TOTO USA Toilets

Product Selection and Description

The plumbing fixture category in BEES is comprised of two TOTO toilet products: its high-efficiency toilet (HET), with a water usage rate of 4.85 L per flush (1.28 gal per flush, gpf), and its standard toilet, with a water usage rate of 6.06 L per flush (1.6 gpf). These toilets are manufactured at TOTO's Morrow, Georgia facility and are an average of all of the Morrow plant's toilet product lines. As such, these two toilets are modeled identically, with the exception of the water usage during the useful life of each toilet. For BEES, the toilet is specified in terms of one toilet in use in a building, and the functional unit is **one toilet used over a span of 50 years**. The life cycle of the toilet includes raw materials acquisition and production, manufacturing, transportation to the customer, installation, use, and end of life.

Flow Diagram and General Process Description

The flow diagram below shows the major elements of the production of this product as it is currently modeled for BEES.

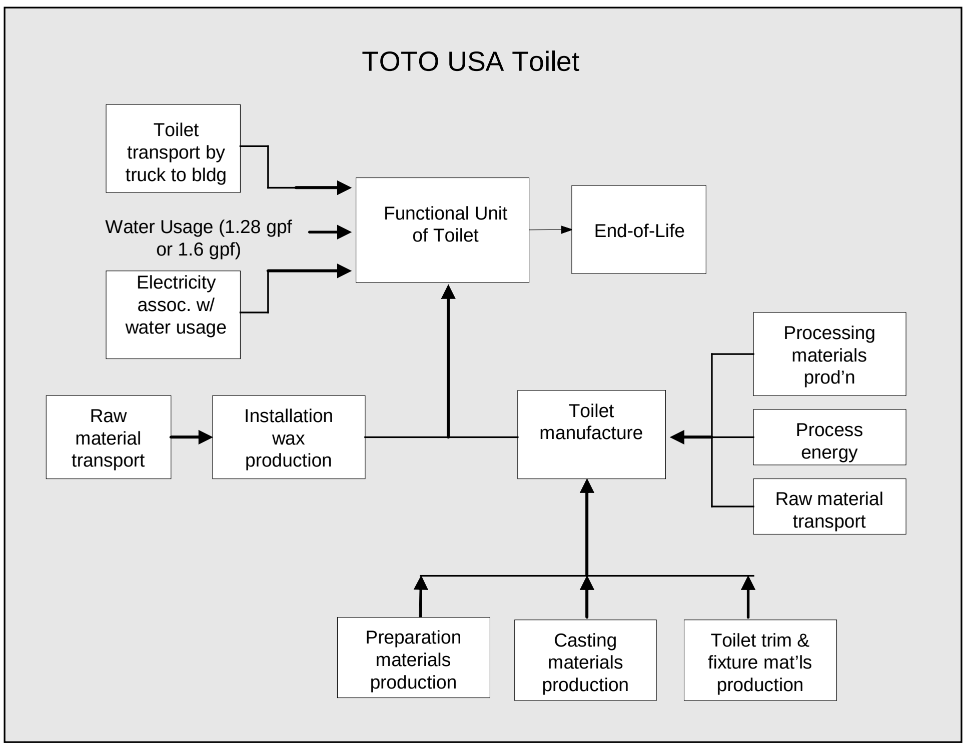

Figure 1: TOTO Toilet System Boundaries

The toilets at the Morrow plant are manufactured as follows:

- Raw materials arrive by truck and are unloaded into silos.
- The preparation materials, primarily materials that embody the mass of the toilet, are batched into two different clay slurries called *slip;* the first is *casting slip* and the second is *glazing slip*.
- The casting slip is pumped into molds and a portion of the water is squeezed out, producing separate body, rim, and tank pieces. While still wet, the body, rim, and tank are bonded together, and the product is dried.
- The dry product is then sprayed with the glaze slip. The water in the glaze slip absorbs into the dry body and leaves a powder coat of glaze.

- The glazed product is fired in a process called *vitrification* during which the pores close up. The glassy raw materials melt and make the body solid and impermeable, and the same materials in the glaze make the surface shiny and hard.
- The fired product is inspected. Products that pass inspection have the fixturing installed, and are boxed and shipped. Products with defects are repaired and refired if possible. Products with unrepairable defects are recycled as road bed aggregate.
- Finished products are boxed and shipped to the warehouse for distribution.

Raw Materials

Toilet Constituents. The average toilet manufactured at the Morrow plant weighs 32.4 kg. For this analysis, the toilet raw materials have been grouped into three categories, presented in Table 1 in terms of their overall contribution by mass to the toilet production process. It should be noted that more than 32.4 kg of materials go into the process; the firing processes cause changes to the material and chemical consistency of many of the materials going in, so the final toilet product may make up different percentages of the inputs below.

Table 1: Raw Material General Categories

Category	*Percentage of Total Toilet (HET and standard)*
Preparation materials	99 %
Casting materials	0.02 %
Fixtures and tank trim	1 %

The preparation materials make up the largest portion of the body of the toilet, and inputs to the system are comprised of the following:

Table 2: Preparation Materials Constituents

Constituent	*Percentage of Preparation Materials (HET and standard)*
Ball clay and other minerals (feldspar, silicates)	66 %
China clay	28 %
Limestone	4.5 %
Oxides of zinc and aluminum	0.7 %
Ceramic stains and other inputs	0.6 %

For the most part, the casting materials are process aids. Exceptions are soluble salts, which are applied to the toilet during casting and do remain as part of the toilet body.

Table 3: Casting Materials Constituents

Constituent	*Percentage of Casting Materials (HET and standard)*
Soluble salts	84 %
Epoxy resin and other bonding ingredients	7 %
Lubricant, other inputs	6 %
Silicone sealant	4 %

The tank trim and fixtures are made up of the following:

Table 4: Tank Trim and Fixtures Constituents

Constituent	***Percentage of Trim and Fixtures (HET and standard)***
Polypropylene	56 %
Brass	31 %
EPDM Rubber	13 %

Materials Data and Modeling. The materials listed in Table 2 through Table 4 are based on the U.S. LCI Database wherever possible, the EcoInvent database (customized to U.S. production using U.S. data on energy and transportation), and elements of the SimaPro database which are comprised of a mix of U.S. and European data. The toilets are packaged in corrugated boxes before being sent to the warehouse for final shipment. It is assumed that these boxes will be recycled, so the production of this packaging is not included in the model.

Manufacturing

Energy Requirements. The major manufacturing processes have been described above; Table 5 provides the energy required to produce one toilet.

Table 5: Toilet Manufacturing Energy Requirements

Energy Source	***MJ per toilet (HET and standard)***
Purchased grid electricity	155
Purchased green power	6.84
Natural gas	556
Gasoline	0.03
Propane	3.3

The energy usage is rather high, mostly from drying and firing. Drying takes 30 h to 35 h, at 60 ˚C (140 ˚F). Firing takes 12 h to 18 h, with the hottest temperature at 1 200 ˚ C (2 200 ˚F). All energy and electricity data are based on the U.S. LCI Database.

Ancillary materials. Manufacturing operations utilize 494 L of water per toilet. Twenty-five percent of this amount is reused after treatment at the on-site treatment facility. Manufacturing also uses a number of ancillary materials, including oils and greases, epoxy resin, caustic soda, and other materials for the process and for the wastewater treatment plant (WWTP). While these ancillary materials are included in the analysis wherever data are available, they make up approximately 0.5 % of total inputs. Data for these inputs come from the U.S. LCI Database wherever possible, the EcoInvent database, and the SimaPro database.

Environmental outputs. The major air emission from manufacturing is carbon dioxide, coming from carbonate decomposition and organic combustion during the firing process, amounting to approximately 3.2 kg per toilet. Particulate matter may also be emitted, but no data were available on particulates not captured by the on-site air emission scrubbers.

Morrow's WWTP treats all wastewater before it is returned to the county water authority. Wastewater emissions, at post-treatment level, are provided in the table below:

Table 6: Wastewater Effluents

Effluent	*Quantity per toilet (HET and standard)*	*Unit*
Wastewater (total)	394	L
Chemical Oxygen Demand	0.004	kg
Nitrogenous matter	0.001	kg
Phosphorous matter	0.00001	kg
Suspended Solids	0.01	kg
Sulfate (SO4--)	0.1	kg
Zinc	0.0001	kg

Waste from the Morrow facility includes general, non-specific waste and filter cake from the WWTP. Together, these wastes amount to 12.7 kg dry weight per toilet. These are both sent to a non-hazardous landfill.

Transportation. Transportation distances for the toilet components and processing aids were provided by TOTO. A majority of the materials purchased come from U.S. manufacturers (and locations), and are transported by truck distances ranging from 161 km (100 mi) within Georgia to 4 345 km (2 700 mi) from Washington State. One of the main materials is sourced from the U.K. and several come from Japan. In these latter cases, transportation by both ocean freighter and truck are accounted for. Trucks are assumed to be diesel-powered combination trucks, and the ocean freighters are diesel-powered. Both of these are based on data from the U.S. LCI Database.

Transportation

TOTO's Morrow plant toilets are transported by both diesel truck (average of 1 342 km, or 834 mi) and rail (average of 1 448 km, or 900 mi). When factoring the quantity transported by truck and rail (97 % and 3 %, respectively), the weighted average transported distance comes to approximately 1 344 km (835 mi). TOTO toilet sourcing data is based on actual 2008 shipment averages. All transportation data come from the U.S. LCI database.

Installation

The toilet may be installed with caulk or wax; for BEES, wax is modeled with an application rate of approximately 0.5 kg wax. Data for wax is based on petroleum-based wax distillate, a coproduct in petroleum refining operations. These data come from the petroleum refining model in a U.S. Department of Agriculture and U.S. Department of Energy study on biodiesel and petroleum diesel fuels.[1]

Use Phase

The toilet is assumed to be used in an average U.S. household over a 50-year time period. With an average of 2.6 persons per household, 5.1 flushes per day per person,[2] and two toilets in the household, this amounts to 586 m^3 (154 877 gal) and 733 m^3 (193 596 gal) of water for one high-efficiency and one standard toilet, respectively, over the 50-year period. The impact of water usage in a household extends beyond just water consumption. Impacts also include electricity usage for acquisition, treatment, and distribution of water to households and collection, conveyance and wastewater treatment of domestic wastewater. Electric Power Research Institute (EPRI) published this type of data in a study on water and sustainability. U.S. EPA data were

[1] Sheehan, J. et al., Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus, NREL/SR-580-24089 (Washington, DC: US Department of Agriculture and US Department of Energy, May 1998).

[2] U.S. Environmental Protection Agency (EPA) Watersense, *Water-Efficient Single-Family New Home Specification* (Washington, DC, May 14, 2008), found at: www.epa.gov/watersense/docs/home_suppstat508.pdf. This document cites 5.1 flushes/day/person per Mayer. P, DeOreo, W. et al 2000 and 2003, and 2.6 persons per household per U.S. Department of Housing and Urban Development 2005.

used to establish weighted average composite factors, to obtain an electricity usage per unit of water consumed:

Table 7: Average National Electricity Usage Factors

Activity	***EPRI factors: MJ/m³ Note 1***	***Weighted average composite factors: MJ/m³***
Acquisition, treatment and distribution of surface water by a Public Water System (PWS)	1.34	1.48 *Note 2*
Acquisition, treatment and distribution of ground water by a PWS	1.73	
Self-supply of drinking water (typically pumping from private wells)	0.67	0.67
Collection, conveyance and < secondary treatment of domestic wastewater	0.63	1.33 *Note 3*
Collection, conveyance and secondary treatment of domestic wastewater	1.15	
Collection, conveyance and advanced treatment of domestic wastewater	1.64	
Collection, conveyance and zero discharge/other treatment of domestic wastewater	0.38	
	Total	**3.48**

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

The table below summarizes the Use Phase data for the HET and standard toilets over a 50 year useful life:

Table 8: Toilet Use Phase Data Summary

Resource Usage	***HET toilet***	***Standard toilet***	***Savings with HET***
Water (m^3)	586	733	147
Electricity (MJ)	2 041	2 552	511

End-of-Life

The toilets are assumed to have a useful life beyond 50 years. At end of life, it is assumed that the toilets are landfilled.

References

Life Cycle Data

National Renewable Energy Laboratory (NREL): *U.S. Life-Cycle Inventory Database*. 2005. Golden, CO. Found at: http://www.nrel.gov/lci/database

PRé Consultants: *SimaPro 7.0 LCA Software*. 2005. The Netherlands.

Sheehan, J. et al., *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus,* NREL/SR-580-24089 (Washington, DC: US Department of Agriculture and US Department of Energy, May 1998).

Swiss Center for Life Cycle Inventories, EcoInvent database, a for-purchase database that is used in conjunction with other databases in the SimaPro software. More information can be found at www.ecoinvent.org.

U.S. Environmental Protection Agency (EPA) WaterSense, *Water-Efficient Single-Family New Home Specification* (Washington, DC, May 14, 2008), found at: www.epa.gov/watersense/docs/home_suppstat508.pdf.

Industry Contacts

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