LIFE CYCLE ASSESSMENT (LCA) OF FERGUSON SINGLE HANDLE LAVATORY FAUCETS & RESIDENTIAL TWO-PIECE TOILETS

PUBLIC VERSION

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Client	FERGUSON
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EXECUTIVE SUMMARY

Ferguson is a leading value-added distributor in North America providing expertise, solutions, and products from infrastructure, plumbing, and appliances to HVAC, fire, fabrication, and more. Ferguson aims to shape the future for enhancing the plumbing products' environmental performance while remaining committed to sustainable manufacturing practices. The company commissioned this study to evaluate the potential environmental impacts of single handle lavatory faucets and residential two-piece toilets using a cradle-to-grave approach.

The first product type covered in this study is the PROFLO® single handle lavatory faucet. Two specific SKUs were evaluated: PFWSC30075CP with a flow rate of 0.5gpm, and PFWSC3007CP with a flow rate of 1.2gpm. Both faucet types are manufactured in Vietnam. The second product type covered in this report was the PROFLO® Calhoun 1500 series two-piece toilet. Three toilet bowl SKUs: PF1500WH, PF1501WH, and PF1503WH; and six toilet tank SKUs: PF6112KWH, PF6110WH, PF6112RWH, PF6112WH, PF6112WHM, and PF6114WH, were evaluated in this study. Since there were many toilet seat SKUs available that could be applied to Ferguson's residential toilets, two seat SKUs were chosen to be evaluated in this study, PFTSE2000WH and PFTSWSC2000WH, as they represent the lightest and heaviest by mass of all suitable toilet seats distributed by Ferguson. Among the toilet tanks included in this study, only PF6112KWH has a flow rate of 1.6gpf, while the remaining have a flow rate of 1.28gpf. All bowl and tank SKUs evaluated in this study are manufactured in China.

For both products, per the product category rules (PCRs), a functional unit of one unit of product over the estimated service of the building was evaluated. The estimated service life of the building (ESL) is 75 years. The reference service life (RSL) of the faucet is 10 years, and the RSL of the two-piece toilet is 20 years. A life cycle assessment (LCA) was conducted conforming to the relevant PCRs and applicable ISO standards using a cradle-to-grave approach, which includes all life cycle stages from raw material extraction through final assembly, transportation of materials between supplier facilities and manufacturing facilities, manufacturing operations, distribution to end users, resource consumption during use, and end-of-life disposal.

A high-level summary of the findings of this study are illustrated in the table below which shows impacts per functional unit. The table presents potential CO_2-equivalent emissions and SM single score results for each product type across various life cycle modules. For other impact categories and a breakdown by each life cycle stage, refer to the tables in the full report. Overall, the study found that environmental performance is driven primarily by the use phase of both products. For faucets, energy consumed for water heating and in the municipal water systems contributes to the bulk of the potential environmental impacts. This electricity consumption during use contributes to ~99% of potential CO_2-equivalent emissions across the life cycle of each faucet type evaluated. As the flow rate of the faucet increased, so did the total results. Raw materials extraction, upstream transport, and the manufacturing of the product represent an insignificant share when compared to the impacts generated in the use phase.

For two-piece residential toilets, energy consumed in municipal water systems for upstream water collection and supply, and for downstream treatment, contributed to ~75% of the total results for the 1.28gpf toilet and ~78% of the total results for the 1.6gpf toilet. As the gallons per flush increased, so did the total results. The production stage also shows considerable impacts, driven by the consumption of electricity and natural gas during ceramic product manufacturing, including casting, drying, glazing, and firing. Replacing the toilet also contributed considerably to the results.

Product	Impact categories	Unit	Production	Construction/ Installation	Use	End of life	Total
			A1-A3	A4-A5	B1-B7	C1-C4	
PROFLO® Single Handle Lavatory Faucet PFWSC30075CP	*Global warming*	kg CO_2 eq	3.80E+00	1.21E+00	3.89E+03	5.62E-01	**3.89E+03**
		%	0.10%	0.03%	99.86%	0.01%	**100%**
	SM single figure score	mPts	2.38E+00	7.31E-02	3.48E+02	1.97E-02	**3.51E+02**
		%	0.68%	0.02%	99.29%	0.01%	**100%**
PROFLO® Single Handle Lavatory Faucet PFWSC3007CP	*Global warming*	kg CO_2 eq	3.80E+00	1.51E+00	9.27E+03	5.62E-01	**9.27E+03**
		%	0.04%	0.02%	99.94%	0.01%	**100%**
	SM single figure score	mPts	2.38E+00	8.50E-02	8.11E+02	1.97E-02	**8.13E+02**
		%	0.29%	0.01%	99.69%	0.00%	**100%**
PROFLO® Calhoun 1500 Series Two-piece Toilet 1.28 gpf	*Global warming*	kg CO_2 eq	6.32E+01	1.11E+01	1.25E+03	5.47E+00	**1.33E+03**
		%	4.74%	0.83%	94.02%	0.41%	**100%**
	SM single figure score	mPts	3.27E+00	7.05E-01	2.12E+02	2.40E-01	**2.16E+02**
		%	1.52%	0.33%	98.05%	0.11%	**100%**
PROFLO® Calhoun 1500 Series Two-piece Toilet 1.6 gpf	*Global warming*	kg CO_2 eq	6.51E+01	1.30E+01	1.52E+03	5.67E+00	**1.61E+03**
		%	4.05%	0.81%	94.79%	0.35%	**100%**
	SM single figure score	mPts	3.36E+00	7.90E-01	2.62E+02	2.49E-01	**2.66E+02**
		%	1.26%	0.30%	98.35%	0.09%	**100%**

CONTENTS

1. BACKGROUND

1.1. Opportunity

Ferguson is a leading value-added distributor in North America providing expertise, solutions, and products from infrastructure, plumbing, and appliances to HVAC, fire, fabrication, and more. With a focus on designing solutions for energy-effective and environment-friendly plumbing products, Ferguson aims to shape the future for enhancing the plumbing products' environmental performance while remaining committed to sustainable manufacturing practices.

As part of the ongoing commitment to environmental sustainability, Ferguson is embarking on a project to develop Environmental Product Declarations (EPDs) for the products it distributes in the North American market. The first step for this action is to transparently communicate the potential environmental impacts and performance of its products. As a result, it is important to conduct life cycle assessments (LCAs) to evaluate the potential environmental impacts from raw materials acquisition through manufacturing. The goal is to explore the potential environmental impacts that Ferguson's products have and to identify ways to improve processes and reduce impacts.

To understand the true impact of its plumbing products, Ferguson commissioned Sustainable Minds to help develop an LCA for its single handle lavatory faucets and residential two-piece toilets using a cradle-to-grave approach. Ferguson is looking forward to having guidance for future product improvements that can be informed by the results of this study.

Ferguson is interested in having LCA data available for its single handle lavatory faucets and residential two-piece toilet products to be able to obtain Sustainable Minds Transparency Reports [EPDs]™ (TRs), which are ISO 14025 Type III environmental declarations that can be used for communication with and amongst other companies, architects, and consumers, and that can also be utilized in whole building LCA tools in conjunction with the LCA background report and life cycle inventory (LCI). This study aims to comply with the requirements of ISO 14040/14044 [1], ISO 21930:2017 [2], and Sustainable Minds Part A [3]. In addition, the faucet portion of this study also aims to comply with the Sustainable Minds Part B for commercial/public metered and manual lavatory faucets [4]. The toilet portion aims to comply with the Sustainable Minds Part B for residential toilets [5].

1.2. Life cycle assessment (LCA)

LCA is performed to comprehensively explore, quantify, and interpret the potential environmental impacts associated with a product or service over the entire life cycle. A product's life cycle consists of various stages, starting from raw material acquisition and manufacturing to product use and maintenance, plus final product disposal. Depending on the inclusion and exclusion of life cycle stages, an LCA could be cradle to gate (from raw material acquisition to the manufactured product ready to be shipped), cradle to gate with options (which also optionally includes other modules such as shipment and installation), and cradle to grave (which includes all other stages including the use phase and disposal once the useful life is over).

Any LCA conducted with the intention of publishing EPDs needs to comply with the internationally accepted ISO 14040 and ISO 14040 standards. ISO 14040 provides principles and frameworks for conducting a LCA, while ISO14044 specifies requirements and provides guidelines for an LCA. ISO 14040 sets out a four-phase methodology framework for completing a LCA, as depicted in **Figure 1**.

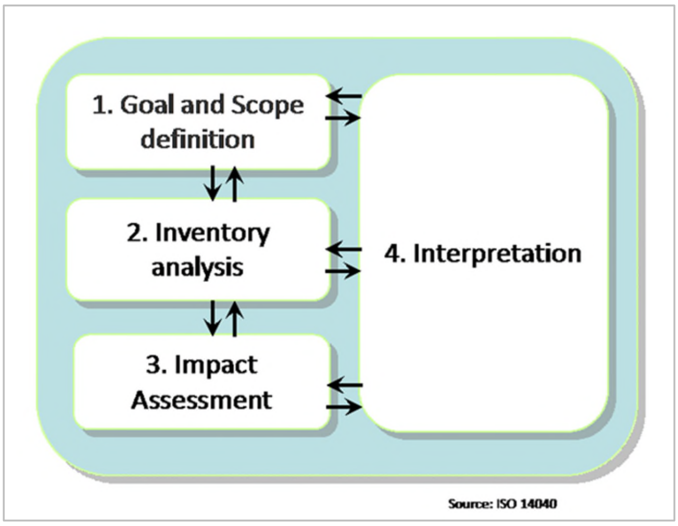

Figure 1. Phases of an LCA

- **Goal and scope definition:** Goals refer to establishing the purpose of the LCA, and they define the environmental aspects to be studied and the intended audience. Scope outlines the system boundaries, the functional unit of analysis, and the life cycle stages to be included. System boundaries set up inclusions and exclusions in an LCA. PCRs usually specify whether the boundary must be cradle-to-gate, cradle-to-installation, or cradle-to-grave.

- **Life cycle inventory analysis:** In this step, a detailed inventory of all the environmental inputs and outputs associated with each stage of the product's life cycle is compiled. Primary data about materials, energy, and emissions assessing the upstream supply chain, company's manufacturing operations, and downstream processes (after product leaves the factory gate) are collected via LCI data collection templates or tools. Annual data is suggested in most cases to be representative of the manufacturing operations. In the case of multi outputs, resources can be allocated to the product of interest via mass or volume, or as relevant. The inventory is then scaled to meet the functional unit of the LCA.

- **Life cycle impact assessment:** The compiled LCI is then modeled using an LCA software like SimaPro, GaBi, openLCA, or others using suitable background datasets available on their databases. Each is assigned to categories according to different impact methodologies, and the software provides final impact values for those different environmental impact categories. Several LCIA methodologies exist in the market including ReCiPe, TRACI, CML, and ILCD, which differ in terms of their approaches, characterization factors, evaluated impact categories, and modeling assumptions. Practitioners can choose a combination of LCIA methodologies to provide a holistic view of the environmental performance of a product.

- **Interpretation of results:** In this step, the LCIA results are analyzed and presented via an LCA report. This stage helps draw conclusions about the environmental performance of the product, identify any environmental hotspots, make recommendations, and assess the significance of the findings. Sensitivity analysis, scenario studies, and uncertainty assessment are often included as a part of the interpretation to ensure the reliability and robustness of the results. LCA, if well interpreted and evaluated, presents a number of opportunities for the manufacturer in developing sustainability goals and initiatives.

This LCA study follows an attributional approach and uses a cradle-to-grave system boundary. This report incorporates LCA terminology. To assist the readers in understanding LCA, special attention has been given to list definitions of important terms used at the end of this report.

A critical review of the LCA and an independent verification of the TR are required for ISO 14025 Type III environmental declarations. Both are included in this project.

1.3. Team

This LCA report is the outcome of the efforts of the project team led by Stephanie Ziegler and Emily-Anne Walker on behalf of Ferguson, with support from Ferguson personnel during the data collection, reporting, and interpretation phases. Sustainable Minds led the development of the LCA results, LCA report, and TRs.

1.4. Status

All information in this report reflects the best possible data inventory by Ferguson at the time it was collected, and Sustainable Minds and Ferguson adhered to best practices in transforming the inventory into this report.

The data covers annual manufacturing data for January 2023 – December 2023 from Ferguson’s outsourced manufacturing facilities in combination with their internal operations data. Where data was missing, assumptions were made for the facilities based on expertise from Ferguson and its upstream suppliers.

This study includes primary data from processes at the upstream manufacturing facilities and background data to complete the inventory and fill gaps where necessary.

This is a supporting LCA report for the Ferguson Transparency Reports [EPDs]™ and was evaluated for conformance to the PCRs according to the ISO 14025 [6] and ISO 14040/14044 [1] standards. The LCA review and verification of the Sustainable Minds Transparency Reports [EPDs]™ were carried out by Thomas P. Gloria, Ph.D., Industrial Ecology Consultants and found to be conformant to ISO 14040/14044 and the relevant PCRs.

Industrial Ecology Consultants

Sustainable Minds

August 12, 2024

Kim Hammer
Director, Technical Services & Senior LCA Analyst | Sustainable Minds

Critical Review Report: Ferguson Commercial Faucets and Residential Toilets

The Life Cycle Assessment (LCA) practitioner, Sustainable Minds, contracted Industrial Ecology Consultants to perform an external independent critical review of the **LCA of Ferguson Single Handle Lavatory Faucets & Residential Two-Piece Toiles, June 2024,** study and verification of their respective Transparency Reports (TRs) on behalf of the commissioning organization, Ferguson.

The review of the study was performed to demonstrate conformance with the following standards and Product Category Rules (PCR):

International Organization for Standardization (ISO). (2020). *Environmental management -- Life cycle assessment – Principles and framework* (ISO 14040:2006/Amd 1:2020).

International Organization for Standardization. (2020). *Environmental management -- Life cycle assessment -- Requirements and guidelines* (ISO 14044:2006/Amd 1:2017/Amd 2 2020).

International Organization for Standardization. (2014). *Environmental management -- Life cycle assessment -- Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006.* (ISO/TS 14071:2014).

International Organization for Standardization. (2017). *Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services.* (ISO 21930:2017).

Sustainable Minds. (2023). *SM Transparency Report™ / EPD Framework Governance and Program Rules.* Version 3.2.

Sustainable Minds. (2023). *Part A LCA calculation rules and report requirements,* Version 2023, August.

Sustainable Minds. (2022). *Part B: Product group definition | Commercial/public metered and manual lavatory faucets | Part B #23-002.* Version 1.0, May.

Sustainable Minds. (2022). *Part B: Product group definition | Residential toilets | Part B #23-006.* Version 1.0, May.

The independent third-party critical review was conducted by an external expert per ISO 14044:2006 Section 6.2: Critical review by internal or external expert:

Thomas P. Gloria, Ph.D.
Founder, Chief Sustainability Engineer
Industrial Ecology Consultants

REVIEW SCOPE

The intent of this review was to provide an independent third-party external verification of an LCA study report and four respective Transparency Reports (TRs) in conformance with the aforementioned ISO standards, PCRs, and Governance Rules. This review did not include an assessment of the Life Cycle Inventory (LCI) model, however, it did include a detailed analysis of the individual datasets used to complete the study.

The four Ferguson Transparency Reports were:

- PROFLO® Single Handle Lavatory Faucet – (0.5gpm)
- PROFLO® Single Handle Lavatory Faucet – (1.2 gpm)
- PROFLO® Calhoun 1500 Series Toilet – (1.28 gpf tank)
- PROFLO® Calhoun 1500 Series Toilet – (1.6 gpf tank)

REVIEW PROCESS

The review process involved the verification of all requirements set forth by the applicable ISO standards, PCRs and Governance Rules cataloged in comprehensive review table along with editorial comments. There was one round of comments by the reviewer submitted to the LCA practitioner. Responses by the LCA practitioner to each issue raised were resolved and acknowledged by the reviewer to have been satisfactorily addressed.

CRITICAL REVIEW STATEMENT

Based on the independent review objectives, the **LCA of Ferguson Single Handle Lavatory Faucets & Residential Two-Piece Toiles, June 2024,** study and the **four Transparency Report (TRs),** were determined to be ***in conformance*** with the applicable ISO standards. The plausibility, quality, and accuracy of the LCA-based data and supporting information are confirmed.

As the External Independent Third-Party Reviewer, I confirm that I have sufficient scientific knowledge and experience in building and construction product systems and the applicable ISO standards to carry out this verification.

Sincerely,

Thomas P. Gloria, Ph.D.
Founder, Chief Sustainability Engineer
Industrial Ecology Consultants

2. Goal and Scope

This chapter explains the goal and scope of the study. The aim of the goal and scope is to define the product under study and the depth and breadth 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 the PROFLO® single handle lavatory faucets and residential two-piece toilet products distributed by Ferguson. The report serves both internal and external purposes and is intended for a diverse audience. The intended audience includes the program operator (Sustainable Minds) and reviewers who will be assessing the LCA for conformance to the PCRs, as well as Ferguson's internal stakeholders involved in marketing and communications, operations, and design.

The results presented in this document are not meant to support comparative claims. The outcomes will be made available to the public in Sustainable Minds Transparency Reports [EPDs]™ (Type III environmental declarations per ISO 14025), which are intended for communication between businesses and consumers (B2C).

2.2. Product description

Ferguson has already served more than a million customers in North America via its eleven national distribution centers and numerous branches. The product categories include bathroom plumbing products (toilets, faucets, etc.), water heaters, HVAC equipment, pipe fittings, and tubing, among others.

The first product type covered in this report is the PROFLO® single handle lavatory faucet, which is constructed from brass and features a ceramic disc valve. Two specific SKUs are evaluated within the faucet product category as shown in **Table 1**: PFWSC30075CP with a flow rate of 0.5 gpm, and PFWSC3007CP with a flow rate of 1.2 gpm. Both faucet types are manufactured in a single facility in Vietnam and shipped to Ferguson distribution centers in the US.

Table 1. Evaluated faucet product SKUs

Product SKU	Description
PFWSC30075CP	PROFLO® Single Handle Centerset Bathroom Sink Faucet Less Pop-Up Drain Assembly in Chrome (0.5 gpm)
PFWSC3007CP	PROFLO® Single Handle Centerset Bathroom Sink Faucet Less Pop-Up Drain Assembly in Chrome (1.2 gpm)

The second product type covered in this report is the PROFLO® Calhoun 1500 series two-piece toilet. Three bowl SKUs: PF1500WH, PF1501WH, and PF1503WH; and six tank SKUs: PF6112KWH, PF6110WH, PF6112RWH, PF6112WH, PF6112WHM, and PF6114WH, are evaluated in this study. Since there are many toilet seat SKUs available, only two seat SKUs: PFTSE2000WH and PFTSWSC2000WH, are considered in this study. These two seat SKUs represent the lightest and heaviest of all suitable toilet seats distributed by Ferguson. Among the tanks, only PF6112KWH has a flow rate of 1.6 gpf, where the remaining have a flow rate of 1.28 gpf. All bowl and tank SKUs are manufactured in a single facility in China and shipped to Ferguson distribution centers. **Table 2** provides a description for each evaluated bowl, tank, and seat SKU.

Table 2. Evaluated toilet bowl, tank, and seat product SKUs

Product SKU	Type	Product description
PF1500WH	Bowl	PROFLO® Calhoun 15-1/2 in. Round Toilet Bowl in White
PF1501WH	Bowl	PROFLO® Calhoun 15-1/2 in. Elongated Toilet Bowl in White
PF1503WH	Bowl	PROFLO® Calhoun Elongated ADA Toilet Bowl in White
PF6110WH	Tank	PROFLO® Calhoun 1.28 gpf 10 in. Rough-In Toilet Tank in White
PF6112KWH	Tank	PROFLO® Calhoun 1.6 gpf Toilet Tank in White
PF6112RWH	Tank	PROFLO® Calhoun 1.28 gpf Right Hand Toilet Tank in White
PF6112WH	Tank	PROFLO® Calhoun 1.28 gpf Toilet Tank in White
PF6112WHM	Tank	PROFLO® Calhoun 1.28 gpf Toilet Tank in White with White Lever
PF6114WH	Tank	PROFLO® Calhoun 1.28 gpf 14 in. Rough-In Toilet Tank in White
PFTSE2000WH	Seat	PROFLO® Tizer Elongated Closed Front Plastic Toilet Seat with Cover in White
PFTSWSC2000WH	Seat	PROFLO® Greenwood Elongated Closed Front Toilet Seat in White with Soft Close

Each bowl SKU can be combined with a tank SKU for a residential 2-piece toilet. **Table 3** provides all the possible combinations. Any suitable toilet seat from Ferguson or from external manufacturers/suppliers can be used in the residential setup, so the table does not specify toilet seats since they apply to all combinations.

Table 3. Possible residential 2-piece toilet combinations

Tank SKUs	Bowl SKUs	Toilet description
PF6110WH	PF1500WH	1.28 GPF 15-1/2" Round front toilet with 10" rough-in tank
PF6110WH	PF1501WH	1.28 GPF 15-1/2" Elongated toilet with 10" rough-in tank
PF6110WH	PF1503WH	1.28 GPF 17" Elongated ADA toilet with 10" rough-in tank
PF6112WH	PF1500WH	1.28 GPF 15-1/2" Round front toilet with 12" rough-in tank
PF6112WH	PF1501WH	1.28 GPF 15-1/2" Elongated front toilet with 12" rough-in tank
PF6112WH	PF1503WH	1.28 GPF 17" Elongated ADA toilet with 12" rough-in tank
PF6112RWH	PF1500WH	1.28 GPF 15-1/2" Round front toilet with 12" rough-in Right hand tank
PF6112RWH	PF1501WH	1.28 GPF 15-1/2" Elongated toilet with 12" rough-in Right hand tank
PF6112RWH	PF1503WH	1.28 GPF 17" Elongated ADA toilet with 12" rough-in Right hand tank
PF6112WHM	PF1500WH	1.28 GPF 15-1/2" Round front toilet with 12" rough-in tank - white lever
PF6112WHM	PF1501WH	1.28 GPF 15-1/2" Elongated toilet with 12" rough-in tank - white lever
PF6112WHM	PF1503WH	1.28 GPF 17" Elongated ADA toilet with 12" rough-in tank - white lever
PF6114WH	PF1500WH	1.28 GPF 15-1/2" Round front toilet with 14" rough-in tank
PF6114WH	PF1501WH	1.28 GPF 15-1/2" Elongated toilet with 14" rough-in tank
PF6114WH	PF1503WH	1.28 GPF 17" Elongated ADA toilet with 14" rough-in tank
PF6112KWH	PF1500WH	1.6 GPF 15-1/2" Round front toilet with 12" rough-in tank
PF6112KWH	PF1501WH	1.6 GPF 15-1/2" Elongated toilet with 12" rough-in tank
PF6112KWH	PF1503WH	1.6 GPF 17" Elongated ADA toilet with 12" rough-in tank

Figure 2 provides representative images for faucets and two-piece toilets evaluated in this study. **Table 4** lists the product information in accordance with PCR, including the declaration name, product included in the declaration, CSI MasterFormat® classification, manufacturing location, and the type of declaration. As shown in the table, one Transparency Report [EPD]™ was developed for each product type. Two sets of results are reported in the TR for the lavatory faucet, with one set of results per each faucet SKU. The two-piece toilet TR also reports two sets of results. The first set of results is for a toilet combination of the PF6112KWH (1.6 gpf) tank with an average bowl and average seat. The second set of results is for an average of the 1.28 gpf tanks with an average bowl and average seat. Weighted average results are used.

Single handle lavatory faucet

Two-piece residential toilet

Figure 2. Visual representation of products

Table 4. Declared product information and type of declaration

Transparency Report [EPD]™ name	Product name	CSI MasterFormat® classification	Manufacturing location	Type of declaration
PROFLO® Single Handle Lavatory Faucet	PFWSC30075CP	22 42 39	Tay Ninh, Vietnam	Specific product from a manufacturer's plant
	PFWSC3007CP			Specific product from a manufacturer's plant
PROFLO® Calhoun 1500 Series Two-piece Toilet	Toilet with 1.6 gpf tank	22 41 13.13	Tangshan, China	Weighted average product from a manufacturer's plant
	Toilet with 1.28 gpf tank			Weighted average product from a manufacturer's plant

For more information about the products, including details about the materials that conform to the relevant standards, visit the Ferguson website or links included for each product SKU.

2.3. Functional unit

This LCA covers the cradle-to-grave stages for Ferguson's Single Handle Lavatory Faucet and 1500 Series Two-piece Toilet. For both products, a functional unit of one unit of product over the estimated service of the building is used.

The estimated service life of the building (ESL) in both cases is 75 years per the PCRs. The reference service life (RSL) of the faucet is 10 years, and the RSL of the two-piece toilet is 20 years. Each two-piece toilet is comprised of a toilet bowl, toilet tank, and toilet seat, and it does not include electronic bidet seat.

2.4. System boundary

This section describes the system boundary for the analysis. The system boundary defines which life cycle stages are included and which are excluded.

This LCA's system boundary is from cradle to grave. Therefore, the life cycle activities and related processes shall include all life cycle stage modules from A1-C4 as illustrated in **Figure 3**. This includes raw materials extraction and preprocessing, transportation, manufacturing, distribution, installation, use stages, and end of life stages. **Table 5** lists specific inclusions and exclusions for the system boundary.

Scope	PRODUCTION STAGE			CONSTRUCTION STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
	Extraction and upstream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/Demolition	Transport to waste processing or disposal	Waste processing	Disposal of waste	Reuse, Recovery, Recycling Potential
Cradle to grave	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	MND

Figure 3. Applied system boundary

Table 5. System boundary inclusions and exclusions

Included	Excluded
• Raw material extraction for components • Transport of raw materials/ purchased components to the manufacturing facility • Processing of raw materials into components (for externally purchased and in-house manufactured) • Packaging of raw materials and their disposal • Energy production • Manufacturing scrap and its disposal • Outbound transportation of product to users • Packaging for the final product and its disposal • Installation of the product • Use phase activities (repair, replacement, refurbishment, operational energy & water use) • Product disposal after usage	• Construction of major capital equipment • Maintenance and operation of support equipment • Human labor and employee transport • Manufacture and transport of packaging materials not associated with final product • Disposal of packaging materials not associated with final product • Building operational energy and water use

2.4.1. Product flow - PROFLO® Single Handle Lavatory Faucet

Both faucet types analyzed in the study are manufactured in Vietnam. Only the cartridge seat is manufactured in-house; all other parts are purchased directly from suppliers. The processing operations are machining, forming, polishing, and surface treatment of the parts. All parts are assembled, tested, and packaged in the facility and later shipped to the Ferguson distribution centers in the US. From there, the faucet is transported to the end user site and installed. Once the product is installed, it requires periodic cleaning and replacement (at the end of the RSL). Water is consumed throughout the ESL. Per the PCR, the product is assumed to be landfilled at the end of life. **Figure 4** provides an overview of the product flow during its life cycle.

Figure 4. System boundary and product flow diagram of PROFLO® Single Handle Lavatory Faucet

2.4.2. Product flow - PROFLO® Calhoun 1500 Series Two-piece Toilet

Both toilet types analyzed in the study are manufactured in China. Only the ceramic parts (toilet tanks and bowls) are manufactured in-house; all other parts are purchased directly from suppliers. The processing operations for ceramic parts are casting, drying, kiln loading, firing, inspection, and testing. All other purchased parts are later assembled with the ceramic parts. Tanks and bowls are packaged separately and later shipped to Ferguson distribution centers in the US. From there, the toilet bowl and tank are transported to the end user site and installed. A complete two-piece residential toilet also requires a toilet seat, and any compatible seat can be used. Once the product is installed, it requires periodic cleaning and replacement (at the end of the RSL). Water is consumed throughout the ESL. Per PCR, the product is assumed to be landfilled at the end of life. **Figure 5** provides an overview of the product flow during its life cycle.

Figure 5. System boundary and product flow diagram of PROFLO® Calhoun 1500 Series Two-piece Toilet

3. LIFE CYCLE INVENTORY ANALYSIS

This chapter includes an overview of the obtained data and data quality that has been used in this study. A complete life cycle inventory calculation workbook, which catalogs the flows crossing the system boundary and provides the starting point for life cycle impact assessment, can be found in the appendix.

3.1. Data collection procedures

Primary data was provided by Ferguson representing the supply chain (A1-A2), manufacturing processes (A3), and distribution (A4) of the faucet and toilet products. Data was collected in a consistent manner and level of detail to ensure high-quality data. All submitted data were checked for quality multiple times on the plausibility of inputs and outputs using mass balance and benchmarking. All questions regarding data, including gaps, outliers, and any inconsistencies, were resolved with Ferguson and their suppliers. Annual data for the year 2023 (January 2023 to December 2023) was collected at the manufacturing facility in Vietnam for the faucet products, and data covering that same time period was collected at the manufacturing facility in China for the toilet products. The resulting inventory calculations were developed by an analyst at Sustainable Minds and subsequently checked internally.

While the inventory for the production and construction/installation stage (A1-A5) was developed using primary data, the inventory for the use stage (B1-B7) and end-of-life stage (C1-C4) were developed using the assumptions prescribed by the PCRs.

Expert judgment was used in selecting appropriate data sets to model the associated activities in this study, including materials and energy, which have been noted in the following sections. Databases adopted in the model include ecoinvent v3.10 and US-EI 2.2 databases. Overall, the quality of the data used in this study is considered to be good and representative of the described systems. All appropriate means were employed to guarantee the data quality and representativeness as described below.

3.2. Primary data and PCR guidelines

For both products, primary data was collected for the A1-A4 modules, and PCR guidelines were used for the remaining product life cycle stages. Primary data were collected using either direct measurement or the manufacturing facility representative personnel's best engineering estimates based on actual production if measurements were not available.

3.2.1. Raw materials acquisition and transportation (A1-A2)

These modules represent raw materials extraction, preprocessing/upstream processing, and transportation to the manufacturing facility.

The full bills of material (BOMs) were provided with a detailed breakdown of product into parts/components and raw materials for each part. Raw materials are extracted and manufactured by material suppliers and transported to the component manufacturing plants. Components are then transported, along with component packaging, to the final manufacturing facilities where the individual components are assembled into the final product. Supply chain primary data, including information on component supplier locations, shipping distances, and transportation modes to the final manufacturing plants, were all provided.

Neither the toilet nor faucet products contain hazardous substances according to the standards or regulations of the Resource Conservation and Recovery Act (RCRA), Subtitle C.

For faucets, all components except the cartridge seats are purchased directly from suppliers. Upstream manufacturing activities have been modeled separately in addition to the upstream raw material extraction. The material composition, reference flow, and transportation data for both Ferguson faucet products is the same and is reported in **Table 6**.

Table 6. Faucet products raw material mass per functional unit and associated transportation

Raw materials	Mass (g)	%	Transport mode	Distance (km)
Zinc	[redacted]	35-40%	[redacted]	[redacted]
Brass	[redacted]	2-5%		[redacted]
Polyamide	[redacted]	2-5%		[redacted]
Polyethylene	[redacted]	2-5%		[redacted]
Packaging (pulp)	[redacted]	12-15%	[redacted]	[redacted]
Packaging (box)	[redacted]	20-25%		[redacted]
Packaging (paper inserts, label)	[redacted]	10-12%		[redacted]
[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]		[redacted]
Total reference flow	**1.57 kg**			

The two-piece residential toilets are comprised of a toilet bowl, tank, and seat. Only the ceramic portions of the bowl and tank are manufactured in-house in China. All other components in the tank and bowl are purchased directly from suppliers. Both toilet types, with a 1.6 gpf tank or 1.28 gpf tank, use a weighted average toilet bowl. The weighted average was developed using 2023 sales data from Ferguson of the three bowl SKUs (PF1500WH, PF1501WH, and PF1503WH) covered in this study. Both toilet types include a toilet seat, which is an average of PFTSE2000WH and PFTSWSC2000WH. The difference between the two toilet types is the type of tank used. The 1.28 gpf toilet uses a weighted average toilet tank of the five tank SKUs (PF6110WH, PF6112RWH, PF6112WH, PF6112WHM, and PF6114WH). Again, the weighted average is based on the 2023 sales data from Ferguson. The 1.6 gpf toilet only uses the PF6112KWH SKU as its toilet tank.

Upstream manufacturing activities have been modeled separately in addition to upstream raw material extraction. The material composition, reference flow, and transportation data for both Ferguson toilet products (including bowl, tank, and seat) varies slightly and is reported in **Table 7**.

Table 7. Toilet products raw material mass per functional unit and associated transportation

Raw materials	Toilet with 1.6 gpf tank				Toilet with 1.28 gpf tank			
	Mass (kg)	**%**	**Transport mode**	**Distance (km)**	**Mass (kg)**	**%**	**Transport mode**	**Distance (km)**
Ceramic	[redacted]	85-90%	[redacted]	[redacted]	[redacted]	85-90%	[redacted]	[redacted]
Polypropylene	[redacted]	2-5%			[redacted]	2-5%		
Acrylonitrile butadiene styrene (ABS)	[redacted]	1-2%		[redacted]	[redacted]	1-2%		[redacted]
Other	[redacted]	<1%			[redacted]	<1%		[redacted]
[redacted]	[redacted]	[redacted]			[redacted]	[redacted]		[redacted]
Packaging (carton, paper inserts and label)	[redacted]	2-5%	[redacted]		[redacted]	2-5%	[redacted]	
[redacted]	[redacted]	[redacted]			[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total reference flow	**47.2 kg**				**45.5 kg**			

3.2.2. Manufacturing (A3)

This module incorporates the manufacturing operations in the product manufacturing facility. For faucets, all components except for the cartridge seat are purchased from suppliers and are shipped directly to a manufacturing facility in Vietnam. The components are assembled into the final faucet product, and it goes through various processing operations including forming, machining, surface treatment, and polishing.

Annual facility resource inputs (energy, water, and ancillary materials) and environmental releases (waste, direct air emissions, and sewage) were allocated to PFWSC30075CP and PFWSC3007CP using volumetric allocation. These two faucet products represented a combined ~0.03% of gross faucet production in the facility. Resources per faucet were then calculated using the annual production units.

$$Resource\ per\ unit\ faucet\ type = \frac{\text{Annual facility resource} * \text{Volumetric share of faucet type in gross production}}{\text{Annual units of that faucet type}}$$

The waste generated in the facility was either incinerated, recycled, or landfilled. Recycled waste includes scrap paper, iron, and metals, which are transported to the nearest recycling center. Landfilled waste includes product scrap (~0.01%) which is sent to landfill. Incinerated waste includes both hazardous and non-hazardous waste streams, and no power is generated during incineration. Resource use during manufacturing is the same for both faucet types and is listed in **Table 8**.

Table 8. Faucet manufacturing inputs per functional unit

Resource category	Flow	Amount	Unit
Energy	Electricity	[redacted]	kWh
	Natural gas	[redacted]	MJ
	Steam	[redacted]	kg
Water	Municipal Water	[redacted]	L
Ancillary materials	Grease (GL320-G)[1]	[redacted]	kg
	Loctite gum 680[2]	[redacted]	L
	Alcohol (Ethanol)	[redacted]	L
	Cotton gloves	[redacted]	kg
	Towel[3]	[redacted]	kg
Waste generation	Landfill disposal – product scrap	[redacted]	kg
	Incinerated without power generation	[redacted]	kg
	Recycled waste	[redacted]	kg
	Sewage	[redacted]	m^3
Waste transport	Transport for landfilled / recycled / incinerated waste	[redacted]	kgkm

For toilet bowls and tanks, all components except for the ceramic portions are purchased from suppliers and are shipped directly to a manufacturing facility in China. Ceramic materials go through glazing, casting, drying, and firing, producing ceramic products. The remaining components are assembled with the ceramic products, making up the fully assembled toilet bowls and tanks. Annual facility resources specific to the SKUs under study were provided, and they were normalized using total ceramic mass manufactured to generate inventory per kg of ceramic product. Using this approach, resources per kg ceramics is appropriate for a majority of the ceramic production. The only exception is the casting process, which consumes the same electricity per piece, whether it's the tank or the bowl regardless of the mass difference. While this is an exception, the electricity used for casting is assumed to be small compared to the energy used in the slurry and glaze, drying, glazing, and firing steps, and energy breakdown per step was not available.

$$Annual\ ceramic\ mass\ manufactured = \sum_{All\ SKUs} Ceramic\ mass\ per\ SKU * Annual\ SKU\ production\ units$$

$$Resource\ per\ unit\ toilet = \frac{\text{Annual facility resource} * \text{Weighted ceramic mass per unit toilet}}{\text{Annual ceramic mass manufactured}}$$

Manufacturing resources for the toilet products are listed in **Table 9**.

[1] Mass composition assumed to be 90% silicone oil (polydimethylsiloxane) and 10% of fumed silica
[2] This is composed of methacrylate ester, which is a derivative of methacrylic acid. The stoichiometry of the reaction between methacrylic acid and an alcohol to produce methacrylate ester is 1:1.
To produce 1 kg of methacrylate ester, it will require 1 kg of methacrylic acid and 0.535 kg of ethanol.
[3] Mass composition assumed to be 85% terylene & 15% polyamide.

Table 9. Toilet manufacturing inputs per functional unit

Resource category	Flow	per kg ceramics	Toilet with 1.6 gpf tank	Toilet with 1.28 gpf tank	Unit
Energy	Electricity	[redacted]	[redacted]	[redacted]	kWh
	Natural gas	[redacted]	[redacted]	[redacted]	MJ
	Coke oven gas	[redacted]	[redacted]	[redacted]	m^3
Water	Municipal water	[redacted]	[redacted]	[redacted]	L
Ancillary materials	Kerosene	[redacted]	[redacted]	[redacted]	kg
	Water sandpaper[4]	[redacted]	[redacted]	[redacted]	kg
	Nylon	[redacted]	[redacted]	[redacted]	kg
	Polyurethane	[redacted]	[redacted]	[redacted]	kg
Waste generation	Ceramic waste recycled	[redacted]	[redacted]	[redacted]	kg
	Hazardous waste landfilled	[redacted]	[redacted]	[redacted]	kg
	Hazardous waste incinerated *(with energy recovery)*	[redacted]	[redacted]	[redacted]	kg
	Ceramic sewage	[redacted]	[redacted]	[redacted]	kg
Waste transport	Transport for landfilled / recycled / incinerated waste	[redacted]	[redacted]	[redacted]	kgkm
Air emissions	Particulate matters (PM)	[redacted]	[redacted]	[redacted]	kg
	Sulphur dioxide (SO_2)	[redacted]	[redacted]	[redacted]	kg
	Nitrogen oxides (NO_x)	[redacted]	[redacted]	[redacted]	kg

3.2.3. Product distribution (A4)

This module refers to the transport and delivery of products from the manufacturing facility to the sites where the products are installed and used.

Faucets manufactured in Vietnam are first shipped to Ferguson's distribution center (DC) in Perris, California and then distributed to other distribution centers in the US, which are then transported to end users and building sites. The average transportation distance differs for each faucet type as shown in **Table 10**, and the calculation is based on the entire 2023 transportation distances from Ferguson DCs to final sites.

Table 10. Faucet distribution distances and methods per functional unit

Resource category	Flow	PFWSC30075CP	PFWSC3007CP	Unit
Manufacturing facility to Ferguson DCs	Road transport (average)	3,161		km
	Sea transport	13,316		
	[redacted]	[redacted]		
	[redacted]	[redacted]		
Transport to final users	Road transport (average)	910	1,932	

Toilet bowls and tanks manufactured in China are first shipped to Ferguson's distribution center (DC) in the United States via several US ports, which are then transported to end users and building sites as shown in **Table 11**. The final transportation distance differs for each bowl and tank SKU as shown in **Table 12**,

4 Mass composition assumed to be 65% abrasive particle (aluminium oxide), 25% backing material (polyester), and 10% adhesive (phenolic resin)

and the calculation is based on the entire 2023 transportation distances from Ferguson DCs to final sites.

Table 11. Toilet distribution distances and methods per functional unit for transport to DCs

Resource category	Flow	Distance (km)	Notes
Manufacturing facility to Ferguson DCs	Total road transport (average)	651	-
	Sea transport to US ports (average)	14,835	Average of all used US ports
	[redacted]	[redacted]	[redacted]

Table 12. Toilet distribution distances by truck per functional unit for transport to final installation

Type	Individual SKU	Distance (km)
Toilet bowl	PF1500WH	372
	PF1501WH	270
	PF1503WH	294
Toilet tank 1.6 gpf	PF6112KWH	853
Toilet tank 1.28 gpf	PF6110WH	351
	PF6112RWH	523
	PF6112WH	278
	PF6112WHM	310
	PF6114WH	573
Toilet seat	-	606

3.2.4. Product installation (A5)

This module represents the installation of the product, making it ready for use.

Installation of both product types, faucets and toilets, are manual with no additional resources being consumed. The inputs in this module include the disposal of packaging waste with a waste transport distance of 100 km. Disposal scenarios for faucet and toilet packaging are assumed to be 80.88% recycled, 15.37% landfilled, and the remaining incinerated, in alignment with US EPA's 2018 end of life data for containers and packaging[5].

3.2.5. Product use (B1)

This module covers any activity related to product use which is not already included in other use modules (B2-B7). There are no activities in this module for either the faucets or the toilets.

3.2.6. Maintenance (B2)

This module covers all planned technical services and associated operations during the reference service life to maintain the product in a state where it can continue provide its required functional and technical services. For both faucets and toilets, based on the PCRs, a building estimated service life (ESL) of 75 years is used.

[5] Product specific data for containers and packaging, EPA 2018. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/containers-and-packaging-product-specific#PaperandPaperboardC&P%20

For faucets, B2 includes the cleaning of the faucet, with a cleaning frequency of 260 days per year using 10 mL of a 1% sodium lauryl sulfate (SLS) solution per cleaning event. Each liter of 1% SLS solution comprises 10 grams of SLS and 0.99 liters of water.

For toilets, B2 includes the cleaning of the toilet bowl, with a cleaning frequency of twice per month using 50 mL of a 1% sodium lauryl sulfate (SLS) solution per cleaning event. The maintenance activity inputs have been listed in **Table 13**.

Table 13. Faucet and toilet maintenance inputs per functional unit

Name	Faucet	Toilet	Unit
Reference service life (RSL)	10	20	years
Estimated service life (ESL)	75	75	years
Number of uses over ESL	1755000	355875	uses/flushes
Maintenance cycles	19500	1800	per ESL
Water consumption	193.05	89.11	L
Auxiliary material (cleaning agent)	1.95	0.9	kg
Other resources			kg
Electricity	-	-	kWh
Other energy carriers	-	-	MJ
Material loss	-	-	kg

3.2.7. Repair (B3)

This module includes all technical services and associated operations during the service life of the product in the form of corrective, responsive, or reactive actions to return the product into an acceptable condition to continue to provide its services.

For faucets, there are no repair activities. For toilets, as prescribed by the PCR, the flush handle, rubber ring, and fill valve seals in the tank are assumed to be fully replaced once during the RSL. Since replacement components can be purchased separately by the user, an upstream transport distance of 2,000 km is assumed. The old components are assumed to be 100% sanitary landfilled with a waste transport distance of 100 km. The repair activity inputs have been listed in **Table 14**.

Table 14. Toilet repair inputs per functional unit

Name	Value	Unit
Information on the repair process	Replacement of flush handle, rubber ring, and fill valve seal once during the RSL.	
Repair cycle	1	number/RSL
	3.75	number/ESL
Repair waste	0.397	kg per ESL
Disposal sent for landfill	100	%

3.2.8. Replacement (B4)

Replacement covers all technical services and associated operations during the ESL associated with replacing the whole product once its RSL is over. Per the PCRs, replacements must be counted proportionally to the nearest tenth of a product and must include the sum of impacts from stages A1-A5 and C1-C4 multiplied by the number of replacements.

For faucets, since the RSL is 10 years, 6.5 replacements will be needed. For toilets, 2.75 replacements will be needed as the RSL is 20 years. The replacement activity inputs have been listed in **Table 15**.

Table 15. Faucet and toilet replacement inputs per functional unit

Name	Faucet	Toilet	Unit
Replacement cycles over RSL	0	0	(RSL/RSL) -1
Replacement cycles over ESL	6.5	2.75	(ESL/RSL) -1
Electricity consumption	-	-	kWh
Liters of fuel	-	-	l/100 km
Replacement of worn parts	-	-	kg
Auxiliary materials	-	-	kg

3.2.9. Refurbishment (B5)

This module covers any applicable restoration activities. Refurbishment is not expected to occur during the normal operation of both faucets and toilets; therefore, there is no activity in this stage.

3.2.10. Operational energy use (B6)

This module covers energy usage during the operation of the product and its associated environmental aspects and potential impacts.

For faucets, the energy used to heat water consumed by the faucet is included. Water heating energy is assumed to be a blend of 67% natural gas and 33% electricity. Water heating is calculated using factors provided in the PCR, which are 0.1765 kWh of electricity per gallon of water and 6.571 liters of natural gas per liter of water. The operational energy use inputs have been listed in **Table 16**.

For toilets, there is no activity within this stage.

Table 16. Faucet operational energy use consumption per functional unit

Name	PFWSC30075CP Faucet	PFWSC30075CP Faucet	Unit
Number of uses over ESL	1755000		uses
Electricity consumption	5962.832	14310.797	kWh
Natural gas consumption	1706.134	4094.721	m^3
Other energy carriers	-	-	MJ

3.2.11. Operational water use (B7)

This module covers water usage during the operation of the product and its associated environmental aspects and potential impacts.

For faucets, water used to operate the faucet is included in this stage, which depends on the water flow rate of the faucet. Time per use is assumed to be 10 seconds per use. An electricity factor of 0.000961 kWh per liter of water is prescribed by the PCR, which includes energy for upstream municipal water collection, treatment, supply, and downstream sewage management. The operational water use inputs have been listed in Table 17.

For toilets, the flow rate per flush determines the total water usage. The same electricity factor of 0.000961 kWh per liter of water was used.

Table 17. Faucet and toilet operational water use consumption per functional unit

Name	PFWSC30075CP Faucet	PFWSC3007CP Faucet	Toilet with 1.6 gpf tank	Toilet with 1.28 gpf tank	Unit
Number of uses over ESL	1755000		355875		uses/flushes
Water flow rate	0.5	1.2	1.6	1.28	gpm/gpf
Water consumption	146250	351000	569400	455520	gallons
Electricity consumption	532.35	1277.64	2072.616	1658.093	kWh
Wastewater generation	146250	351000	569400	455520	gallons

3.2.12. Deconstruction/demolition (C1)

This module includes the dismantling or demolition of the product from the building and associated energy consumption. Both faucets and toilets are assumed to be manually removed using common hand tools at the end of life; thus, there is no activity in this module.

3.2.13. Transport to waste processing or disposal (C2)

This module refers to the transportation of the discarded product to the waste processing sites, either to a recycling site or for final product disposal. Per the PCR, the waste transportation distance is assumed to be 100 km for both products.

3.2.14. Waste processing (C3)

This module represents the processing of waste generated resulting in materials for reuse, secondary materials, and secondary fuels. There is no activity considered in this module for the studied products.

3.2.15. Waste disposal (C4)

This module represents the final waste disposal including the physical treatment and management of the disposal site. Per both PCRs, 100% of the discarded product is sent to sanitary landfills. End of life activity inputs have been reported in Table 18. Processes specific to each material type were selected.

Table 18. Faucet and toilet end of life inputs per functional unit

Name	Faucet	Toilet with 1.6 gpf tank	Toilet with 1.28 gpf tank	Unit
Transport from building site to landfill	100			km
Collected separately	-			kg
Mixed construction waste	0.793	40.312	38.797	kg
Reuse	-			kg
Recycling	-			kg
Energy recovery	-			kg
Landfilling total	0.793	40.312	38.797	kg

3.3. Background data

This section details the background data sets used for modeling all relevant activities associated with the cradle to grave life cycle of faucets and toilets. Each table lists the data set name, database, reference year, and geography. The LCA model was created using the SimaPro Developer 9.6 software system. The ecoinvent v3.10 and US-EI 2.2 databases provided the life cycle inventory data for the raw materials and processes for modeling the products.

3.3.1. Materials

Data representing upstream and downstream raw materials were obtained from the ecoinvent v3.10 database. Data sets matching each raw material were found in the available databases; therefore, no proxies were needed. Where country-specific data were unavailable, global, or rest-of-world averages were used to represent production in those locations. **Table 19** lists the most relevant LCI data sets used in modeling the raw materials.

Table 19. Key material data sets used in inventory analysis

Raw material	Data set	Database	Reference year	Geography[1]
Ceramics	Sanitary ceramics {RoW}| sanitary ceramics production | Cut-off, U --- *manually updated to only include material ingredients*	Ecoinvent v3.10	2023	RoW
Zinc	Zinc {GLO}| market for zinc | Cut-off, U	Ecoinvent v3.10	2023	GLO
Brass	Brass {RoW}| market for brass | Cut-off, U	Ecoinvent v3.10	2023	RoW
Polyamide	Glass fibre reinforced plastic, polyamide, injection moulded {GLO}| market for glass fibre reinforced plastic, polyamide, injection moulded | Cut-off, U	Ecoinvent v3.10	2023	GLO
Acrylonitrile butadiene styrene (ABS)	Acrylonitrile-butadiene-styrene copolymer {GLO}| market for acrylonitrile-butadiene-styrene copolymer | Cut-off, U	Ecoinvent v3.10	2023	GLO
Pulp	Sulfate pulp, unbleached {RoW}| market for sulfate pulp, unbleached | Cut-off, U	Ecoinvent v3.10	2019	GLO
Polyethylene	Polyethylene, high density, granulate {GLO}| market for polyethylene, high density, granulate | Cut-off, U	Ecoinvent v3.10	2023	GLO
Polyurethane	Polyurethane, flexible foam {RoW}| market for polyurethane, flexible foam | Cut-off, U	Ecoinvent v3.10	2023	RoW
Polypropylene	Polypropylene, granulate {GLO}| market for polypropylene, granulate | Cut-off, U	Ecoinvent v3.10	2023	GLO
Nylon	Nylon 6 {RoW}| market for nylon 6 | Cut-off, U	Ecoinvent v3.10	2023	RoW
Rubber	Synthetic rubber {GLO}| market for synthetic rubber | Cut-off, U	Ecoinvent v3.10	2023	GLO
Steel	Steel, low-alloyed {GLO}| market for steel, low-alloyed | Cut-off, U	Ecoinvent v3.10	2020	GLO
Expanded polyethylene foam & polyethylene bag	Polyethylene, low density, granulate {GLO}| market for polyethylene, low density, granulate | Cut-off, U	Ecoinvent v3.10	2023	GLO
White box carton	Solid bleached and unbleached board carton {RoW}| solid bleached and unbleached board carton production | Cut-off, U	Ecoinvent v3.10	2020	RoW
Corrugated carton	Corrugated board box {RoW}| corrugated board box production | Cut-off, U	Ecoinvent v3.10	2023	RoW
Adhesive in label	Adhesive, for metal {RoW}| market for adhesive, for metal | Cut-off, U	Ecoinvent v3.10	2023	RoW
Label	Paper, woodfree, coated {RoW}| market for paper, woodfree, coated | Cut-off, U	Ecoinvent v3.10	2020	RoW
Instruction manual paper	Printed paper, offset {RoW}| offset printing, per kg printed paper | Cut-off, U	Ecoinvent v3.10	2022	RoW
Ethanol	Ethanol, without water, in 99.7% solution state, from ethylene {RoW}| market for ethanol, without water, in 99.7% solution state, from ethylene | Cut-off, U[2]	Ecoinvent v3.10	2011	RoW
Cotton gloves	Textile, woven cotton {GLO}| market for textile, woven cotton | Cut-off, U[2]	Ecoinvent v3.10	2011	GLO
Municipal water	Water, decarbonised {RoW}| market for water, decarbonised | Cut-off, U	Ecoinvent v3.10	2018	RoW
Kerosene	Kerosene {RoW}| market for kerosene | Cut-off, U	Ecoinvent v3.10	2022	RoW

[1] 'GLO' stands for global geography; 'RoW' stands for Rest of World (non-Europe) geography
[2] Data sets older than 10 years (ethanol and woven cotton) were chosen because they closest represent the technology used to manufacture the material and are assumed to be more accurate than other potential proxies with more precise geography and temporal representativeness.

3.3.2. Transportation

Raw materials and components are transported to the product manufacturing facility from the suppliers via different transport modes. Depending on distances, and suggested by facility personnel, vehicle types used are 4T trucks, light commercial vehicles, or heavier trucks. Final products are first shipped using container ships to Ferguson distribution centers in the US and then transported to end users. Transportation distances from the production facility to the adjacent ports and from the destination port to the Ferguson distribution centers are included. As the transportation data sets represent load factors as an average of empty and fully loaded (i.e., average load factor), empty backhauls are accounted for in the model. Data sets matching each transportation mode were found in the available databases. Where country-specific data were unavailable, global or rest-of-world averages were used to represent transportation in those locations. **Table 20** shows the most relevant LCI data sets used in modeling transportation.

Table 20. Transportation data sets used in inventory analysis

Transport mode & legs	Data set	Database	Reference year	Geography[1]
Upstream road transport	Transport, freight, lorry 3.5-7.5 metric ton, EURO6 {RoW}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, U	Ecoinvent v3.10	2014	RoW
Upstream road transport	Transport, freight, light commercial vehicle {RoW}| market for transport, freight, light commercial vehicle | Cut-off, U[2]	Ecoinvent v3.10	2011	RoW
Upstream road transport	Transport, freight, lorry 16-32 metric ton, EURO5 {RoW}| market for transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U[2]	Ecoinvent v3.10	2011	RoW
Road transport from facility to origin port	Transport, freight, lorry >32 metric ton, EURO6 {RoW}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, U[2]	Ecoinvent v3.10	2011	RoW
Sea transport	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	Ecoinvent v3.10	2022	GLO
Road transport from US port to distribution centers	Transport, combination truck, diesel powered NREL/US U	US-EI 2.2	2021	United States
Final transport to building sites	Transport, lorry 7.5-16t, EURO5/US-US-EI U	US-EI 2.2	2021	US
Overseas waste transport	Municipal waste collection service by 21 metric ton lorry {GLO}| market for municipal waste collection service by 21 metric ton lorry | Cut-off, U[2]	Ecoinvent v3.10	2011	GLO
US waste transport	Transport, municipal waste collection, lorry 21t/US* US-EI U[2]	US-EI 2.2	2021	United States

[1] 'GLO' stands for global geography; 'RoW' stands for Rest of World (non-Europe) geography
[2] Data sets older than 10 years (light commercial vehicle, EURO5 16-32t lorry, EURO6 >32t lorry, and waste collection lorry) were chosen because they closest represent the technology used to manufacture the material and are assumed to be more accurate than other potential proxies with more precise geography and temporal representativeness.

3.3.3. Fuels and energy

The fuel inputs and electricity grid mixes were obtained using the databases available in SimaPro. For upstream processing of purchased components, relevant processing data sets from ecoinvent v3.10 were selected, and the embedded electricity was modified to represent the supplier country. The manufacturing of faucets occurs in Vietnam, so the electricity data set for Vietnam was used, while toilets are manufactured in North China, so the electricity data set specific to North China was used.

For electricity consumed during use phase, most recent eGRID average dataset was used. **Table 21** shows the most relevant LCI datasets used in modeling transportation.

Table 21. Key energy datasets used in inventory analysis

Energy source	Data set	Database	Reference year	Geography[1]
Faucet manufacturing electricity	Electricity, medium voltage {VN}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	2021	Vietnam
Toilet manufacturing electricity	Electricity, medium voltage {CN-NCGC}| market for electricity, medium voltage | Cut-off, U	Ecoinvent v3.10	2021	China
Natural gas	Heat, district or industrial, natural gas {RoW}| market for heat, district or industrial, natural gas | Cut-off, U[2]	Ecoinvent v3.10	2011	RoW
Coke oven gas	Heat, district or industrial, other than natural gas {RoW}| heat production, at coal coke industrial furnace 1-10MW | Cut-off, U	Ecoinvent v3.10	2015	RoW
Steam	Steam, in chemical industry {RoW}| market for steam, in chemical industry | Cut-off, U	Ecoinvent v3.10	2019	RoW
Use phase electricity	Electricity mix 2021/US US-EI U	US-EI 2.2	2021	United States
Use phase natural gas	Heat, central or small-scale, natural gas {GLO}| market group for heat, central or small-scale, natural gas | Cut-off, U	Ecoinvent v3.10	2023	GLO

[1] 'GLO' stands for global geography; 'RoW' stands for Rest of World (non-Europe) geography
[2] Data set older than 10 years (natural gas) was chosen because it closest represents the technology used to manufacture the material and are assumed to be more accurate than other potential proxies with more precise geography and temporal representativeness.

3.3.4. Disposal

Disposal processes were obtained from the ecoinvent v3.10 and US-EI 2.2 databases. Processes specific to waste types, if available, were selected to correspond to the disposal of facility waste streams, packaging waste during installation, and end-of-life waste streams. Rest of world data sets were selected to represent disposal outside of the US, since country-specific data sets were not available. **Table 22** lists the relevant disposal data sets used in the model.

Table 22. Key disposal data sets used in inventory analysis

Material disposed	Data set	Database	Reference year	Geography[1]
Incinerated hazardous waste	Hazardous waste, for incineration {RoW}| treatment of hazardous waste, hazardous waste incineration | Cut-off, U	Ecoinvent v3.10	2020	RoW
Landfilled municipal waste	Municipal solid waste {RoW}| treatment of municipal solid waste, sanitary landfill | Cut-off, U	Ecoinvent v3.10	2023	United States
Incinerated municipal waste	Municipal solid waste {RoW}| treatment of municipal solid waste, incineration | Cut-off, U	Ecoinvent v3.10	2023	RoW

Landfilled hazardous waste	Municipal solid waste {GLO}| treatment of municipal solid waste, unsanitary landfill, moist infiltration class (300mm) | Cut-off, U	Ecoinvent v3.10	2023	GLO
Generic manufacturing sewage	Wastewater, average {RoW}| market for wastewater, average | Cut-off, U	Ecoinvent v3.10	2022	RoW
Ceramic sewage	Wastewater from ceramic production {RoW}| market for wastewater from ceramic production | Cut-off, U	Ecoinvent v3.10	2022	RoW
Landfilled cardboard packaging	Disposal, packaging cardboard, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	2021	United States
Incinerated cardboard packaging	Disposal, packaging cardboard, 0% water, to municipal incineration/US* US-EI U	US-EI 2.2	2021	United States
Landfilled ceramics	Disposal, inert material, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	2021	United States
Landfilled metals	Disposal, municipal solid waste, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	2021	United States
Landfilled polyethylene	Disposal, polyethylene, to US sanitary landfill/US US-EI U	US-EI 2.2	2021	United States
Landfilled polypropylene	Disposal, polypropylene, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	2021	United States
Landfilled plastics	Disposal, plastics, mixture, to US sanitary landfill/US US-EI U	US-EI 2.2	2021	United States
Landfilled paper	Disposal, paper, 0% water, to sanitary landfill/US* US-EI U	US-EI 2.2	2021	United States

[1] 'GLO' stands for global geography; 'RoW' stands for Rest of World (non-Europe) geography

3.4. Cut-off criteria

The cut-off criteria on a unit process level can be summarized as follows:

- All inputs and outputs to a (unit) process shall be included in the calculation of the pre-set parameters results, for which data are available. Data gaps shall be filled by conservative assumptions with average, generic or proxy data. Any assumptions for such choices shall be documented. Assumptions and proxies, whenever used, have been explained in this report.
- 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. No known mass flow has been omitted in this study.
- 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. No known energy flow has been omitted in this study.
- Environmental relevance – If a flow meets the above criteria for exclusion, yet it is thought to potentially have a significant environmental impact, it is included. No known mass or energy flow has been omitted in this study.
- Hazardous and toxic materials – The study shall include all hazardous and toxic materials in the inventory therefore the cutoff rules shall not apply to such substances. All known hazardous waste released from the manufacturing facility have been included in this study.
- 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). No known mass flow has been omitted in this study.

In this report, no known flows are deliberately excluded; therefore, these criteria have been met. The completeness of the bill of materials defined in this report satisfies the above-defined cut-off criteria.

3.5. Allocation

Whenever a system boundary is crossed, environmental inputs and outputs have to be assigned to the different products. Where multi-inputs or multi-outputs are considered, the same applies. The PCR prescribes to report where and how allocation occurs in the modeling of the LCA.

The faucet manufacturing facility manufactures several faucet SKUs, and resources were allocated to the SKUs of interest via volumetric allocation. PFWSC30075CP and PFWSC3007CP represented a combined ~0.03% of gross faucet production in the facility. Annual resources were first normalized to each SKU type based on the total volume of production (m^3) and later scaled down to a per-unit level using annual production quantities. All associated manufacturing resources (electricity, water, natural gas, ancillary materials, etc.) and waste flows (sewage, solid waste, air emissions etc.) were allocated using the same approach.

The toilet manufacturing facility also manufactures several toilet tank and bowl SKUs. Annual facility resources specific to the SKUs under study were provided by the facility. Mass allocation was performed to normalize the manufacturing resources, and total ceramic mass manufactured was used to generate the inventory per kg of ceramic product. This approach is appropriate for the majority of ceramic production steps. The only exception is the casting process, which consumes the same amount of electricity per piece, whether it's casting the tank or the bowl regardless of mass difference. While this is an exception, the electricity used for casting is assumed to be small compared to the energy used in the slurry & glaze, drying, glazing, and firing steps, and energy breakdown per step was not available.

3.6. Discussion of data quality

Inventory data quality is judged by its precision (measured, calculated, or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied on a study serving as a data source), and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the ecoinvent v3.10 and US-EI 2.2 databases were used.

Precision and completeness

- *Precision*: As the relevant foreground data is primary data or modeled based on primary information sources of the owner of the technology, precision is considered to be high. Background data are from the ecoinvent v3.10 and US-EI 2.2 databases with documented precision to the extent available.

- *Completeness*: Sustainable Minds worked with Ferguson and its manufacturing partners to obtain a comprehensive set of primary data associated with the manufacturing processes. The product system was checked for mass balance and completeness of the inventory. The data set was considered complete based on our understanding of the manufacturing site and a review with key stakeholders on the Ferguson team, and cut-off criteria were observed consistent with those prescribed in the PCR. Besides capital equipment, no data was knowingly omitted.

Consistency and reproducibility

- *Consistency*: Primary data were collected with a similar level of detail, while background data were sourced primarily from the ecoinvent database. Other databases were used if data were not available in ecoinvent or the data set was judged to be more representative. Other methodological choices were made consistently throughout the model.

- *Reproducibility*: Reproducibility is warranted as much as possible through the disclosure of input-output data, dataset choices, and modeling approaches in this report. Based on this information, a knowledgeable third party should be able to approximate the results of this study using the same data and modeling approaches.

Representativeness

- *Temporal:* All primary data were collected for January 2023 – December 2023, ensuring the representativeness of the manufacturing process. Secondary data were obtained from the ecoinvent v3.10 and US-EI 2.2 databases and are typically representative of recent years.

- *Geographical*: Primary data are representative of primary production in Vietnam for faucets and in China for toilets. The upstream manufacturing processes of purchased components have been represented with the country of production. In general, secondary data were collected specific to the country under study. Where country-specific data were unavailable, global or rest-of-world averages were used to represent production in those locations. Geographical representativeness is therefore considered to be high.

- *Technological*: All primary and secondary data were modeled to be specific to the technologies under study. Technological representativeness is considered to be high.

3.7. Comparability

ISO 21930:2017 section 5.5 highlights the following limitations and clarifications in EPD comparability: EPDs are comparable only if they use the same PCR (or sub-category PCR where applicable), include all relevant information modules, and are based on equivalent scenarios with respect to the context of construction works [2]. Per Sustainable Minds Part A, EPDs are not comparative assertions; that is, no claim of environmental superiority can be inferred or implied [3].

EPDs can only be compared when the same functional requirements between products are ensured and the requirements of ISO 21930:2017 section 5.5 are met. However, variations and deviations are possible. For example, different LCA software and background LCI datasets may lead to different results for the life cycle stages declared.

3.8. Limitations

A life cycle assessment of a product system is broad and complex, and it inherently requires assumptions and simplifications. The following limitations of the study should be recognized:

- Primary data were modeled based on the information provided by corresponding manufacturing facilities for calendar year 2023. Upstream supply chain data, manufacturing operations, and downstream transport might vary.
- Since energy and resource inputs were not available on a per-product basis, electricity and other resources consumed in the faucet manufacturing facility were allocated proportionately based on the volumetric share of faucets analyzed to the total faucets produced. It was later scaled down per faucet using the total production units of faucets studied. Similarly, for toilet tanks and bowls, resources were allocated to the SKUs studied by mass. Later, resources per kilogram of ceramic processed were developed. Slight deviations between SKUs are possible.
- Toilet seats be sourced from any manufacturer, including Ferguson. Ferguson also has several seat SKUs; however, an average of the heaviest and lightest seats (by mass) has been used. While the environmental impact from the seat is insignificant in the overall lifecycle, some seat types will have higher impacts than others.
- Generic data sets used for material inputs, transportation, and waste processing are considered good quality, but actual impacts from material suppliers, transport carriers, and local waste processing may vary.
- The impact assessment methodology categories do not represent all possible environmental impact categories.
- Characterization factors used within the impact assessment methodology may contain varying levels of uncertainty.
- LCA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.

4. Impact Assessment Methods

4.1. Impact assessment characterization

The environmental indicators as required by the PCR are included as well as other indicators required to use the SM2013 Methodology [7] (see Table 23). The impact indicators are derived using the 100-year time horizon[6] factors, where relevant, as defined by TRACI 2.1 classification and characterization [8]. Long-term emissions (>100 years) are not taken into consideration in the impact estimate. USEtox indicators[7] are used to evaluate toxicity. Emissions from waste disposal are considered part of the product system under study, according to the "polluter pays principle".

Table 23. Selected impact categories and units

Impact category	Unit	Description
Acidification	kg SO_2 eq (sulphur dioxide)	Acidification processes increase the acidity of water and soil systems and causes damage to lakes, streams, rivers and various plants and animals as well as building materials, paints, and other human-built structures.
Ecotoxicity	CTUe	Ecotoxicity causes negative impacts to ecological receptors and, indirectly, to human receptors through the impacts to the ecosystem.
Eutrophication	kg N eq (nitrogen)	Eutrophication is the enrichment of an aquatic ecosystem with nutrients (nitrates and phosphates) that accelerate biological productivity (growth of algae and weeds) and an undesirable accumulation of algal biomass.
Global warming	kg CO_2 eq (carbon dioxide)	Global warming is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere.
Ozone depletion	kg CFC-11 eq	Ozone depletion is the reduction of ozone in the stratosphere caused by the release of ozone depleting chemicals.
Carcinogenics	CTUh	Carcinogens have the potential to form cancers in humans.
Non-carcinogenics	CTUh	Non-Carcinogens have the potential to causes non-cancerous adverse impacts to human health.
Respiratory effects	kg $PM_{2.5}$ eq (fine particulates)	Particulate matter concentrations have a strong influence on chronic and acute respiratory symptoms and mortality rates.
Smog	kg O_3 eq (ozone)	Smog formation (photochemical oxidant formation) is the formation of ozone molecules in the troposphere by complex chemical reactions.
Fossil fuel depletion	MJ surplus	Fossil fuel depletion is the surplus energy to extract minerals and fossil fuels.

With respect to global warming potential, biogenic carbon is included in impact category calculations. The biogenic carbon measured in this study originates from packaging materials, and no raw materials in the faucet and toilet are expected to contain biogenic carbon. Greenhouse gas emissions from land-use change are expected to be insignificant and were not reported. Carbon emissions during carbonation and calcination are also considered in this study, and no carbonation or calcination are expected to occur during the production and manufacture of the faucets and toilets.

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

It shall be noted that the above impact categories represent impact potentials. They are approximations of environmental impacts that could occur if the emitted molecules follow the underlying impact pathway and meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach).

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 at a single score indicator, normalization [9] and weighting [10] as shown in **Table 24** conforming to the SM 2013 Methodology were applied. The SM 2013 Methodology uses TRACI 2.1 impact categories developed by U.S. EPA, and North American normalization and weighting values developed by EPA and NIST respectively, to calculate single figure LCA results. Sustainable Minds recognizes that weighting is socially defined based on the importance that society attaches to the different environmental impact categories. However, these single score indicators serve as an easy starting point to get to know the product under consideration across all impact categories, rather than focusing all efforts on just one impact category (like global warming potential). The interpretation of the results starts with the Sustainable Minds single score results and then allows users to further explore the underlying impact categories individually. Details including the characterization models, factors, and methods used, including all assumptions and limitations, can be found in the SM 2013 Methodology Report [7].

Table 24. Normalization and weighting factors

Impact category	Normalization	Weighting (%)
Acidification	90.9	3.6
Ecotoxicity	11000	8.4
Eutrophication	21.6	7.2
Global warming	24200	34.9
Ozone depletion	0.161	2.4
Carcinogenics	5.07E-05	9.6
Non-carcinogenics	1.05E-03	6.0
Respiratory effects	24.3	10.8
Smog	1390	4.8
Fossil fuel depletion	17300	12.1

5. ASSESSMENT AND INTERPRETATION

This chapter includes the results from the LCA for the products studied. It details the results per functional unit, outlines the sensitivity analysis, and concludes with recommendations.

5.1. Resource use and waste flows

Resource use indicators, output flows and waste category indicators, and carbon emissions and removals are presented in this section. These life cycle inventory (LCI) indicators reflect the flows from and to nature for the product system, prior to characterization using an impact assessment methodology to calculate life cycle impact assessment (LCIA) results (as shown in section 5.2).

LCI flows were calculated with the help of American Center for Life Cycle Assessment's (ACLCA) guidance for calculating the ISO 21930:2017 metrics [11]. The consumption of freshwater indicator, which was calculated in accordance with this guidance, is reported in compliance with ISO 14046. Use of renewable and non-renewable energy resources with energy content were calculated using the Cumulative Energy Demand (LHV) impact assessment methodology [12]. LCI flows were reported in conformance to ISO 21930:2017 [2].

Resource use indicators represent the amount of materials consumed to produce not only the product itself but also the raw materials, electricity, natural gas, etc. that go into the product’s life cycle.

Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process and is expressed in energy demand from renewable and non-renewable resources. Efficiencies in energy conversion are considered when calculating primary energy demand from process energy consumption. Water use represents the total water used over the entire life cycle. No renewable energy was used in production beyond that accounted for in the electricity grid mix used.

Hazardous and non-hazardous wastes are calculated based on the amount of waste generated during the life cycle of each product studied, mainly during the manufacturing of the products. All waste treatments in models were considered based on the local waste management code and the assumptions mentioned in the PCRs. Waste treatments included within the system boundary are reported. Unrecyclable wastes either are disposed of in landfills or incinerated.

There is no biogenic carbon associated with the product, but biogenic carbon relevant to packaging materials has been reported per life cycle stage. CO_2 from calcination and carbonation does not apply to these studied products. **Table 25** represents all the resource use and waste flow indicators, with the acronyms used, evaluated in this study.

Table 25. Resource use and waste flow indicators

Indicators	Acronyms used
Resource use indicators	
Renewable primary energy used as energy carrier (fuel)	**RPR_E**
Renewable primary resources with energy content used as material	**RPR_M**
Total use of renewable primary resources with energy content	**RPR_{total}**
Non-renewable primary resources used as an energy carrier (fuel)	**$NRPR_E$**
Non-renewable primary resources with energy content used as material	**$NRPR_M$**
Total use of non-renewable primary resources with energy content	**$NRPR_{total}$**
Secondary materials	**SM**
Renewable secondary fuels	**RSF**
Non-renewable secondary fuels	**NRSF**
Recovered energy	**RE**
Use of net fresh water resources	**FW**
Output flows and waste category indicators	
Hazardous waste disposed	**HWD**
Non-hazardous waste disposed	**NHWD**
High-level radioactive waste, conditioned, to final repository	**HLRW**
Intermediate- and low-level radioactive waste, conditioned, to final repository	**ILLRW**
Components for re-use	**CRU**
Materials for recycling	**MR**
Materials for energy recovery	**MER**
Exported energy	**EE**
Carbon emissions and removals	
Biogenic Carbon Removal from Product	**BCRP**
Biogenic Carbon Emission from Product	**BCEP**
Biogenic Carbon Removal from Packaging	**BCRK**
Biogenic Carbon Emission from Packaging	**BCEK**
Biogenic Carbon Emission from Combustion of Waste from Renewable Sources Used in Production Processes	**CBCEW**
Calcination Carbon Emissions	**CCE**
Carbonation Carbon Removals	**CCR**
Carbon Emissions from Combustion of Waste from Non-Renewable Sources used in Production Processes	**CWNR**

Resource use, output flows, waste categories, and carbon emissions & removals for each product type have been tabulated in the sections below.

5.1.1. PROFLO® Single Handle Lavatory Faucet PFWSC30075CP

Table 26 shows resource use, output and waste flows, and carbon emissions and removals for PFWSC30075CP per functional unit.

Table 26. Resource use, output and waste flows, and carbon emissions and removals for the PFWSC30075CP faucet per functional unit

Parameters	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Resource use indicators																
RPR_E	MJ, NCV	2.14E+01	2.28E-02	4.48E-03	0	1.66E+02	0	1.40E+02	0	4.92E+03	7.10E+02	0	2.16E-03	0	1.03E-02	**5.96E+03**
RPR_M	MJ, NCV	8.96E+00	0	0	0	0	0	5.82E+01	0	0	0	0	0	0	0	**6.72E+01**
RPR_{total}	MJ, NCV	3.04E+01	2.28E-02	4.48E-03	0	1.66E+02	0	1.98E+02	0	4.92E+03	7.10E+02	0	2.16E-03	0	1.03E-02	**6.02E+03**
$NRPR_E$	MJ, NCV	5.17E+01	1.20E+01	1.37E+00	0	3.53E+01	0	4.29E+02	0	6.08E+04	6.99E+03	0	1.35E+00	0	1.66E-01	**6.84E+04**
$NRPR_M$	MJ, NCV	5.41E+00	0	0	0	0	0	3.89E+01	0	0	0	0	0	0	0	**4.06E+01**
$NRPR_{total}$	MJ, NCV	5.71E+01	1.20E+01	1.37E+00	0	3.53E+01	0	4.68E+02	0	6.08E+04	6.99E+03	0	1.35E+00	0	1.66E-01	**6.84E+04**
SM	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
NRSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RE	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FW	m^3	2.81E+01	2.35E-02	3.17E-04	0	1.08E+01	0	1.83E+02	0	1.75E+02	6.34E+02	0	2.26E-04	0	1.39E-04	**1.03E+03**
Output flows and waste category indicators																
HWD	kg	4.58E-02	0	0	0	0	0	2.98E-01	0	0	0	0	0	0		**3.44E-01**
NHWD	kg	2.73E-02	0	1.20E-01	0	0	0	6.11E+00	0	0	0	0	0	0	7.93E-01	**7.05E+00**
HLRW	kg	4.54E-03	7.76E-06	6.90E-07	0	4.18E-04	0	2.96E-02	0	7.49E-01	8.76E-02	0	3.32E-07	0	1.30E-06	**8.71E-01**
ILLRW	kg	1.65E-03	1.59E-05	2.26E-06	0	3.31E-04	0	1.09E-02	0	2.49E+00	2.94E-01	0	1.09E-06	0	4.34E-06	**2.80E+00**
CRU	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MR	kg	0	6.31E-01	4.10E+00	0	4.74E+00	0	4.10E+00	0	0	0	0		0		**4.74E+00**
MER	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
EE	MJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
BCRP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCEP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCRK	kg CO_2	1.44E+00	0	0	0	0	0	9.33E+00	0	0	0	0	0	0	0	**1.08E+01**
BCEK	kg CO_2	0	0	1.21E+00	0	0	0	7.89E+00	0	0	0	0	0	0	1.04E-03	**9.10E+00**
CBCEW	kg CO_2	0	0	5.37E-02	0	0	0	3.49E-01	0	0	0	0	0	0	0	**4.03E-01**
CCE	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CCR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CWNR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

5.1.2. PROFLO® Single Handle Lavatory Faucet PFWSC3007CP

Table 27 shows resource use, output and waste flows, and carbon emissions and removals for PFWSC3007CP per functional unit.

Table 27. Resource use, output and waste flows, and carbon emissions and removals for the PFWSC3007CP faucet per functional unit

Parameters	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Resource use indicators																
RPR_E	MJ, NCV	2.14E+01	2.93E-02	4.48E-03	0	1.66E+02	0	1.40E+02	0	1.18E+04	1.70E+03	0	2.16E-03	0	1.03E-02	**1.38E+04**
RPR_M	MJ, NCV	8.96E+00	0	0	0	0	0	5.82E+01	0	0	0	0	0	0	0	**6.72E+01**
RPR_{total}	MJ, NCV	3.04E+01	2.93E-02	4.48E-03	0	1.66E+02	0	1.98E+02	0	1.18E+04	1.70E+03	0	2.16E-03	0	1.03E-02	**1.39E+04**
$NRPR_E$	MJ, NCV	5.17E+01	1.59E+01	1.37E+00	0	3.53E+01	0	4.55E+02	0	1.46E+05	1.68E+04	0	1.35E+00	0	1.66E-01	**1.63E+05**
$NRPR_M$	MJ, NCV	5.41E+00	0	0	0	0	0	3.89E+01	0	0	0	0	0	0	0	**4.06E+01**
$NRPR_{total}$	MJ, NCV	5.71E+01	1.59E+01	1.37E+00	0	3.53E+01	0	4.93E+02	0	1.46E+05	1.68E+04	0	1.35E+00	0	1.66E-01	**1.63E+05**
SM	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
NRSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RE	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FW	m^3	2.81E+01	2.35E-02	3.17E-04	0	1.08E+01	0	1.83E+02	0	1.75E+02	6.34E+02	0	2.26E-04	0	1.39E-04	**2.16E+03**
Output flows and waste category indicators																
HWD	kg	4.58E-02	0	0	0	0	0	2.98E-01	0	0	0	0	0	0		**3.44E-01**
NHWD	kg	2.73E-02	0	1.20E-01	0	0	0	6.11E+00	0	0	0	0	0	0	7.93E-01	**7.05E+00**
HLRW	kg	4.54E-03	8.75E-06	6.89E-07	0	4.18E-04	0	2.96E-02	0	1.80E+00	2.10E-01	0	3.32E-07	0	1.30E-06	**2.04E+00**
ILLRW	kg	1.65E-03	1.92E-05	2.26E-06	0	3.31E-04	0	1.09E-02	0	5.98E+00	7.05E-01	0	1.09E-06	0	4.34E-06	**6.70E+00**
CRU	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MR	kg	0	6.31E-01	4.10E+00	0	4.74E+00	0	4.10E+00	0	0	0	0		0		**4.74E+00**
MER	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
EE	MJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals																
BCRP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCEP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCRK	kg CO_2	1.44E+00	0	0	0	0	0	9.33E+00	0	0	0	0	0	0	0	**1.08E+01**
BCEK	kg CO_2	0	0	1.21E+00	0	0	0	7.89E+00	0	0	0	0	0	0	1.04E-03	**9.10E+00**
CBCEW	kg CO_2	0	0	5.37E-02	0	0	0	3.49E-01	0	0	0	0	0	0	0	**4.03E-01**
CCE	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CCR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CWNR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

5.1.3. PROFLO® Calhoun 1500 Series Two-piece Toilet 1.28 gpf

Table 28 shows resource use, output and waste flows, and carbon emissions and removals for the 1.28 gpf toilet per functional unit.

Table 28. Resource use, output and waste flows, and carbon emissions and removals for the 1.28 gpf toilet per functional unit

Parameters	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Resource use indicators																
RPR_E	MJ, NCV	4.18E+01	2.50E-01	1.08E-02	0	7.67E+01	1.44E+00	1.16E+02	0	0	1.59E+03	0	1.06E-01	0	5.54E-02	**1.83E+03**
RPR_M	MJ, NCV	2.43E+01	0	0	0	0	0	5.82E+01	0	0	0	0	0	0	0	**9.11E+01**
RPR_{total}	MJ, NCV	6.61E+01	2.50E-01	1.08E-02	0	7.67E+01	1.44E+00	1.16E+02	0	0	1.59E+03	0	1.06E-01	0	5.54E-02	**1.92E+03**
$NRPR_E$	MJ, NCV	7.60E+02	1.33E+02	3.29E+00	0	1.63E+01	0	4.47E+01	0	0	1.78E+04	0	6.58E+01	0	2.93E+00	**2.15E+04**
$NRPR_M$	MJ, NCV	9.41E+01	0	0	0	0	0	0	0	0	0	0	0	0	0	**3.53E+02**
$NRPR_{total}$	MJ, NCV	8.54E+02	1.33E+02	3.29E+00	0	1.63E+01	0	4.47E+01	0	0	1.78E+04	0	6.58E+01	0	2.93E+00	**2.18E+04**
SM	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
NRSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RE	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FW	m^3	8.58E+01	9.72E-01	2.98E-02	0	5.31E+00	6.05E+00	2.39E+02	0	0	5.36E+02	0	2.08E-01	0	1.00E-01	**8.74E+02**
Output flows and waste category indicators																
HWD	kg	2.10E-02	0	0	0	0	0	5.78E-02	0	0	0	0	0	0		**7.56E-02**
NHWD	kg	0	0	2.98E-01	0	0	0	1.12E+02	0	0	0	0	0	0	4.03E+01	**1.47E+02**
HLRW	kg	8.58E-03	1.11E-04	5.66E-07	0	1.62E-04	4.34E-04	2.39E-02	0	1.80E+00	2.80E-01	0	9.37E-06	0	4.87E-06	**2.56E-01**
ILLRW	kg	1.43E-03	6.07E-05	1.79E-07	0	1.53E-07	2.76E-04	4.17E-03	0	5.98E+00	9.39E-01	0	1.96E-05	0	1.08E-05	**7.57E-01**
CRU	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MR	kg	5.13E+00	6.31E-01	4.10E+00	0	4.74E+00	0	1.83E+01	0	0	0	0		0		**2.41E+01**
MER	kg	5.29E-02	0	0	0	0	0	1.45E-01	0	0	0	0	0	0	0	**1.90E-01**
EE	MJ	9.72E-01	0	0	0	0	0	2.67E+00	0	0	0	0	0	0	0	**3.50E+00**
Carbon emissions and removals																
BCRP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCEP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCRK	kg CO_2	3.46E+00	0	0	0	0	0	9.52E+00	0	0	0	0	0	0	0	**1.30E+01**
BCEK	kg CO_2	0	0	2.89E+00	0	0	0	7.99E+00	0	0	0	0	0	0	1.18E-02	**1.09E+01**
CBCEW	kg CO_2	0	0	1.28E-01	0	0	0	3.52E-01	0	0	0	0	0	0	0	**4.80E-01**
CCE	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CCR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CWNR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

5.1.4. PROFLO® Calhoun 1500 Series Two-piece Toilet 1.6 gpf

Table 29 shows resource use, output and waste flows, and carbon emissions and removals for the 1.6 gpf toilet per functional unit.

Table 29. Resource use, output and waste flows, and carbon emissions and removals for the 1.6 gpf toilet per functional unit

Parameters	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Resource use indicators																
RPR_E	MJ, NCV	4.26E+01	2.91E-02	1.08E-02	0	7.67E+01	1.58E+00	1.18E+02	0	0	1.99E+03	0	1.10E-01	0	5.75E-02	**2.23E+03**
RPR_M	MJ, NCV	2.43E+01	0	0	0	0	0	6.69E+01	0	0	0	0	0	0	0	**9.13E+01**
RPR_{total}	MJ, NCV	6.69E+01	2.91E-02	1.08E-02	0	7.67E+01	1.58E+00	1.85E+02	0	0	1.99E+03	0	1.10E-01	0	5.75E-02	**2.32E+03**
$NRPR_E$	MJ, NCV	7.82E+02	1.58E+02	3.29E+00	0	1.63E+01	4.82E+01	2.79E+03	0	0	2.22E+04	0	6.84E+01	0	3.04E+00	**2.61E+04**
$NRPR_M$	MJ, NCV	9.44E+01	0	0	0	0	0	2.60E+02	0	0	0	0	0	0	0	**3.54E+02**
$NRPR_{total}$	MJ, NCV	8.76E+02	1.58E+02	3.29E+00	0	1.63E+01	4.82E+01	3.05E+03	0	0	2.22E+04	0	6.84E+01	0	3.04E+00	**2.64E+04**
SM	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
NRSF	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
RE	MJ, NCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FW	m^3	8.70E+01	9.99E-01	2.98E-02	0	5.31E+00	0	2.43E+02	0	0	6.70E+02	0	2.08E-01	0	1.00E-01	**1.01E+03**
Output flows and waste category indicators																
HWD	kg	2.10E-02	0	0	0	0	0	5.78E-02	0	0	0	0	0	0	0	**7.88E-02**
NHWD	kg	0	0	2.98E-01	0	0	0	1.12E+02	0	0	0	0	0	0	4.03E+01	**1.52E+02**
HLRW	kg	8.58E-03	1.11E-04	5.66E-07	0	1.62E-04	4.34E-04	2.39E-02	0	0	2.80E-01	0	9.37E-06	0	4.87E-06	**3.13E-01**
ILLRW	kg	1.43E-03	6.07E-05	1.79E-07	0	1.53E-07	2.76E-04	4.17E-03	0	0	9.39E-01	0	1.96E-05	0	1.08E-05	**9.45E-01**
CRU	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MR	kg	5.13E+00	0	1.51E+00	0	0	0	1.83E+01	0	0	0	0	0	0	0	**2.49E+01**
MER	kg	5.29E-02	0	0	0	0	0	1.45E-01	0	0	0	0	0	0	0	**1.98E-01**
EE	MJ	9.72E-01	0	0	0	0	0	2.67E+00	0	0	0	0	0	0	0	**3.64E+00**
Carbon emissions and removals																
BCRP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCEP	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BCRK	kg CO_2	3.47E+00	0	0	0	0	0	9.53E+00	0	0	0	0	0	0	0	**1.30E+01**
BCEK	kg CO_2	0	0	2.90E+00	0	0	0	8.00E+00	0	0	0	0	0	0	1.19E-02	**1.09E+01**
CBCEW	kg CO_2	0	0	1.28E-01	0	0	0	3.53E-01	0	0	0	0	0	0	0	**4.80E-01**
CCE	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CCR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CWNR	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

5.2. Life cycle impact assessment (LCIA)

It shall be reiterated at this point that the reported impact categories represent impact potentials; they are approximations of environmental impacts that could occur if the emitted molecules follow the underlying impact pathway and meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen declared unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

Life cycle impact assessment (LCIA) results are shown per functional unit of both faucet types and toilet types. Unlike life cycle inventories, which only report sums for individual inventory flows, the LCIA includes a classification of individual emissions with regard to the impacts they are associated with and subsequently a characterization of the emissions by a factor expressing their respective contribution to the impact category indicator. The end result is a single metric for quantifying each potential impact, such as “Global Warming Potential”.

The impact assessment results are calculated using characterization factors published by the United States Environmental Protection Agency. The TRACI 2.1 (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts 2.1) methodology is the most widely applied impact assessment method for U.S. LCA studies. The SM 2013 Methodology is also applied to come up with single score results for the sole purpose of representing total impacts per life cycle phase to explain where in the product life cycle greatest impacts are occurring and what is contributing to the impacts.

TRACI impact categories are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development; however, the EPD users shall not use additional measures for comparative purposes. All impact categories from TRACI are used to calculate single score millipoints using the SM2013 Methodology, but it should be noted that there are known limitations related to these impact categories due to their high degree of uncertainty.

Life cycle impact assessment results are reported per functional unit, i.e., per unit of faucet and per unit of toilet.

5.2.1. PROFLO® Single Handle Lavatory Faucet PFWSC30075CP

The LCIA results of the PFWSC30075CP faucet per functional unit are shown in **Table 30**. The percent contribution of each of the cradle-to-grave life cycle stages to the total impacts is tabulated in **Table 31** and is also presented in **Figure 6**.

Table 30. Life cycle impact assessment results for PFWSC30075CP faucet per functional unit

Impact categories	Unit	Production	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	kg CFC-11 eq	7.81E-08	5.69E-08	1.99E-08	0	8.01E-08	0	1.14E-06	0	1.38E-04	2.56E-05	0	2.00E-08	0	1.08E-09	**1.65E-04**
Global warming	kg CO_2 eq	3.80E+00	9.31E-01	2.81E-01	0	4.73E+00	0	3.62E+01	0	3.41E+03	4.37E+02	0	9.98E-02	0	4.62E-01	**3.89E+03**
Smog	kg O_3 eq	4.29E-01	1.93E-01	1.66E-02	0	3.13E-01	0	4.27E+00	0	1.11E+02	2.39E+01	0	1.62E-02	0	1.86E-03	**1.40E+02**
Acidification	kg SO_2 eq	4.45E-02	8.64E-03	5.91E-04	0	4.91E-02	0	3.54E-01	0	1.30E+01	2.73E+00	0	5.51E-04	0	1.26E-04	**1.62E+01**
Eutrophication	kg N eq	4.96E-03	4.59E-04	3.35E-04	0	6.68E-02	0	4.59E-02	0	1.06E+00	1.62E+01	0	5.64E-05	0	1.26E-03	**1.74E+01**
Carcinogenics	CTU_h	7.80E-07	6.29E-09	2.07E-10	0	1.35E-07	0	5.13E-06	0	6.26E-06	4.31E-05	0	2.85E-11	0	1.76E-09	**5.54E-05**
Non-carcinogenics	CTU_h	8.88E-06	7.34E-08	6.10E-09	0	6.64E-06	0	5.83E-05	0	1.02E-04	8.77E-04	0	4.76E-09	0	2.97E-09	**1.05E-03**
Respiratory effects	kg $PM_{2.5}$ eq	4.78E-03	4.04E-04	6.66E-05	0	7.50E-03	0	3.46E-02	0	7.70E-01	1.42E-01	0	6.43E-05	0	1.14E-05	**9.59E-01**
Additional impact categories																
Ecotoxicity	CTU_e	3.10E+01	1.28E+00	1.85E-02	0	1.78E+02	0	2.10E+02	0	2.49E+02	2.06E+03	0	1.28E-02	0	8.46E-02	**2.73E+03**
Fossil fuel depletion	MJ surplus	5.12E+00	1.69E+00	1.93E-01	0	2.64E+00	0	4.69E+01	0	4.50E+03	5.03E+02	0	1.92E-01	0	1.63E-02	**5.05E+03**

Table 31. Percent contributions of each life cycle stage to each impact category for PFWSC30075CP per functional unit

Impact categories	Unit	Production	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	%	0.05%	0.03%	0.01%	0	0.05%	0	0.69%	0	83.66%	15.50%	0	0.01%	0	0.00%	**100%**
Global warming	%	0.10%	0.02%	0.01%	0	0.12%	0	0.93%	0	87.56%	11.24%	0	0.00%	0	0.01%	**100%**
Smog	%	0.31%	0.14%	0.01%	0	0.22%	0	3.06%	0	79.15%	17.10%	0	0.01%	0	0.00%	**100%**
Acidification	%	0.28%	0.05%	0.00%	0	0.30%	0	2.19%	0	80.27%	16.91%	0	0.00%	0	0.00%	**100%**
Eutrophication	%	0.03%	0.00%	0.00%	0	0.38%	0	0.26%	0	6.08%	93.23%	0	0.00%	0	0.01%	**100%**
Carcinogenics	%	1.41%	0.01%	0.00%	0	0.24%	0	9.25%	0	11.31%	77.78%	0	0.00%	0	0.00%	**100%**
Non-carcinogenics	%	0.84%	0.01%	0.00%	0	0.63%	0	5.53%	0	9.72%	83.26%	0	0.00%	0	0.00%	**100%**
Respiratory effects	%	0.50%	0.04%	0.01%	0	0.78%	0	3.61%	0	80.26%	14.79%	0	0.01%	0	0.00%	**100%**
Additional impact categories																
Ecotoxicity	%	1.13%	0.05%	0.00%	0	6.52%	0	7.70%	0	9.12%	75.47%	0	0.00%	0	0.00%	**100%**
Fossil fuel depletion	%	0.10%	0.03%	0.00%	0	0.05%	0	0.93%	0	88.93%	9.95%	0	0.00%	0	0.00%	**100%**

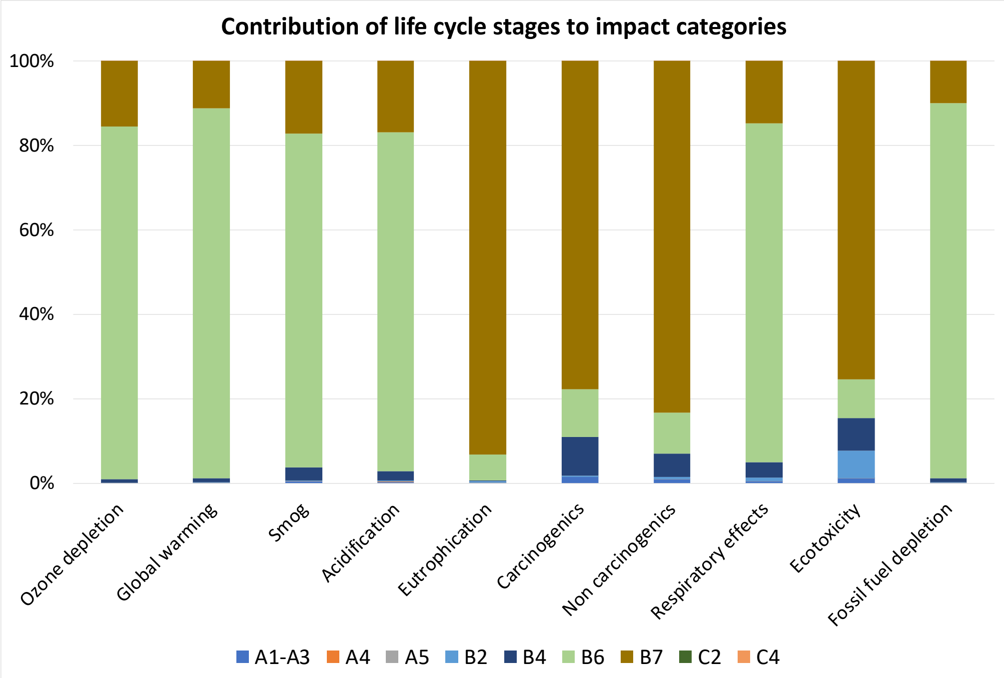

Figure 6. Contribution analysis of each impact category for the PFWSC30075CP faucet per functional unit

The SM2013 Methodology single figure millipoint (mPt) score by life cycle module for this product is presented in **Table 32**. In terms of single figure scores and overall environmental impacts, operational water use (B7) dominates the results (~61%), followed by operational energy use (B6) which accounts for ~33% of the total.

Table 32. Averaged SM millipoint scores for the PFWSC30075CP faucet per functional unit

Parameters	**Unit**	**Produc-tion**	**Construction/ Installation**		**Use**							**End of life**				**Total**
		A1-A3	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	
SM single figure score	mPts	2.38E+00	6.46E-02	8.50E-03	0	2.37E+00	0	1.61E+01	0	1.16E+02	2.14E+02	0	4.46E-03	0	1.53E-02	**3.51E+02**

In the cradle-to-grave life cycle of the product, operational energy use (B6) dominates the results for six impact categories, followed by operational water use (B7). The six impact categories are ozone depletion, global warming, smog, acidification, respiratory effects, and fossil fuel depletion. During B6, water heating uses a blend of 67% natural gas and 33% electricity. In terms of impacts, electricity accounts for >93% of the B6 impacts. For B7, electricity used by municipal systems makes up >40% of the total B7 impacts for the abovementioned six impact categories. The rest comes mostly from the sewage treatment. For these six impact categories, electricity consumption during product use, including in B6 and B7, contributes to a minimum of 85% of the impacts. Looking at just the global warming potential, electricity used during B6 and B7 alone makes up ~92% of total global warming potential impacts.

In the other four impact categories, namely eutrophication, carcinogenics, non-carcinogenics, and ecotoxicity, impacts from B7 make up the biggest share, followed by B6 impacts. Within B7, municipal sewage treatment makes up >98% of the B7 impacts.

All indicators show that the product use stage is the most dominant stage, primarily stemming from two major activities: electricity use (for water heating and municipal water upstream and downstream systems) and municipal sewage treatment.

Product replacements (B4) and maintenance (B2) also show significant impacts across most impact categories. B2 impacts are driven by the use of SLS solution, and B4 impacts stem from product replacement after every 10 years. Impacts coming from all other life cycle stages are minimal. It should be noted that product manufacturing contributes insignificantly to total impacts.

5.2.2. PROFLO® Single Handle Lavatory Faucet PFWSC3007CP

The LCIA results of PFWSC3007CP faucet per functional unit are shown in **Table 33**. The percent contribution of each of the cradle-to-grave life cycle stages to the total impacts is tabulated in **Table 34** and is also presented in **Figure 7**.

Table 33. Life cycle impact assessment results for the PFWSC3007CP faucet per functional unit

Impact categories	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	kg CFC-11 eq	7.81E-08	5.69E-08	1.99E-08	0	8.01E-08	0	1.14E-06	0	3.32E-04	6.15E-05	0	2.00E-08	0	1.08E-09	**3.96E-04**
Global warming	kg CO_2 eq	3.80E+00	9.31E-01	2.81E-01	0	4.73E+00	0	3.62E+01	0	8.18E+03	1.05E+03	0	9.98E-02	0	4.62E-01	**9.27E+03**
Smog	kg O_3 eq	4.29E-01	1.93E-01	1.66E-02	0	3.13E-01	0	4.27E+00	0	2.65E+02	5.73E+01	0	1.62E-02	0	1.86E-03	**3.28E+02**
Acidification	kg SO_2 eq	4.45E-02	8.64E-03	5.91E-04	0	4.91E-02	0	3.54E-01	0	3.12E+01	6.56E+00	0	5.51E-04	0	1.26E-04	**3.82E+01**
Eutrophication	kg N eq	4.96E-03	4.59E-04	3.35E-04	0	6.68E-02	0	4.59E-02	0	2.54E+00	3.89E+01	0	5.64E-05	0	1.26E-03	**4.16E+01**
Carcinogenics	CTU_h	7.80E-07	6.29E-09	2.07E-10	0	1.35E-07	0	5.13E-06	0	1.50E-05	1.03E-04	0	2.85E-11	0	1.76E-09	**1.25E-04**
Non-carcinogenics	CTU_h	8.88E-06	7.34E-08	6.10E-09	0	6.64E-06	0	5.83E-05	0	2.46E-04	2.11E-03	0	4.76E-09	0	2.97E-09	**2.43E-03**
Respiratory effects	kg $PM_{2.5}$ eq	4.78E-03	4.04E-04	6.66E-05	0	7.50E-03	0	3.46E-02	0	1.85E+00	3.41E-01	0	6.43E-05	0	1.14E-05	**2.24E+00**
Additional impact categories																
Ecotoxicity	CTU_e	3.10E+01	1.28E+00	1.85E-02	0	1.78E+02	0	2.10E+02	0	5.98E+02	4.95E+03	0	1.28E-02	0	8.46E-02	**5.97E+03**
Fossil fuel depletion	MJ surplus	5.12E+00	1.69E+00	1.93E-01	0	2.64E+00	0	4.69E+01	0	1.08E+04	1.21E+03	0	1.92E-01	0	1.63E-02	**1.21E+04**

Table 34. Percent contributions of each life cycle stage to each impact category for PFWSC3007CP per functional unit

Impact categories	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	%	0.05%	0.03%	0.01%	0	0.05%	0	0.69%	0	83.66%	15.50%	0	0.01%	0	0.00%	**100%**
Global warming	%	0.10%	0.02%	0.01%	0	0.12%	0	0.93%	0	87.56%	11.24%	0	0.00%	0	0.01%	**100%**
Smog	%	0.31%	0.14%	0.01%	0	0.22%	0	3.06%	0	79.15%	17.10%	0	0.01%	0	0.00%	**100%**
Acidification	%	0.28%	0.05%	0.00%	0	0.30%	0	2.19%	0	80.27%	16.91%	0	0.00%	0	0.00%	**100%**
Eutrophication	%	0.03%	0.00%	0.00%	0	0.38%	0	0.26%	0	6.08%	93.23%	0	0.00%	0	0.01%	**100%**
Carcinogenics	%	1.41%	0.01%	0.00%	0	0.24%	0	9.25%	0	11.31%	77.78%	0	0.00%	0	0.00%	**100%**
Non-carcinogenics	%	0.84%	0.01%	0.00%	0	0.63%	0	5.53%	0	9.72%	83.26%	0	0.00%	0	0.00%	**100%**
Respiratory effects	%	0.50%	0.04%	0.01%	0	0.78%	0	3.61%	0	80.26%	14.79%	0	0.01%	0	0.00%	**100%**
Additional impact categories																
Ecotoxicity	%	1.13%	0.05%	0.00%	0	6.52%	0	7.70%	0	9.12%	75.47%	0	0.00%	0	0.00%	**100%**
Fossil fuel depletion	%	0.10%	0.03%	0.00%	0	0.05%	0	0.93%	0	88.93%	9.95%	0	0.00%	0	0.00%	**100%**

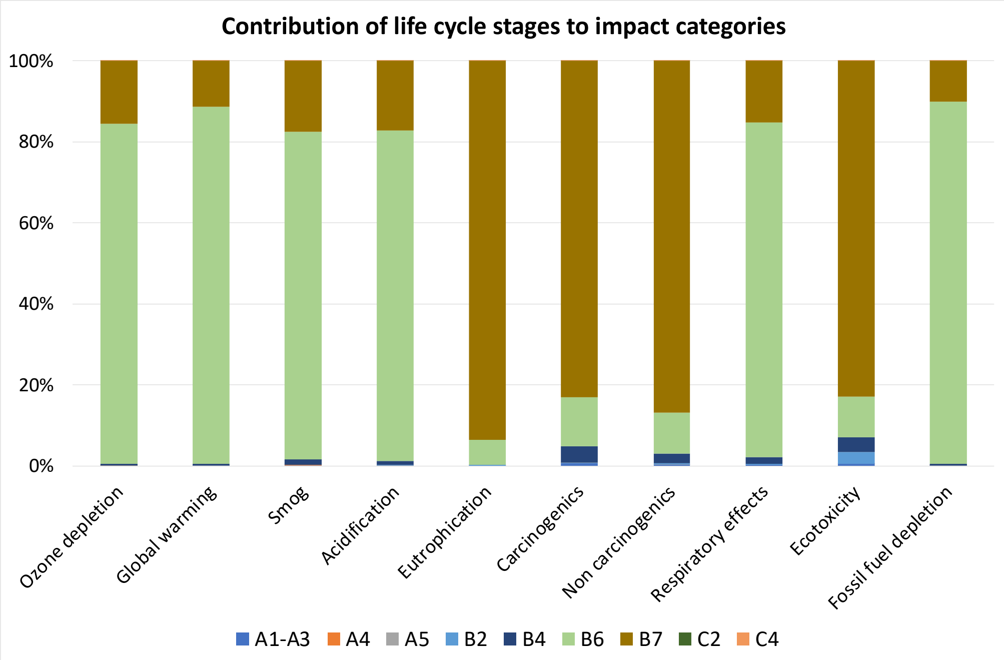

Figure 7. Contribution analysis of each impact category for the PFWSC3007CP faucet per functional unit

The SM2013 Methodology single figure millipoint (mPt) score by life cycle module for this product is presented in **Table 35**. In terms of single figure scores and overall environmental impacts, operational water use (B7) dominates the results (~63%), followed by operational energy use (B6) which accounts for ~34% of the total.

Table 35. Averaged SM millipoint scores for the PFWSC3007CP faucet per functional unit

Parameters	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
SM single figure score	mPts	2.38E+00	7.65E-02	8.50E-03	0	2.37E+00	0	1.62E+01	0	2.79E+02	5.13E+02	0	4.46E-03	0	1.53E-02	**8.13E+02**

In the cradle-to-grave life cycle of the product, operational energy use (B6) dominates the results for six impact categories, followed by operational water use (B7). The six impact categories are ozone depletion, global warming, smog, acidification, respiratory effects, and fossil fuel depletion. During B6, water heating uses a blend of 67% natural gas and 33% electricity. In terms of impacts, electricity accounts for >93% of B6 impacts. For B7, electricity used by municipal systems makes up >40% of the total B7 impacts for the abovementioned six impact categories. The rest comes mostly from the sewage treatment. For these six impact categories, electricity consumption during product use, including B6 and B7, contributes to a minimum of 87% of the impacts. Looking at just the global warming potential, electricity used during B6 and B7 alone makes up ~92% of total global warming potential impacts.

In the other four impact categories, namely eutrophication, carcinogenics, non-carcinogenics, and ecotoxicity, impacts from B7 make up the biggest share, followed by B6 impacts. Within B7, municipal sewage treatment makes up >97% of the B7 impacts.

All indicators show that the product use stage is the most dominant stage, primarily stemming from two major activities: electricity use (for water heating and municipal water upstream and downstream systems) and municipal sewage treatment. Product replacements (B4) and maintenance (B2) also show significant impacts across most impact categories. B2 impacts are driven by the use of SLS solution, and B4 impacts stem from product replacement after every 10 years. Impacts coming from all other life cycle stages are minimal. It should be noted that product manufacturing contributes insignificantly to impacts.

5.2.3. PROFLO® Calhoun 1500 Series Two-piece Toilet 1.28 gpf

The LCIA results of the 1.28 gpf toilet per functional unit are shown in **Table 36**. The percent contribution of each of the cradle-to-grave life cycle module groups to the total impacts is tabulated in **Table 37** and is also presented in **Figure 8**.

Table 36. Life cycle impact assessment results for the 1.28 gpf toilet per functional unit

Impact categories	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	kg CFC-11 eq	1.03E-06	5.52E-07	4.79E-08	0	3.70E-08	3.31E-08	7.27E-06	0	0	4.89E-05	0	9.80E-07	0	2.96E-08	**5.89E-05**
Global warming	kg CO_2 eq	6.32E+01	1.04E+01	6.81E-01	0	2.18E+00	2.35E+00	2.19E+02	0	0	1.03E+03	0	4.88E+00	0	5.91E-01	**1.33E+03**
Smog	kg O_3 eq	3.93E+00	3.38E+00	4.01E-02	0	1.44E-01	1.10E-01	2.25E+01	0	0	4.19E+01	0	7.93E-01	0	5.04E-02	**7.29E+01**
Acidification	kg SO_2 eq	2.57E-01	1.72E-01	1.42E-03	0	2.27E-02	7.93E-03	1.26E+00	0	0	4.89E+00	0	2.69E-02	0	1.78E-03	**6.64E+00**
Eutrophication	kg N eq	2.40E-02	7.13E-03	8.02E-04	0	3.08E-02	7.29E-04	9.72E-02	0	0	1.36E+01	0	2.76E-03	0	6.36E-04	**1.37E+01**
Carcinogenics	CTU_h	2.59E-07	3.35E-08	5.11E-10	0	6.23E-08	1.15E-08	8.12E-07	0	0	3.67E-05	0	1.40E-09	0	7.49E-10	**3.79E-05**
Non-carcinogenics	CTU_h	5.84E-06	5.00E-07	1.47E-08	0	3.07E-06	7.45E-08	1.81E-05	0	0	7.43E-04	0	2.33E-07	0	5.24E-09	**7.70E-04**
Respiratory effects	kg $PM_{2.5}$ eq	4.19E-02	9.53E-03	1.60E-04	0	3.46E-03	1.17E-03	1.51E-01	0	0	2.71E-01	0	3.14E-03	0	2.22E-04	**4.82E-01**
Additional impact categories																
Ecotoxicity	CTU_e	5.94E+01	7.67E+00	4.87E-02	0	8.22E+01	1.18E+00	1.87E+02	0	0	1.75E+03	0	6.28E-01	0	3.69E-01	**2.09E+03**
Fossil fuel depletion	MJ surplus	8.27E+01	1.89E+01	4.65E-01	0	1.22E+00	5.33E+00	3.08E+02	0	0	1.27E+03	0	9.41E+00	0	3.73E-01	**1.70E+03**

Table 37. Percent contributions of each life cycle stage to each impact category for the 1.28 gpf toilet per functional unit

Impact categories	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	%	1.75%	0.94%	0.08%	0	0.06%	0.06%	12.33%	0	0	83.07%	0	1.66%	0	0.05%	**100%**
Global warming	%	4.74%	0.78%	0.05%	0	0.16%	0.18%	16.44%	0	0	77.24%	0	0.37%	0	0.04%	**100%**
Smog	%	5.39%	4.64%	0.06%	0	0.20%	0.15%	30.94%	0	0	57.47%	0	1.09%	0	0.07%	**100%**
Acidification	%	3.87%	2.59%	0.02%	0	0.34%	0.12%	19.01%	0	0	73.61%	0	0.41%	0	0.03%	**100%**
Eutrophication	%	0.18%	0.05%	0.01%	0	0.22%	0.01%	0.71%	0	0	98.80%	0	0.02%	0	0.00%	**100%**
Carcinogenics	%	0.68%	0.09%	0.00%	0	0.16s%	0.03%	2.14%	0	0	96.89%	0	0.00%	0	0.00%	**100%**
Non-carcinogenics	%	0.76%	0.06%	0.00%	0	0.40%	0.01%	2.35%	0	0	96.38%	0	0.03%	0	0.00%	**100%**
Respiratory effects	%	8.69%	1.98%	0.03%	0	0.72%	0.24%	31.36%	0	0	56.28%	0	0.65%	0	0.05%	**100%**
Additional impact categories																
Ecotoxicity	%	2.85%	0.37%	0.00%	0	3.94%	0.06%	8.98%	0	0	83.75%	0	0.03%	0	0.02%	**100%**
Fossil fuel depletion	%	4.87%	1.11%	0.03%	0	0.07%	0.31%	18.12%	0	0	74.91%	0	0.55%	0	0.02%	**100%**

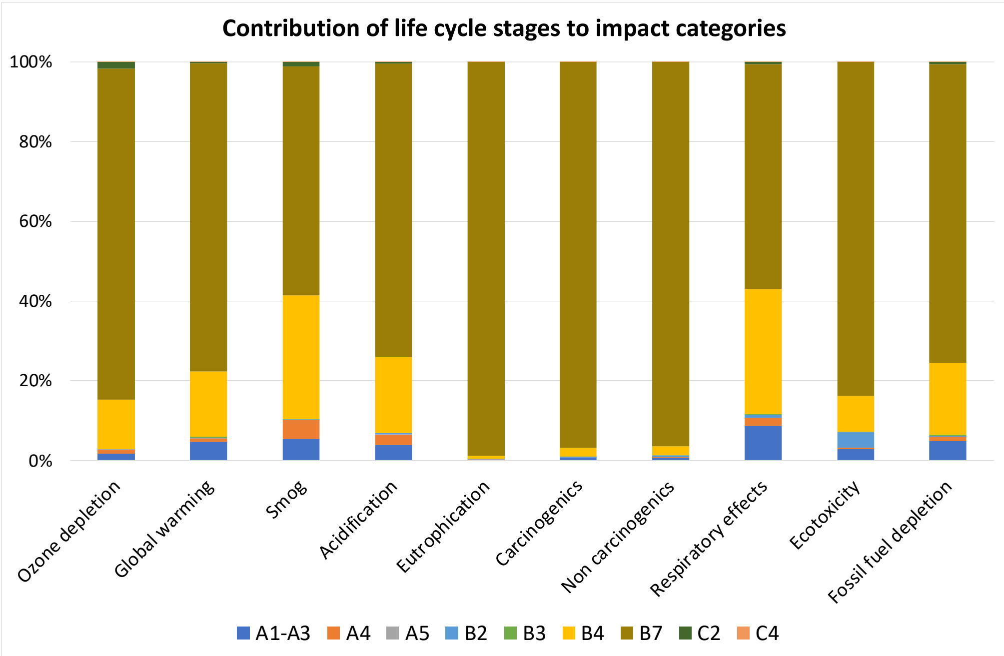

Figure 8. Contribution analysis of each impact category for the 1.28 gpf toilet per functional unit

The SM2013 Methodology single figure millipoint (mPts) score by life cycle module for this product is presented in **Table 38**. In terms of single figure scores and overall environmental impacts, operational water use (B7) dominates the results (~92%), followed by the product replacement (B4) which accounts for ~5% of the total.

Table 38. Averaged SM millipoint scores for the 1.28 gpf toilet per functional unit

Parameters	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
SM single figure score	mPts	3.27E+00	6.84E-01	2.06E-02	0	1.09E+00	1.21E-01	1.16E+01	0	0	1.99E+02	0	2.18E-01	0	2.12E-02	**2.16E+02**

In the cradle-to-grave life cycle of the product, operational water use (B7) dominates the results for all impact categories, followed by product replacement (B4) and production (A1-A3). For B7, electricity consumed in municipal water systems (for upstream water supply and downstream sewage) makes up >72% of the total B7 impacts for the six impact categories: ozone depletion, global warming, smog, acidification, respiratory effects, and fossil fuel depletion. For the remaining four impact categories, municipal sewage treatment contributes to the bulk of B7 impacts (>94%). The entire toilet combination, including bowl, tank, and seat, needs to be replaced after every 20 years. This requires the disposal of old toilets and the manufacturing, supply, and installation of new toilets. This process cumulated over the ESL of 75 years leads to significant environmental impacts. Electricity consumed during ceramic manufacturing (tank and bowl) makes up the bulk of A3 impacts. Ceramic wastewater contributes significantly to three impact categories in the A3 stage: carcinogenics, non-carcinogenics, and ecotoxicity.

All indicators show that the product use stage is the most dominant stage, primarily stemming from two major activities: electricity use (consumed during municipal water supply and downstream sewage systems) and municipal sewage treatment. Product replacement (B4) and production (A1-A3) also show significant impacts across most impact categories. A3 impacts are driven by the consumption of electricity and natural gas during ceramic product manufacturing, including casting, drying, glazing, and firing. Product distribution (A4), maintenance (B2), and repair

(B3) also contribute considerable impacts. A4 impacts are driven by the product shipping from distribution centers to installation sites, B2 impacts are driven by the use of SLS solution, and B3 impacts stem from the replacement of the flush handle, flapper seal, and fill valve seal after every 10 years. Impacts coming from all other life cycle stages are minimal.

5.2.4. PROFLO® Calhoun 1500 Series Two-piece Toilet 1.6 gpf

The LCIA results of the 1.6 gpf toilet per functional unit are shown in **Table 39**. The percent contribution of each of the cradle-to-grave life cycle stages to the total impacts is tabulated in **Table 40** and is also presented in **Figure 9**.

Table 39. Life cycle impact assessment results for the 1.6 gpf toilet per functional unit

Impact categories	Unit	Production	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	kg CFC-11 eq	1.06E-06	8.68E-07	4.80E-08	0	3.70E-08	3.65E-08	8.31E-06	0	0	6.12E-05	0	1.02E-06	0	3.07E-08	**7.26E-05**
Global warming	kg CO_2 eq	6.51E+01	1.23E+01	6.82E-01	0	2.18E+00	2.52E+00	2.30E+02	0	0	1.29E+03	0	5.07E+00	0	6.03E-01	**1.61E+03**
Smog	kg O_3 eq	4.06E+00	3.63E+00	4.01E-02	0	1.44E-01	1.18E-01	2.37E+01	0	0	5.23E+01	0	8.24E-01	0	5.23E-02	**8.48E+01**
Acidification	kg SO_2 eq	2.65E-01	1.83E-01	1.42E-03	0	2.27E-02	8.56E-03	1.32E+00	0	0	6.11E+00	0	2.80E-02	0	1.85E-03	**7.94E+00**
Eutrophication	kg N eq	2.45E-02	8.01E-03	8.03E-04	0	3.08E-02	7.87E-04	1.01E-01	0	0	1.69E+01	0	2.87E-03	0	6.55E-04	**1.71E+01**
Carcinogenics	CTU_h	2.64E-07	3.54E-08	5.11E-10	0	6.23E-08	1.23E-08	8.30E-07	0	0	4.59E-05	0	1.45E-09	0	7.72E-10	**4.71E-05**
Non-carcinogenics	CTU_h	5.98E-06	5.73E-07	1.48E-08	0	3.07E-06	8.15E-08	1.87E-05	0	0	9.28E-04	0	2.42E-07	0	5.38E-09	**9.57E-04**
Respiratory effects	kg $PM_{2.5}$ eq	4.32E-02	1.02E-02	1.60E-04	0	3.46E-03	1.27E-03	1.57E-01	0	0	3.39E-01	0	3.27E-03	0	2.30E-04	**5.58E-01**
Additional impact categories																
Ecotoxicity	CTU_e	6.12E+01	8.55E+00	4.87E-02	0	8.22E+01	1.27E+00	1.95E+02	0	0	2.18E+03	0	6.52E-01	0	3.71E-01	**2.53E+03**
Fossil fuel depletion	MJ surplus	8.46E+01	2.24E+01	4.66E-01	0	1.22E+00	5.74E+00	3.24E+02	0	0	1.59E+03	0	9.78E+00	0	3.88E-01	**2.04E+03**

Table 40. Percent contributions of each life cycle stage to each impact category for the 1.6 gpf toilet per functional unit

Impact categories	Unit	Production	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Ozone depletion	%	1.46%	1.20%	0.07%	0	0.05%	0.05%	11.45%	0	0	84.29%	0	1.40%	0	0.04%	**100%**
Global warming	%	4.05%	0.77%	0.04%	0	0.14%	0.16%	14.33%	0	0	80.16%	0	0.32%	0	0.04%	**100%**
Smog	%	4.78%	4.28%	0.05%	0	0.17%	0.14%	27.87%	0	0	61.68%	0	0.97%	0	0.06%	**100%**
Acidification	%	3.34%	2.30%	0.02%	0	0.29%	0.11%	16.60%	0	0	76.97%	0	0.35%	0	0.02%	**100%**
Eutrophication	%	0.14%	0.05%	0.00%	0	0.18%	0.00%	0.59%	0	0	99.01%	0	0.02%	0	0.00%	**100%**
Carcinogenics	%	0.56%	0.08%	0.00%	0	0.13%	0.03%	1.76%	0	0	97.44%	0	0.00%	0	0.00%	**100%**
Non-carcinogenics	%	0.62%	0.06%	0.00%	0	0.32%	0.01%	1.96%	0	0	97.00%	0	0.03%	0	0.00%	**100%**
Respiratory effects	%	7.75%	1.83%	0.03%	0	0.62%	0.23%	28.13%	0	0	60.79%	0	0.59%	0	0.04%	**100%**
Additional impact categories																
Ecotoxicity	%	2.42%	0.34%	0.00%	0	3.25%	0.05%	7.69%	0	0	86.22%	0	0.03%	0	0.01%	**100%**
Fossil fuel depletion	%	4.15%	1.10%	0.02%	0	0.06%	0.28%	15.88%	0	0	78.01%	0	0.48%	0	0.02%	**100%**

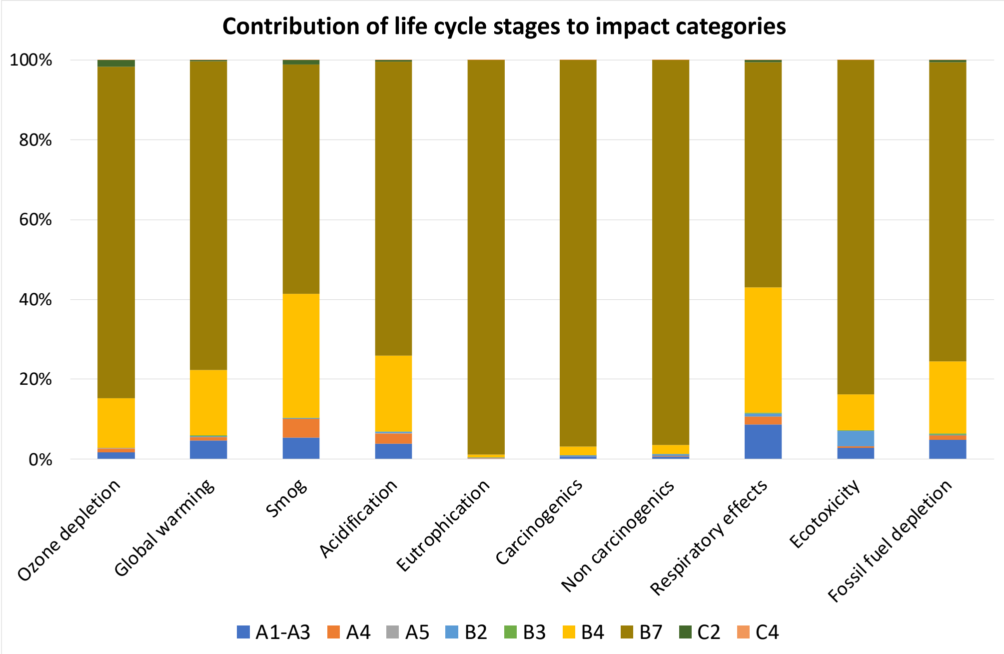

Figure 9. Contribution analysis of each impact category for the 1.6 gpf toilet per functional unit

The SM2013 Methodology single figure millipoint (mPts) score by life cycle module for this product is presented in **Table 41**. In terms of single figure scores and overall environmental impacts, operational water use (B7) dominates the results (~93%), followed by the product replacements (B4) which account for ~5% of the total.

Table 41. Averaged SM millipoint scores for the 1.6 gpf toilet per functional unit

Parameters	Unit	Produc-tion	Construction/ Installation		Use							End of life				Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
SM single figure score	mPts	3.36E+00	7.69E-01	2.06E-02	0	1.09E+00	1.30E-01	1.21E+01	0	0	2.49E+02	0	2.27E-01	0	2.18E-02	**2.66E+02**

In the cradle-to-grave life cycle of the product, operational water use (B7) dominates the results for all impact categories, followed by product replacement (B4) and production (A1-A3). For B7, electricity consumed in municipal water systems (for upstream water supply and downstream sewage) makes up >72% of the total B7 impacts for the six impact categories: ozone depletion, global warming, smog, acidification, respiratory effects, and fossil fuel depletion. For the remaining four impact categories, municipal sewage treatment contributes to the bulk of B7 impacts (>94%). The entire toilet combination, including bowl, tank, and seat, needs to be replaced after every 20 years. This requires the disposal of old toilets and the manufacturing, supply, and installation of new toilets. This process cumulated over the ESL of 75 years leads to significant environmental impacts. Electricity consumed during ceramic manufacturing (tank and bowl) makes up the bulk of A3 impacts. Ceramic wastewater contributes significantly to three impact categories in the A3 stage: carcinogenics, non-carcinogenics, and ecotoxicity.

All indicators show that product use stage is the most dominant stage, primarily stemming from two major activities: electricity use (consumed during municipal water supply and downstream sewage systems) and municipal sewage treatment. Product replacement (B4) and production (A1-A3) also show significant impacts across most impact categories. A3 impacts are driven by the consumption of electricity and natural gas during ceramic product manufacturing, including casting, drying, glazing, and firing. Product distribution (A4), maintenance (B2), and repair

(B3) also contribute considerable impacts. A4 impacts are driven by the product shipping from distribution centers to installation sites, B2 impacts are driven by the use of SLS solution, and B3 impacts stem from the replacement of the flush handle, flapper seal, and fill valve seal after every 10 years. Impacts coming from all other life cycle stages are minimal.

5.3. Sensitivity analysis

The consumption of electricity for water heating during operational energy use (B6) and electricity use for the municipal water supply and sewage system during operational water use (B7) make up the bulk of impacts across all impact categories for both types of faucets. Similarly, for toilets, electricity consumed for the municipal water supply and sewage system during operational water use (B7) contributes significantly to environmental impacts. Impacts due to this electricity consumption are expected to vary depending on the location and its available electricity grid mix.

Sensitivity analyses were performed to check the impact of changing electricity grid mixes. After analyzing potential CO_2-equivalent emissions per unit of electricity for each of the 27 available eGRID subregions, subregions with the highest and lowest impacts have been used. MROE, *Midwest Reliability Organization – East*, is the regional mix with the highest CO_2 emissions per unit electricity. NYUP, *Northeast Power Coordinating Council – Upstate NY*, is the regional mix with the lowest. For both faucet types and toilet types, results have been generated for use in both MORE and NYUP eGRID subregions and have been compared with the average results. Only the change in potential CO_2-equivalent emissions was evaluated; however, similar changes were expected to be observed in other impact categories.

The results for both faucet types are tabulated in **Table 42**. Both B6 and B7 CO_2-equivalent emissions increase in MROE, while the emissions decrease in NYUP. The total life cycle CO_2-equivalent emissions in MROE are ~56% higher than the baseline, while they are ~59% lower in NYUP for both faucet types.

Table 42. Sensitivity analysis of electricity grid mix region choice on faucet GWP emissions per functional unit

eGRID subregion	B6 (Operational energy use)		B7 (Operational water use)		Total life cycle	
	kg CO_2-eq emissions	% change	kg CO_2-eq emissions	% change	kg CO_2-eq emissions	% change
PFWSC30075CP						
Baseline	3.41E+03	N/A	4.37E+02	N/A	3.89E+03	N/A
NYUP	1.29E+03	-62.06%	2.49E+02	-43.15%	1.59E+03	-59.19%
MROE	5.40E+03	58.50%	6.15E+02	40.68%	6.06E+03	55.80%
PFWSC3007CP						
Baseline	8.18E+03		1.05E+03		9.27E+03	
NYUP	3.10E+03	-62.06%	5.97E+02	-43.15%	3.75E+03	-59.59%
MROE	1.30E+04	58.50%	1.48E+03	40.68%	1.45E+04	56.18%

The results for both toilet types are tabulated in **Table 43**. The MROE subregion saw an increase in B6 and thus increased total CO_2-equivalent emissions (by ~42%), while the NYUP subregion resulted in decreased total CO_2-equivalent emissions by ~44% for the 1.28 gpf toilet. Similar changes were observed for the 1.6 gpf toilet.

Table 43. Sensitivity analysis of electricity grid mix region choice on toilet GWP emissions per functional unit

eGRID subregion	B7 (Operational water use)		Total life cycle	
	kg CO_2-eq emissions	% change	kg CO_2-eq emissions	% change
1.28 gpf toilet				
Baseline	1.03E+03	N/A	1.33E+03	N/A
NYUP	4.42E+02	-57.07%	7.46E+02	-44.08%
MROE	1.58E+03	53.79%	1.89E+03	41.55%
1.6 gpf toilet				
Baseline	1.29E+03	N/A	1.61E+03	N/A
NYUP	5.53E+02	-57.07%	8.72E+02	-45.75%
MROE	1.98E+03	53.79%	2.30E+03	43.12%

The results of the sensitivity analyses show that the region of product use plays a significant role in the total life cycle impacts for both faucets and toilets, and the results are sensitive to the location of product use.

5.4. Overview of relevant findings

This study assessed a multitude of inventory and environmental indicators. The primary finding for the Ferguson faucet and toilet products, across all environmental indicators, was that the product use phase is responsible for most of the impacts across all impact categories.

For faucets, environmental impacts are driven by the operational energy use (B6) and operational water use (B7) modules. All other life cycle modules have insignificant impacts, including the production (A1-A3) stage. For toilets, operational water use (B7) drives the majority of environmental impacts, followed by the product replacement (B4) module. The production (A1-A3) stage also shows considerable impacts, in contrast to faucets.

5.5. Conclusion and recommendations

The goal of this study was to conduct cradle-to-grave LCAs on Ferguson's single handle lavatory faucets and residential two-piece toilets so as to develop Transparency Reports [EPDs]™. The creation of these TRs will allow consumers in the building and construction industry to make better informed decisions about the environmental impacts associated with the products they choose.

Overall, the study found that environmental performance is driven primarily by the use phase of both the products. Two faucet SKUs were evaluated in this study: PFWSC3007CP with a flow rate of 1.2gpm and PFWSC30075CP with a flow rate of 0.5gpm. Energy consumed for water heating and in the municipal water systems for upstream water collection and supply, and downstream treatment, shares the bulk of the potential environmental impacts. This electricity consumption during the use phase contributes to ~99% of potential CO_2-equivalent emissions across the life cycle of each faucet type evaluated. As the faucet's water flow rate increased, the impacts also increased. The potential CO_2-equivalent emissions for the 1.2gpm faucet are about 2.4 times higher than those for the 0.5gpm faucet. Raw materials extraction, upstream transport, and manufacturing of the product represent an insignificant share when compared to the impacts generated during the use phase.

The results show that the greatest opportunity for reducing faucets' potential environmental impact is in the use phase. This is an important area for Ferguson to focus its efforts on and one which it can influence. Particularly, Ferguson should explore opportunities to reduce water consumption during product use. Some of the measures that can be adopted by Ferguson are promoting use of lower flow faucets, incorporating motion sensors, or building in metered delivery. Building owners can contribute to lowering emissions during the use phase by purchasing water-efficient faucets, turning off faucets when not in use, and regularly monitoring for leaks.

A total of three toilet bowl and six toilet tank SKUs were evaluated in this study. The bowls and tanks can be combined to form either 1.28gpf and 1.6gpf residential toilets. Results show that the use phase of the toilets drives the environmental impacts. Energy consumed in municipal water systems for upstream water collection and supply, and downstream treatment, contributes to about 75% of the impacts for the 1.28gpf toilet and about 78% of impacts for the 1.6gpf toilet. As the toilet's water flow rate increased, the impacts also increased. The production stage also shows considerable impacts, driven by the consumption of electricity and natural gas during ceramics manufacturing, including casting, drying, glazing, and firing. Replacing the toilet at the end of its reference service life also contributes significantly to impacts. These three life cycle modules—product use, production, and replacement—provide opportunities for reducing potential environmental impacts for Ferguson's toilets.

It is recommended that Ferguson look into strategies and technologies to engineer toilets that use less water per flush. Redesigning the toilet bowls to improve water efficiency can potentially lower impacts. The use of adjustable or pre-calibrated flapper valves to control the amount of water released per flush can ensure optimal water use. End users can also help reduce impacts by regularly monitoring for leaks. On the ceramics manufacturing side, the manufacturing facility should consider using renewable energy options, which can reduce the environmental impacts in the production stage significantly. Renewable sources can be solar, wind, hydropower, or purchasing renewable electricity certificates (RECs). Implementing energy management system monitors to control energy use throughout the facility helps in identifying inefficiencies and optimizing energy consumption.

Additionally, an update to this LCA and the associated Transparency Reports [EPDs]™ would enable high-quality year-to-year comparisons and serve as the basis for potential optimized EPDs. A post-project review could provide opportunities for improving the data collection process in future years and for continuing to align with Ferguson's goals for sustainability.

6. References

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

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ACRONYMS

ACLCA	American Center for Life Cycle Assessment
BOM	Bill of materials
ESL	Estimated service life
ISO	International Standardization Organization
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact analysis
PCR	Product Category Rule document
REC	Renewable energy certificates
RSL	Reference service life
TR	Transparency Report [EPD]™

GLOSSARY

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

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
Close loop & open loop	A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials. An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties.
Cradle to grave	Addresses the environmental aspects and potential environmental impacts (e.g., use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of life
Cradle to gate	Addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of the production process ("gate of the factory"). It may also include transportation until use phase
Declared unit	Quantity of a product for use as a reference unit in an EPD based on one or more information modules
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 inventory - LCI	phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle
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

APPENDIX

- [redacted]