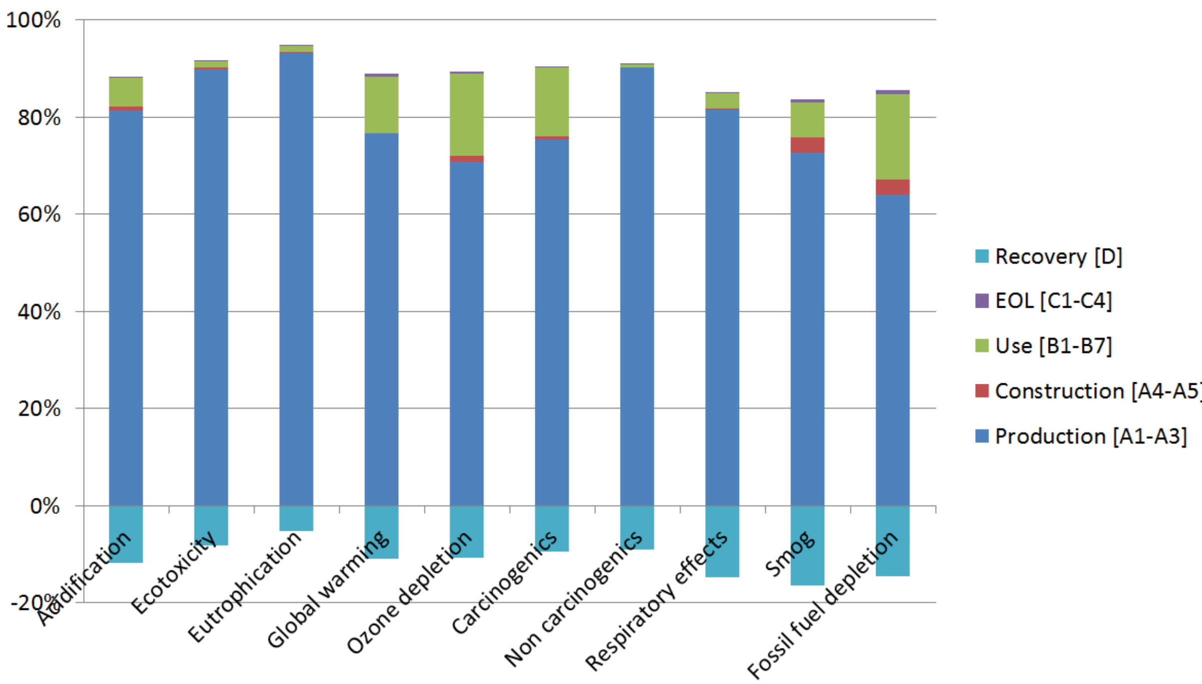


Figure 5.6 Life cycle impacts for TEU1UA – relative results

Table 5.5 Life cycle impacts for TEU1UA – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
Ecological damage							
Acidification	kg SO_2 eq	1.33E+00	1.41E+00	1.29E-02	1.03E-01	2.62E-03	-2.06E-01
Ecotoxicity	CTUe	4.35E+02	4.68E+02	2.87E+00	6.82E+00	5.30E-01	-4.33E+01
Eutrophication	kg N eq	8.17E-01	8.53E-01	1.42E-03	1.14E-02	3.62E-04	-4.87E-02
Global warming	kg CO_2 eq	6.00E-06	5.92E-06	3.84E-09	8.97E-07	4.13E-08	-8.55E-07
Ozone depletion	kg CFC-11 eq	9.17E+01	8.26E+01	1.52E+00	1.98E+01	3.58E-01	-1.25E+01

Human health damage							
Carcinogenics	CTUh	2.31E-06	2.16E-06	1.62E-08	4.07E-07	6.03E-09	-2.72E-07
Non carcinogenics	CTUh	2.76E-04	3.05E-04	1.51E-07	1.68E-06	2.66E-07	-3.07E-05
Respiratory effects	kg PM2.5 eq	1.49E-01	1.73E-01	2.33E-04	6.95E-03	3.08E-04	-3.15E-02
Smog	kg O_3 eq	8.64E+00	9.34E+00	4.13E-01	9.44E-01	5.75E-02	-2.11E+00
Resource depletion							
Fossil fuel depletion	MJ surplus	4.79E+01	4.33E+01	2.06E+00	1.19E+01	5.12E-01	-9.82E+00

SM results

The SM millipoint scores by life cycle phase for this product are presented below (Table 5.6). They confirm the trends in the results using the impact assessment results before normalization and weighting.

Table 5.6 SM millipoint scores for TEU1UA by life cycle phase – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
SM single figure score	mPts	31.47	31.04	0.12	1.43	0.04	-1.17

5.4 TEL105-D10E and TEL105-C20E

Cradle-to-gate

Figure 5.7 shows the results for the finished products. The assembly results are not averaged for the two models because the BOM has no variations. Brass and the turing brass process, together with the printed wiring board have significant material contributions to the results. Stainless steel materials and the turning steel process are relevant to the carcenogenics category. The electroplating process along with injection molding are major contributors to the ozone depletion catgory. Furthermore, polishing has somewhat significant processing contribution to the results. Because these products are manufactured in China but sold in the US market, the transportation via oceanic freighter appears as a relevant contributor to the fossil fuel depletion and smog categories. The other parts and processes contribute between 5% and 20% of the overall impacts in the remaining categories.

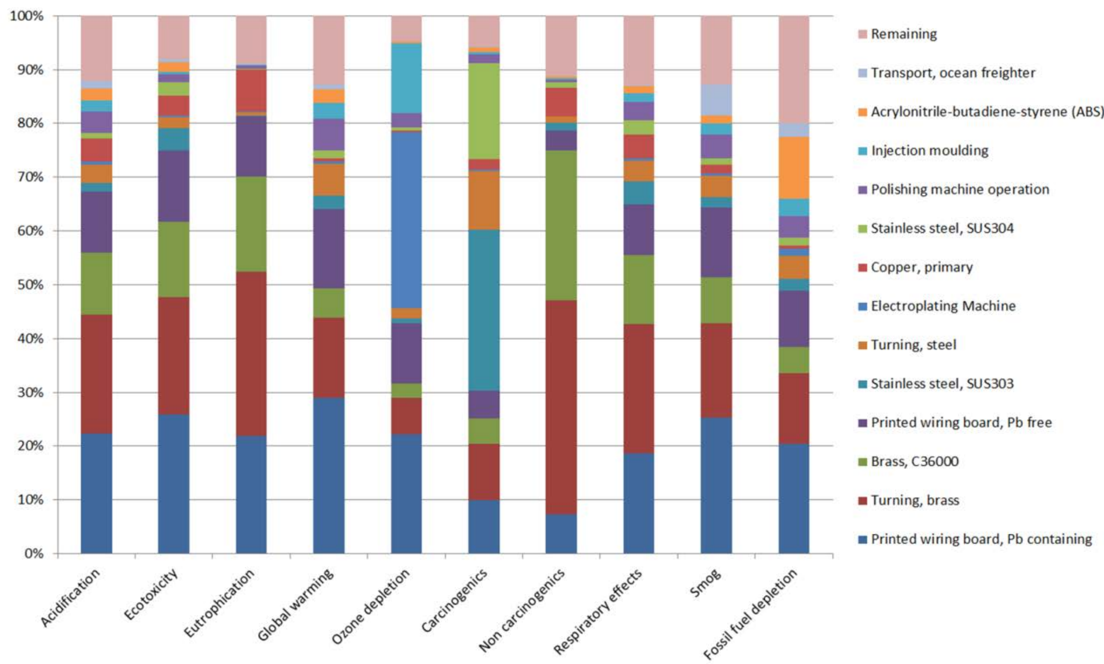


Figure 5.7 Cradle-to-gate impacts for TEL105-D10E and TEL105-C20E – relative results

Variations

There are no variations within the assembly of these two models.

Full life cycle

Figure 5.8 and Table 5.7 show the results for the average of the full life cycle of the product. Results show that the production [A1-A3] dominates all impact categories and is most significant as a contributor 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 production of the product itself [A1-A3] are discussed above in the cradle-to-gate section. The use phase [B1-B7] is relevant to most impact categories, especially fossil fuel depletion, ozone depletion, and global warming. This is mostly due to the embedded electricity used for the water supply and the water consumed during use. Relative to the other phases, it does not appear that the use phase is significant to ecotoxicity, eutrophication, or non-carcinogens. The end-of-life scenario [D] includes recycling, which appears as benefits by preventing the need to generate primary materials. It is a relevant factor for some of the impact categories, offsetting a portion of the impacts caused by manufacturing the parts of the product. The transportation to the installation site [A4], the construction/installation of the product and the processes for dismantling [A5], and final waste treatment of the product [C1-C4] do not have a significant impact according to these results.

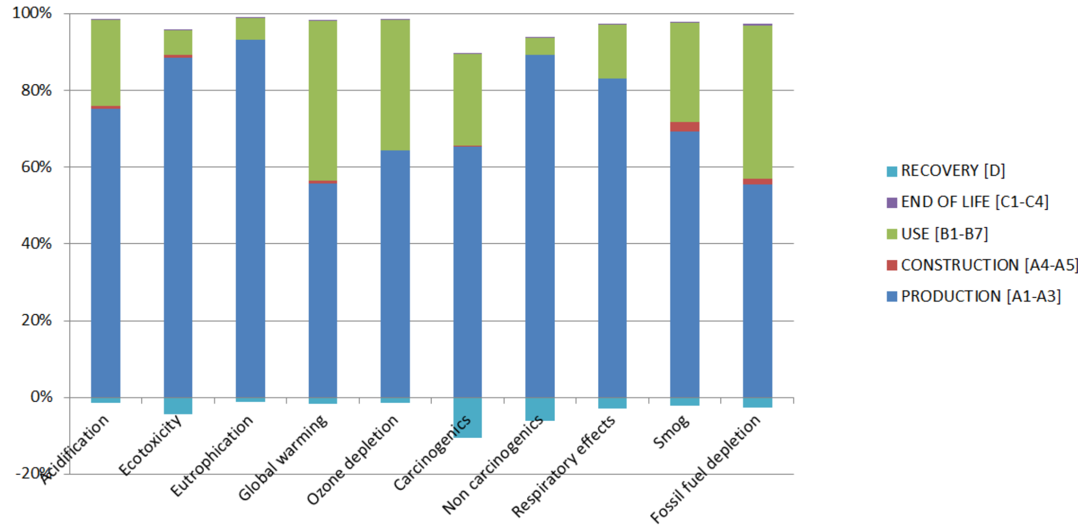


Figure 5.8 Life cycle impacts for the average of TEL105-D10E and TEL105-C20E – relative results

Table 5.7 Life cycle impacts for average of TEL105-D10E and TEL105-C20E – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
Ecological damage							
Acidification	kg SO_2 eq	1.07E+00	8.29E-01	7.04E-03	**2.48E-01**	1.09E-03	-1.68E-02
Ecotoxicity	CTUe	2.36E+02	2.29E+02	1.57E+00	**1.64E+01**	1.96E-01	-1.12E+01
Eutrophication	kg N eq	4.75E-01	4.52E-01	6.89E-04	**2.73E-02**	2.01E-04	-5.14E-03
Global warming	kg CO_2 eq	1.10E+02	6.34E+01	7.85E-01	**4.76E+01**	1.88E-01	-1.81E+00
Ozone depletion	kg CFC-11 eq	6.20E-06	4.11E-06	1.72E-09	**2.16E-06**	1.67E-08	-9.39E-08
Human health damage							
Carcinogenics	CTUh	3.25E-06	2.69E-06	8.88E-09	**9.80E-07**	2.35E-09	-4.31E-07
Non carcinogenics	CTUh	8.15E-05	8.31E-05	8.30E-08	**4.04E-06**	7.35E-08	-5.78E-06
Respiratory effects	kg PM2.5 eq	1.14E-01	1.00E-01	1.25E-04	**1.67E-02**	1.12E-04	-3.39E-03
Smog	kg O_3 eq	8.46E+00	6.13E+00	2.25E-01	**2.27E+00**	2.23E-02	-1.95E-01
Resource depletion							
Fossil fuel depletion	MJ surplus	6.80E+01	3.99E+01	1.13E+00	**2.87E+01**	2.13E-01	-1.94E+00

Numbers shown in **blue** have a variation of 10 to 20%

Numbers shown in **red** have a variation greater than 20%

Variations

Because there are no variations in the materials between these two models, all life cycle stage impacts are the same, with the exception of the use phase. The variations in the use phase are a result of the difference between the two water consumption values. TEL105-C20E uses more water than the TEL105-D10E. This is because the TEL105-C20E utilizes a continuous cycle, while the TEL105-D10E utilizes on-demand functionality.

SM results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.8). They confirm the trends in the results using the impact assessment results before normalization and weighting.

Table 5.8 Averaged SM millipoint scores for TEL105-D10E and TEL105-C20E by life cycle phase – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
SM single figure score	mPts	17.47	15.27	0.07	3.44	0.02	-1.32

Numbers shown in **blue** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

5.5 TEL105-D10ET, TEL105-C20ET, TEL105-D10EM, and TEL105-C20EM

Cradle-to-gate

Figure 5.9 shows the results for the average of the two modeled finished products. Brass and its turning brass process, together with the printed wiring board have significant contributions to the results. Stainless steel and the turning steel process are relevant to the carcenogenics category. The electroplating process along with injection molding are major contributors to the ozone depletion category. Furthermore, polishing has a somewhat significant processing contribution to the results. Because these products are manufactured in China but sold in the US market, the transportation via oceanic freighter appears as a relevant contributor to the fossil fuel depletion and smog categories. The other parts and processes contribute between 5% and 20% of the overall impacts in the remaining categories.

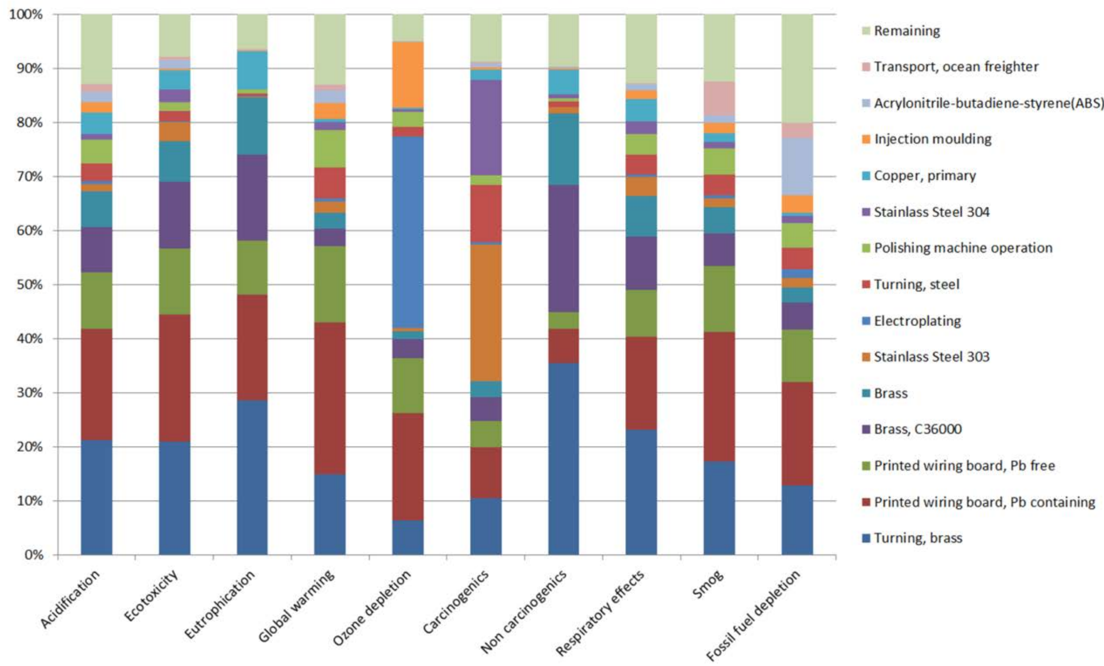


Figure 5.9 Cradle-to-gate impacts for the average of TEL105-D10ET, TEL105-D10EM, TEL105-C20ET, and TEL105-C20EM – relative results

Full life cycle

Figure 5.10 and Table 5.9 show the results for the average of the full life cycle of the product. Results show that the production [A1-A3] dominates all impact categories and is most significant as a contributor 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 production of the product itself [A1-A3] are discussed above in the cradle-to-gate section. The use phase [B1-B7] is relevant to most impact categories, especially fossil fuel depletion, ozone depletion, carcinogens, and global warming. This is mostly due to the embedded electricity used for the water supply and the water consumed during use. Relative to the other phases, it does not appear that the use phase is significant to ecotoxicity, eutrophication, or non-carcinogens. The end-of-life scenario [D] includes recycling, which appears as benefits by preventing the need to generate primary materials. It is a relevant factor for many of the impact categories, offsetting a portion of the impacts caused by manufacturing the parts of the product. The transportation to the installation site [A4] the construction/installation of the product and the processes for dismantling [A5], and final waste treatment of the product [C1-C4] do not have a significant impact according to these results.

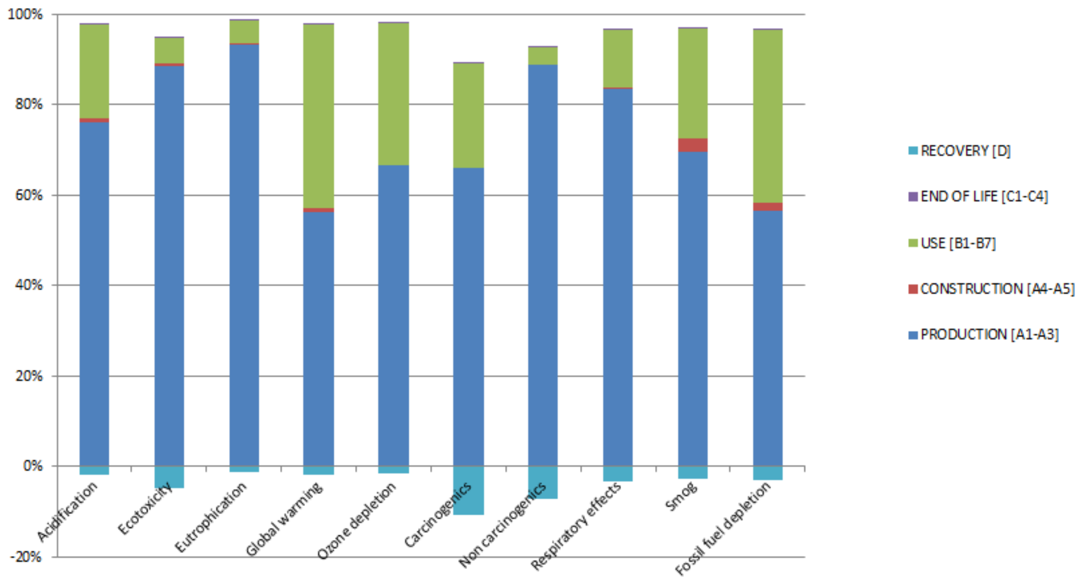


Figure 5.10 Life cycle impacts for the average of TEL105-D10ET, TEL105-D10EM, TEL105-C20ET, and TEL105-C20EM – relative results

Table 5.9 Life cycle impacts for average of TEL105-D10ET, TEL105-D10EM, TEL105-C20ET, and TEL105-C20EM – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
Ecological damage							
Acidification	kg SO_2 eq	1.13E+00	9.00E-01	8.73E-03	2.48E-01	1.42E-03	-2.40E-02
Ecotoxicity	CTUe	2.55E+02	2.50E+02	1.90E+00	1.64E+01	2.89E-01	-1.40E+01
Eutrophication	kg N eq	5.26E-01	5.05E-01	8.14E-04	2.73E-02	2.61E-04	-7.08E-03
Global warming	kg CO_2 eq	1.12E+02	6.55E+01	9.35E-01	4.76E+01	2.42E-01	-2.22E+00
Ozone depletion	kg CFC-11 eq	6.65E-06	4.58E-06	1.99E-09	2.16E-06	2.23E-08	-1.20E-07
Human health damage							
Carcinogenics	CTUh	3.34E-06	2.81E-06	1.07E-08	9.80E-07	3.29E-09	-4.61E-07
Non carcinogenics	CTUh	9.31E-05	9.66E-05	1.00E-07	4.04E-06	1.30E-07	-7.79E-06
Respiratory effects	kg PM2.5 eq	1.21E-01	1.09E-01	1.55E-04	1.67E-02	1.53E-04	-4.23E-03
Smog	kg O_3 eq	8.79E+00	6.46E+00	2.80E-01	2.27E+00	2.89E-02	-2.55E-01
Resource depletion							
Fossil fuel depletion	MJ surplus	7.06E+01	4.25E+01	1.37E+00	2.87E+01	2.80E-01	-2.29E+00

Numbers shown in **blue** have a variation of 10 to 20%

Numbers shown in **red** have a variation greater than 20%

Variations

Variations in the life cycle phases, other than the use phase, are a result of a difference in the BOM (shown in Table 5.10). The differences in mass contributes to the variation in the construction and EOL phases. TEL105-D/CET contains more mass than TEL105-D/CEM. The recovery phase contains variations due to the differences in the amount of materials recovered from recycling. TEL105-D/CET contains more metals for recycling than the TEL105-D/CEM. The variations in the use phase are a result of the disparity between the two water consumption values. TEL105-C10ET/M uses more water than TEL105-D10ET/M. This is because TEL105-C20E utilizes a continuous cycle, while TEL105-D10E utilizes on-demand functionality.

Table 5.10 Variations in the bill of materials for TEL105-D/CET & TEL105-D/CEM (confidential)

Material	Average (g)
AA Li-ion Battery	
ABS	
Brass (C360000)	
Brass (Covalent Coating)	
Brass (primary)	
Brass (secondary)	
Brass C49260	
Brass Pb free	
Cu	
Double Wall (primary)	
Double Wall (secondary)	
EPDM	
Epoxy Resin	
Magnet	
NBR	
Nickel Titanium Alloy	
Paper (primary)	
Paper (secondary)	
Pb w/ Surfacemount	
PE	
Polyacetal	
POM	
PP	
PPO	
PPS	
PU Rigid	
PVC	
Steel	
Surfacemount	
SUS	
SUS303 (primary)	
SUS303 (secondary)	
SUS304	

Numbers shown in **blue** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

SM results

The SM millipoint score by life cycle phase for this product is presented below (Table 5.11). They confirm the trends in the results using the impact assessment results before normalization and weighting.

Table 5.11 Averaged SM millipoint scores for TEL105-D10E and TEL105-C20E by life cycle phase – absolute results

Impact category	Unit	Total	PRODUCTION [A1-A3]	CONSTRUCTION [A4-A5]	USE [B1-B7]	END OF LIFE [C1-C4]	RECOVERY [D]
SM single figure score	mPts	18.74	16.73	0.08	**3.44**	0.02	-1.53

Numbers shown in **blue** have a variation of 10 to 20%
Numbers shown in **red** have a variation greater than 20%

5.6 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 (disregarding outliers is appropriate). Identifying which choices or assumption influence the results in any environmental parameter by more than 20% shall be reported. The previous section includes the variations within the product groups which are dominated by the use phase and the product composition as indicated.

Additionally, the chosen approach for the following parameters must also be reported:

The impact of the geographical and technological variation on various production locations	This does not apply as the products included are all out of the same manufacturing facility and location.
The variation due to using average composition	This is covered for the multiproduct reports by averaging both products and indicating the variations in section 5.4 and 5.5.
The variation due to using a group-average using the highest and lowest values in the sensitivity analysis. Outliers can be disregarded.	This does not apply as only TOTO products are included.
Allocation of recycling processes	A sensitivity analysis is included below in this section.
Allocation of multi-input and multi-output processes	Allocations follow a mass-based approach in the collected data, which is the most appropriate for the unit processes modeled. Allocation approaches in the background data follow the ecoinvent methodology.

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. 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.

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

5.7 Discussion on data quality

Discussion of the role of excluded elements
This study followed the completeness criteria stated in section 3.4 herein. Small amounts of input materials have not been included based on the mass criteria. These materials (i.e. excluded materials) were identified and evaluated on environmental relevance and are of similar nature to the included materials and hence are deemed to have an small impact in the results of the LCA in line with their weight. The exclusions have been made to streamline the data collection, validation and modeling process and fit well within the defined cut-off criteria. Examples are the adhesive glue placed on stickers, grease on o-rings and washers for secured tightening, less than 0.01 ml of locktite, minute amounts (less/more than 0.05mg) of variation for sealing materials. The impact from these minute amounts of materials on final LCA results is marginal and as such excluded.

Discussion of the precision, completeness and representativeness of data
The inventory mostly relies on primary data for the TOTO and the supplier data, but it also includes estimated data for different reasons. For example, the vendor has not responded to the same level of detail as the request for data entailed. In that case, missing data was estimated from other products whose data are known from other vendors in consultation with TOTO’s experts. Another example is that incomplete data on the recycled content of the components of the modeled products was provided. To model this, a worst-case scenario was applied assuming no recycled content. The impact of this assumption is important because the material inputs are major drivers of the LCA results for the modeled products.

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 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.

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.

5.8 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:

- Streamline the process for LCI data collection for the manufacturing process at the vendors. This should simplify the data collection for the different locations defining the primary sources for the data, and alignment of the reported data. 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 the impact. Good candidates are the recycled content of the metals.
- As further research regarding the use phase is conducted, make adjustments to the model in order to more accurately reflect the impacts. The use phase for TET1LN and for the TEL faucet series is currently defined in a way that heavily impacts this phase. More appropriate research results were available for the urinal flush valve models.
- 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] Bare JC (2012) Tool for the reduction and assessment of chemical andother environmental impacts (TRACI), Software name andversion number: TRACI Version 2.1, User’s Manual. US EPA.

[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. Version 2016, March 2016.

[7] Sustainable Minds Transparency Report™ / EPD Framework, Part B: Commercial Flush Valves, version Sept 1, 2014.

[8] Sustainable Minds Transparency Report™ / EPD Framework, Part B: Commercial Faucets, version Sept 1, 2014.

ACRONYMS

CDC	Centers for Disease Control and Prevention
EPA	United States Environmental Protection Agency
EPD	Environmental Product Declaration
FAP	Fairburn Assembly Plant
ISO	International Organization for Standardization
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact analysis
PCR	Product Category Rule document

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 inventory and BOM 2016". 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 TET1LA (confidential)

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

Table A.2 Raw materials definition of TEU1LA (confidential)

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

Table A.3 Raw materials definition of TEU1UA (confidential)

			Availability					
Component	Material	Mass %	Renewable	Non-renewable	Recycled post-industrial	Recycled post-consumer	Origin of raw materials	Supply Distance (miles)
Metal Housing	Zinc Die cast		No	Yes				
	Zinc Die cast		No	Yes				
	Zinc Die cast		No	Yes				
	Remaining materials		No	Yes				
Valve Metal Body	Bronze (C836000)		No	Yes				
	Brass		No	Yes				
	Bronze (C836000)		No	Yes				
	Remaining materials		No	Yes				
Solenoid Assembly	Miscellaneous materials		No	Yes				

Push manual Button	Miscellaneous materials		No	Yes				
Generator	Copper		No	Yes				
	Remaining materials		No	Yes				
Controller	Miscellaneous materials		No	Yes				
Sensor	Miscellaneous materials		No	Yes				
Battery	AA Li-ion battery		No	Yes				
Other parts	Miscellaneous materials		No	Yes				
	TOTAL	**100%**						

Table A.4 Raw materials definition of TEL105-D/CE (confidential)

			Availability					
Component	**Material**	**Mass%**	**Renewable**	**Non-renewable**	**Recycled post-industrial**	**Recycled post-consumer**	**Origin of raw materials**	**Supply Distance (miles)**
Spout Assembly	Brass (C360000)		No	Yes				
	SUS304		No	Yes				
	Polyacetal		No	Yes				
	NBR		No	Yes				
	Brass		No	Yes				
	Brass		No	Yes				
	SUS303		No	Yes				
	PVC		No	Yes				
	Steel		No	Yes				
	Remaining materials		No	Yes				
Sensor	Miscellaneous materials		No	Yes				
Solenoid Assembly	Polyacetal		No	Yes				
	Remaining materials		No	Yes				
Generator	PPO		No	Yes				
	Copper		No	Yes				
	Brass (covalent coating)		No	Yes				
	Remaining materials		No	Yes				
Controller box parts	Brass, Pb free		No	Yes				
	ABS		No	Yes				
	SUS303		No	Yes				
	PP		No	Yes				
	Remaining materials		No	Yes				
Controller	ABS		No	Yes				

box (circuit board)	Surface mount, Pb containing		No	Yes				
	Epoxy resin		No	Yes				
	Remaining materials		No	Yes				
Battery	Miscellaneous materials		No	Yes				
Flow regulator	Miscellaneous materials		No	Yes				

Table A.5 Raw materials definition of TEL105-D/CET (confidential)

			Availability					
Component	**Material**	**Mass%**	**Renewable**	**Non-renewable**	**Recycled post-industrial**	**Recycled post-consumer**	**Origin of raw materials**	**Supply Distance (miles)**
Spout Assembly	Brass (C360000)		No	Yes				
	SUS304		No	Yes				
	Polyacetal		No	Yes				
	NBR		No	Yes				
	Brass		No	Yes				
	Brass		No	Yes				
	SUS303		No	Yes				
	PVC		No	Yes				
	Steel		No	Yes				
	Remaining materials		No	Yes				
Sensor	Miscellaneous materials		No	Yes				
Solenoid Assembly	Polyacetal		No	Yes				
	Remaining materials		No	Yes				
Generator	PPO		No	Yes				
	Copper		No	Yes				
	Brass (covalent coating)		No	Yes				
	Remaining materials		No	Yes				
Controller box parts	Brass, Pb free		No	Yes				
	ABS		No	Yes				
	SUS303		No	Yes				
	PP							
	Remaining materials		No	Yes				
Controller box (circuit board)	ABS		No	Yes				
	Surface mount, Pb containing		No	Yes				
	Remaining materials		No	Yes				

Battery	Miscellaneous materials		No	Yes				
Flow regulator	Miscellaneous materials		No	Yes				
Thermostatic Mixing Valve	Brass		No	Yes				
	Remaining materials		No	Yes				

Table A.6 Raw materials definition of TEL105-D/CEM (confidential)

			Availability					
Component	**Material**	**Mass%**	**Renewable**	**Non-renewable**	**Recycled post-industrial**	**Recycled post-consumer**	**Origin of raw materials**	**Supply Distance (miles)**
Spout Assembly	Brass (C360000)		No	Yes				
	SUS304		No	Yes				
	Polyacetal		No	Yes				
	NBR		No	Yes				
	Brass		No	Yes				
	Brass		No	Yes				
	SUS303		No	Yes				
	PVC		No	Yes				
	Steel		No	Yes				
	Remaining materials		No	Yes				
Sensor	Miscellaneous materials		No	Yes				
Solenoid Assembly	Polyacetal		No	Yes				
	Remaining materials		No	Yes				
Generator	PPO		No	Yes				
	Copper		No	Yes				
	Brass (covalent coating)		No	Yes				
	Remaining materials		No	Yes				
Controller box parts	Brass, Pb free		No	Yes				
	ABS		No	Yes				
	SUS303		No	Yes				
	PP							
	Remaining materials		No	Yes				
Controller box (circuit board)	ABS		No	Yes				
	Surface mount, Pb containing		No	Yes				
	Remaining materials		No	Yes				
Battery	Miscellaneous materials		No	Yes				

Flow regulator	Miscellaneous materials		No	Yes				
Thermostatic Mixing Valve	Brass (C49260)		No	Yes				
	Brass		No	Yes				
	Remaining materials		No	Yes				

Table A.7 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 brass and bronze. Geographical coverage encompasses the industrialized countries. Data of 2009 LCI data of metals covering average technological processes from Switzerland or one of the European regions were adapted using US electricity. Updated 2012.		
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.8 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. Geographical coverage encompasses the industrialized countries based on 2007 LCI data using industry average technology.		
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.9 LCI data for turning steel CNC process

Turning, steel, CNC, average	1	kg
This dataset encompasses the direct electricity consumption of the machine as well as compressed air and lubricant oil. Furthermore, the metal removed is included. Machine as well as factory infrastructure and operation are considered as well. The disposal of the lubricant oil is also included while the metal removed is assumed to be recycled. Geographical coverage encompasses the industrialized countries based on 2007 LCI data using industry average technology.		
Materials/fuels		

Electricity, low voltage, production	1.78	kWh
Compressed air, average installation, >30kW, 7 bar gauge, at supply network	1.28	m3
Lubricating oil, at plant	0.00382	kg
Metal working machine, unspecified, at plant	0.000174	kg
Metal working factory	2.02E-09	p
Metal working factory operation, average heat energy	4.41	kg
Steel, low-alloyed, at plant	1	kg
Emissions to air		
Heat, waste	6.39	MJ
Waste to treatment		
Disposal, used mineral oil, 10% water, to hazardous waste incineration	0.00382	kg

Table A.10 LCI data for injection molding process

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

Table A.11 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; Data sourced from Shanghai, China; 2013		
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.12 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. Geographical coverage encompasses the industrialized countries based on 2007 LCI data using industry average technologies.		
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
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.13 LCI data for polishing process

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

Polishing	1	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.14 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; Data sourced from Shanghai, China; 2013		
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.15 LCI data for electroplating process

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

Table A.16 LCI data for casting bronze process

Casting Bronze	1	kg
This data contains the energy demand for the melting of copper and tin and casting of bronze. Data is based on assumptions and theoretcal modeling. Geographical coverage realtes to European average; based on 2003 LCI data using present technologies.		
Materials/fuels		
Aluminum casting, plant	4.9E-11	p
Electricity, medium voltage, production	0.02	kWh
Heat, heavy fuel oil, at industrial furnace 1MW	0.288	MJ
Heat, natural gas, at industrial furnace >100kW	0.36	MJ
Emissions to air		
Heat, waste	0.072	MJ
Tin	5.05E-05	kg

Table A.17 LCI data for plastic film extrusion process

Extrusion, Plastic Film	1	kg

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

Table A.18 LCI for sheet rolling steel

Sheet Rolling, Steel	1	kg
This dataset ncludes the process steps continuous pickling line, cold rolling, annealing, tempering, inspecting and finishing, packing coils or sheets, roll maintenance. Does not include the material being rolled. This process is to be used only for un- and low-alloyed steel. Data-set is representative for European Union based on 2003 LCI data using industry average technology.		
Resources		
Water, cooling, unspecified natural origin/m3	0.027	m3
Materials/fuels		
Chemicals inorganic, at plant	1.58E-08	kg
Electricity, medium voltage, production	0.223	kWh
Heat, unspecified, in chemical plant	0.171	MJ
Hydrochloric acid, 30% in H2O, at plant	0.000397	kg
Kraft paper, bleached, at plant	1.6E-06	kg
Kraft paper, unbleached, at plant	2.68E-05	kg
Lime, hydrated, loose, at plant	5.42E-05	kg
Lubricating oil, at plant	0.00459	kg
Natural gas, burned in industrial furnace >100kW	0.912	MJ
Packaging film, LDPE, at plant	8.49E-05	kg
Kraft paper, bleached, at plant	1.62E-09	p
Rolling mill	1.85E-06	m3
Sawn timber, softwood, raw, air dried, u=20%, at plant	4.47E-05	kg
Silicon carbide, at plant	0.00015	kg

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

Table A.19 LCI for wire drawing copper

Wire Drawing, Copper	1	kg
This dataset includes the production of wire rod and the further drawing of this to wire. Does not include the material being rolled or drawn;only the amount of scrap lost in waste is balanced as primary copper input. Wire rod production is comparable to sheet rolling leading to another final shape. Further drawing leads to wires with cross sections ranging from 1.6 to 3.5 mm and higher. Dataset is representative for European Union. Data on which assumptions are basing are from 1998		
Resources		
Water, cooling, unspecified natural origin/m3	0.0108	m3
Materials/fuels		
Sawn timber, softwood, raw, air dried, u=20%, at plant	6.12E-07	m3
Sheet rolling, steel	0.001652	kg

Steel, converter, unalloyed, at plant	0.001652	kg
Electricity, medium voltage, production	0.44667	kWh
Lubricating oil, at plant	0.0072	kg
Transport, lorry >16t, fleet average	0.015045	tkm
Packaging film, LDPE, at plant	0.001322	kg
Light fuel oil, burned in industrial furnace 1MW	0.80011	MJ
Rolling mill	1.43E-09	p
Packaging, corrugated board, mixed fibre, single wall, at plant	0.00033	kg
Copper, at regional storage	0.039644	kg
Natural gas, burned in industrial furnace low-NOx >100kW	0.80011	MJ
Emissions to air		
Heat, waste	1.608	MJ
NMVOC, non-methane volatile organic compounds, unspecified origin	0.00072	kg
Emissions to water		
BOD5, Biological Oxygen Demand	0.000079	kg
COD, Chemical Oxygen Demand	0.000079	kg
DOC, Dissolved Organic Carbon	2.06E-05	kg
TOC, Total Organic Carbon	2.06E-05	kg
Waste to treatment		
Disposal, municipal solid waste, 22.9% water, to municipal incineration	0.023192	kg
Disposal, used mineral oil, 10% water, to hazardous waste incineration	0.00432	kg
Disposal, hazardous waste, 0% water, to underground deposit	0.015462	kg

APPENDIX B. ADDITIONAL RESULTS

No additional result view 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 fittings LCI-LCA modeling data and results 06-2016.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 06-2016.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 06-2016.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 06-2016.xlsx". The modeled materials and energy flows are presented.