Circular Living Standards

Circular Living Standards: LCA Screening report



Version 1.0

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WRAP

Introduction

Purpose

The goal of the circular economy is to facilitate the transition from a take-make-waste linear economy/pattern of product use to a circular economy/system for maximum utilization of products, materials, and resources. The circular economy can take various forms, including sharing, reusing, repairing, refurbishing, and/or recycling existing materials and products. Refillable product systems are one of the circularity pathways gaining wide traction as they can reduce container and packaging waste, and reduce the need for new materials to make new containers and packaging. It is important to understand the potential environmental benefits generated from using refillable product systems as opposed to single-use containers.

This life cycle assessment (LCA) report outlines the methodology used to estimate the environmental impacts associated with single-use containers and refillable product systems in an effort to establish the *Circular Living Standards (CLS): Refillable Certified Standard*. This report details the process by which environmental impacts were assessed for single-use products, as well as the keeper containers and auxiliary unit containers that make up a refillable product system, as defined and detailed in the report below. The report includes sample calculations for 60 bills of materials toward this end in an effort to understand the impact of product type, form factor, container type, primary materials, and material quantities on environmental performance. Sensitivity analysis explores the impact of different end-of-life pathways on each relevant impact category. Further calculations were conducted to explore new variables that could serve as proxies for environmental impact, but were not used to determine eligibility in the standard. Ultimately, this report and associated work on the *CLS: Refillable Certified Standard* produced the refillable eligibility scanning tool (REST), which can be used by the certifying body for the standard to determine eligibility by directly calculating the minimum uses for impact (MUFI). The MUFI is a metric designating the minimum number of product refills necessary for a product to achieve an environmental impact reduction consistent with the standard. Although this report details a number of variables that were considered throughout the core LCA analysis, the MUFI is ultimately the key LCA result output by the REST that will be used, along with other requirements in the standard, to determine eligibility.

The following product types were utilized as the practical foundation of this study: 1) Personal hygiene soaps and moisturizers (referred to as ‘Facial moisturizer, facial cleanser, liquid soap’ in this document), 2) personal hygiene deodorant (‘deodorant’), 3) skin complexion compacts (‘skin complexion compact’), and 4) household cleaning agents (‘cleaning agent’), but this methodology could be adapted to other refillable product types.

The LCA and LCA report were developed by NSF in collaboration with Amazon, which commissioned the LCA and report, and WRAP.

Why Refillable Product Systems Contribute to a Circular Economy

When a consumer decides to use a refillable product system instead of a conventional single-use disposable container, they are committing to reuse the dispensing container (referred to herein as the

"keeper container"). Because the container's useful life is extended rather than ending in disposal, less waste is created, and fewer new materials are needed to make an additional container. In a linear/conventional container flow, the life cycle starts from the extraction of constituent raw materials, which are transported to the manufacturing facilities, where the raw materials are processed into the final container for consumer use. These containers are distributed to the end users, and once the service period is over, the containers are disposed of, landfilled, recycled, and/or incinerated. Single-use containers are designed to go through only one use cycle, but refillable product systems are designed to go through multiple use cycles. Each use cycle for a refillable product system extends the life of a container and avoids the extraction, production, and end-of-life disposal of a new container; over multiple cycles, these avoided impacts can provide significant environmental benefits.

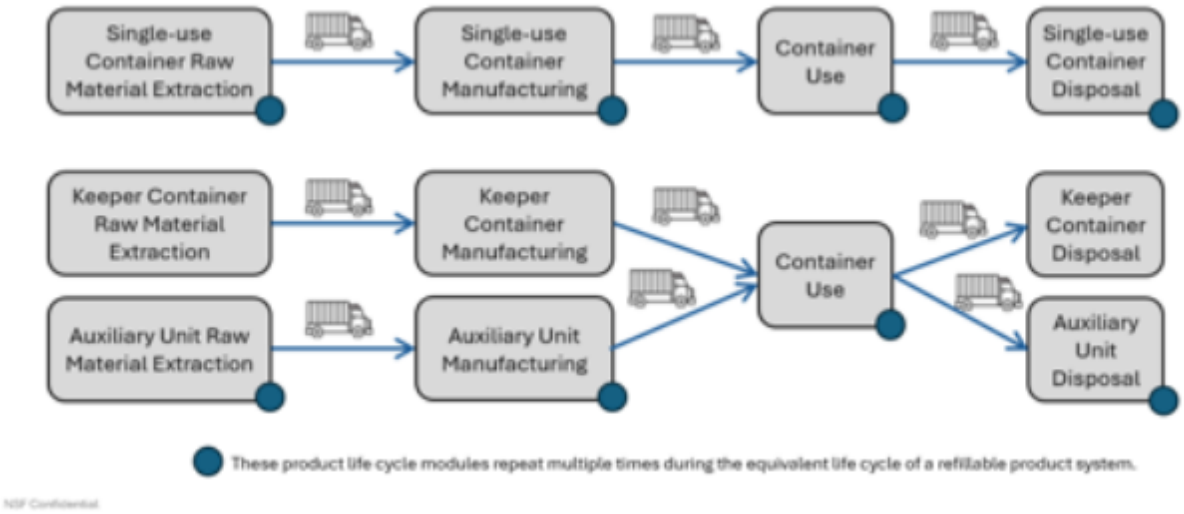

Figure 1. Single-use container flow vs. refillable system container flow. Auxiliary unit containers are assumed to generate impact once per auxiliary unit count.

This study only considered refillable product systems for which the dispensed product in the refillable system was the same form as in the single-use system. This excludes refill products that take a different form than the single-use product, such as dehydrated or compact versions of the single-use product. Such products have differences in manufacturing impacts, and it was not in the scope of this analysis to determine and inventory those differences. Therefore, this study only considers the containers themselves and excludes analysis of the dispensed product, which is assumed to be essentially equal in impact.

To effectively distinguish containers within the refillable product systems analyzed, the rest of this report uses the term "keeper container" to indicate the container that is repeatedly refilled and is designed to go through multiple use cycles while maintaining the quality of the intended service. The term "auxiliary unit" or "auxiliary unit container" is a single-use container that is used to supply the product used to refill the keeper container.

Role of Life Cycle Assessments (LCAs)

To assess the benefits of circular economy pathways, they need to be measured against their linear economy counterparts. In the case of refillable product systems, environmental impacts should be evaluated against an applicable single-use counterpart. LCA is a widely used approach to analyze the potential environmental impacts of a product or service during its entire life cycle. LCAs can calculate the impacts of a product across dozens of environmental impact categories. Because of this ability, LCA has been used as the scientific backbone to analyze the potential environmental benefits of refillable product systems and inform the protocol for the *CLS: Refillable Certified Standard*. For this study, a macro-analysis – an LCA screen – was preferred and utilized to have a broader understanding of the environmental impacts of the refillable verification pathway. A screening LCA helps identify and understand the main drivers of environmental impacts within the value chain, as well as the aspects that require deeper examination.

Methodology Summary

The LCA methodology was developed with reference to the principles and framework of ISO 14044, but it does not meet all requirements for full ISO compliance. The LCA has undergone significant review by the partner organizations developing the standard (NSF, WRAP, and Amazon), and a third-party review by the global sustainability consulting firm Anthesis, to ensure that it provides a robust underpinning for the *CLS: Refillable Certified Standard*. This third-party review was a technical review and not a critical review as defined in ISO 14044. Listed below are the major steps taken for the estimation of potential environmental benefits generated from the refillable pathway:

- *LCA Literature Review/Information Collection:* Information about the inputs and outputs of the container systems (materials, energy, waste, emissions, etc.) is needed to estimate the corresponding environmental impacts of flows to and from the environment. A screening LCA typically relies on secondary data sources – such as industry averages, literature values, and established life cycle inventory databases – to provide insights. Where available, this assessment also incorporated select primary data to improve the relevance and accuracy of key assumptions. Because it relies on many secondary and researched data sources, this screening LCA has inherent uncertainty. External LCA studies were identified, though none were directly applicable to the product types and boundary used in this study. We were able to obtain material and mass data for specific containers, either from stakeholder manufacturers or by examining specific containers in a teardown laboratory. In a few cases, minor assumptions or proxies were used to fill gaps in information for the manufacturer's packaging or dispensing mechanism. In one case of a typical container made from recycled content, we adapted the bill of materials to reflect primary content as an alternative scenario.
- *Linear Life Cycle Inventory (LCI) Modeling:* Life cycle inventory was modeled in SimaPro to generate results for a linear economy model in the case of single-use containers. Single-use container baselines are based on a single BOM for each product type. The baseline was chosen as a product that was deemed to be sufficiently representative of the product type and, if possible,

perceived to be conservative (i.e., relatively lower impact and/or efficient design). Choosing a conservative (low-impact) container means that refillable product systems are evaluated more stringently and must demonstrate impact reductions relative to single-use containers that are already materially efficient and relatively low-impact.

- *Circular LCI Modeling:* Life cycle inventory was modeled in SimaPro to generate results for a circular economy model in the case of refillable product systems. Models were developed for both the keeper containers and the auxiliary unit containers.
- *Impact Calculation:* Excel-based analysis was developed with a generic formula for all product types to estimate the environmental impacts and the number of auxiliary unit counts (defined as the number of auxiliary unit containers consumed) required to break even on each environmental impact. The environmental impacts evaluated in this LCA report and used to determine eligibility are climate change, end-of-life waste, water use, and resource use (minerals and metals). The prioritization of environmental impacts is discussed further in the body of this report. The number of auxiliary unit counts required to break even is calculated for each container system compared to the single-use baseline for that product type. Additionally, the number of auxiliary unit counts required to break even with an additional 15-30% impact reduction is calculated, termed the minimum uses for impact (MUFI). The MUFI is a critical parameter that influences whether and how much environmental benefit might be realized from using the refillable system.
- *Refillable Eligibility Scanning Tool (REST):* An Excel-based tool was developed to directly calculate the eligibility of refillable product systems by the certifying body (CB) during product certification. This tool performs life cycle assessments of refillable keeper containers, auxiliary units, and their respective manufacturer's packaging to calculate a MUFI value for a given product system (a specific pairing of a keeper container and an auxiliary unit). This tool also performs quality control to ensure that the certifying body auditor has input data and checked it against specific aspects of the standard.
- *Sensitivity Analysis:* End-of-life waste pathways vary across countries and regions within countries. Notably, the EU incinerates and recycles a higher proportion of waste compared to the US, which has a higher proportion of landfill waste. For each container, we calculated impact results using waste statistics from the US and EU, and calculated the difference in results for each impact category. The results are shown in the sensitivity section of the report.

The methodology used in this screening is not intended to conform to the GHG Protocol. An analysis of container circularity requires a broader set of measures than greenhouse gas emissions. Understanding unsustainable resource utilization and waste generation is a key part of evaluating circularity. An LCA screening that uses a broad set of data inputs, scenarios, and assumptions is a more appropriate method than the GHG Protocol, which focuses on analyses of GHG footprints of specific products or organizations.

Definitions

The following are the main terms used in this study and their definitions:

- **Auxiliary unit**: The single-use component or container that supplies the refilled content to the keeper container.

- **Auxiliary unit count**: The number of auxiliary unit containers consumed in a refillable product system.
- **Avoided Impacts**: Environmental impacts avoided by refilling keeper containers for a certain number of auxiliary unit counts instead of using and disposing single-use containers for each cycle. This represents the environmental benefits generated from the refillable pathway and is dependent on the auxiliary unit counts. If a breakeven point can be achieved, a higher number of auxiliary unit counts results in more impact avoided.
- **Breakeven Point**: The minimum number of auxiliary units (rounded up to the nearest integer) required for a refillable product system to have an equivalent environmental impact to its single-use counterpart. This is calculated through life cycle assessment.
- **Calculated MUFI:** The calculated MUFI for a given product system is the MUFI computed by the Refillable Eligibility Scanning Tool (REST) based on the product system's bill of materials and product type.
- **Capacity ratio:** The ratio of the container mass, measured in grams, to container content, measured in liters, sometimes referred to as 'mass-to-capacity ratio'
- **Container:** A physical component designed to directly contain, hold, or dispense the contents, and that comes into direct contact with the contents during normal use. The word container refers to single-use containers, keeper containers, and auxiliary unit containers only, and excludes all manufacturer's packaging.
- **Container Impacts**: Impacts from the entire life cycle of a container, relevant to both single-use and refillable product systems. This is inclusive of container manufacturing impacts, container transport impacts, and end-of-life impacts defined below.
- **Container Manufacturing Impacts**: Impacts generated during the manufacturing of containers, either single-use, refillable, or auxiliary unit containers. This includes the extraction of raw materials, material processing, container manufacturing, manufacturer's packaging, and all associated transports.
- **Container Transport Impacts**: Impacts generated as the container is shipped from the manufacturer's gate to consumers.
- **Efficiency Ratio:** The ratio of the product amount, expressed in the label's unit of measure, to the mass of either the container or the combined mass of the container and the manufacturer's packaging
- **End-of-life (EOL) impacts**: Impacts from the disposal of the container after the consumer discards the container, including both the end-of-life transport and disposal.
- **Environmental impact:** An effect on the environment produced by emissions to air, water, or land or through use of resources. In this standard, environmental impact is quantified based on greenhouse gas emissions, waste produced, water use, and depletion of mineral and metal resources.
- **Form Factor:** The physical design and structure of a package, including its shape, size, and functionality, that determines how it is used, refilled, and stored. In the context of the Refillable standard, form factor must support repeated use, facilitate easy and hygienic refilling, and be compatible with the brand's refill system or infrastructure.

- **Keeper container**: The primary container, or base unit, of a refillable product system, designed to be refilled multiple times while maintaining the quality of intended service
- **Life cycle assessment:** A standardized method to evaluate the environmental impacts of a product or system across its lifecycle, from raw material extraction to end-of-life disposal
- **Manufacturer's packaging:** Any branded or non-branded packaging component supplied by the manufacturer that encloses, protects, or presents the container and/or contents for sale to the end user, but which does not come into direct contact with the contents during normal use. Manufacturer's packaging may include boxes, sleeves, blister packs, shrink wrap, inserts, or similar materials delivered to the consumer with the product. Manufacturer's packaging explicitly excludes shipping boxes, mailers, pallets, strapping, or other logistics packaging used for distribution or fulfillment. For the purposes of this report, manufacturer's packaging does not include keeper containers, auxiliary unit containers, or single-use containers.
- **Minimum uses for impact (MUFI):** The minimum number of auxiliary unit counts required for a refillable product system to avoid 15-30% of the environmental impact associated with delivering the same function via a single-use equivalent. This reduction is required for both greenhouse gas emissions and total end of life (EOL) waste, and at least one of either water use or non-renewable resource depletion. The avoided environmental impact (15-30%) is determined by product type and detailed in the LCA report.
- **MUFI Threshold:** The value against which a system-specific MUFI computed by the REST (referred to as the "calculated MUFI") is compared for purposes of certification eligibility. MUFI Thresholds are calculated in the REST for each refillable product system based on the quantity of product dispensed at the MUFI threshold (Q_{MUFI}), the keeper container capacity, and the auxiliary unit capacity. The Q_{MUFI} is established by the scheme owner based on validated consumer use data and may be pre-validated by the scheme owner or require manufacturer validation, as specified in the standard.
- **Packaging:** Item used for the containment, protection, handling, delivery, storage, transport, and presentation of goods, from raw materials to processed goods, from the producer to the user or consumer. This includes an item that is necessary to contain, support or preserve a product throughout its lifetime, without being an integral part of the product, and which is intended to be used, consumed or disposed of together with the product, or any component or ancillary element to such an item, such as a pump, lid, or label.
- **Product**: A finished good, including all components necessary for its intended function, that is designed, manufactured, and placed on the market for use by an end user.
- **Refillable Eligibility Scanning Tool (REST):** The life cycle assessment tool maintained by the scheme owner and used by certification bodies to assess the environmental performance of the containers of a refillable product system. The REST takes the bill of materials of a keeper container and auxiliary unit as inputs and computes a system-specific calculated MUFI. The calculated MUFI is then compared against the MUFI Threshold per the standard to determine eligibility. Certification bodies access the REST under license from the scheme owner.
- **Refillable product system:** A product design framework where the keeper container and auxiliary units function together to allow the product to be replenished and reused multiple times.

- **Single-use container**: Container which is designed to go through a single use cycle and is disposed after the service period is over.
- **Total EOL Waste:** The total quantity of waste, measured in units of mass, that is disposed of by the consumer at the end of a product's service life.
- **Q_{MUFI}** (Quantity of Product Dispensed at the MUFI Threshold): The quantity of consumable product that is used by the consumer at the MUFI threshold. This number is established by product type, subtype, and form factor based on consumer survey data. The consumer data used to establish Q_{MUFI} is detailed in Appendix F of this document.

LCA Screening Methodology

For a single use, environmental impacts from the upstream production of a keeper container are typically higher than those of a disposable single-use container due to more durable construction. However, the impacts of a keeper container can be amortized over multiple refill cycles, defined in this study as auxiliary unit counts (the number of auxiliary unit containers consumed), as opposed to a single-use container, which undergoes only one use. While each refill of a keeper container avoids the manufacturing, transport, and disposal of corresponding single-use containers, additional environmental impacts occur during the life cycle of refillable product systems, since each auxiliary unit container also has impacts.

For this study, a macro-analysis – a screening LCA, informed by ISO 14040 and 14044 standards – was used to gain a broader understanding of the potential environmental benefits of refillable product systems to inform the refillable standard. A screening LCA combines product-specific bills of materials with secondary data from established life cycle inventory databases, enabling the identification of data-driven trends and conclusions – in this case, environmental impact conclusions – from relevant studies that can cover multiple product types.

This study is informed by, but not designed to be compliant with, ISO 14040 and ISO 14044. The original intent was to develop methods to broadly compare the performance of refillable and single-use product systems without requiring a full ISO 14040/14044-compliant comparative LCA. This would have required a significant amount of additional data from manufacturers, which was not necessary to meet the intent of this work. Even if this were the intent, it would be challenging to collect representative data, given that data would need to be provided voluntarily by manufacturers.

Since its inception, the proposed method of product assessment has changed considerably, from a "guard-rail" approach based on the LCA to a detailed, product-specific assessment using the REST. The LCA has undergone significant review by the partner organizations developing the standard (NSF, WRAP, and Amazon), and a third-party review by the global sustainability consulting firm Anthesis, to ensure that it provides a robust underpinning for the REST.

When considering potential weaknesses of the LCA (and consequently the REST) relative to a fully ISO 14044-compliant study, the principal risk concerns the representativeness of the product used to model the single-use comparator. As discussed above, it was not feasible to conduct a comprehensive market analysis and multiple product assessments to ensure representativeness. Instead, the approach was to select a single product that was assessed as a "typical" representative based on discussions among the partners developing the standard. Where doubts were present, selection erred on the side of selecting

low-impact, simple single-use comparators to reduce the risk of setting an inappropriately low bar. To ensure transparency, it is recommended that environmental claims under the Refillable Standard include a description of the single-use comparator, in terms of form factor, primary materials and their relative proportions, and total product weight.

Consistent with common practice in refillable LCA studies, the first step in estimating the environmental impacts of using a refillable product system instead of single-use containers is to quantify the environmental impacts associated with the life cycles of keeper containers, auxiliary units, and single-use containers. The second step is then to estimate the number of auxiliary unit counts the refillable product systems must use in order to reach the breakeven point or the MUFI.

Table 1 below presents the life cycle stages and activities in the scope of this study for single-use and refillable product systems.

Table 1. Summary of the life cycle stages and activities in the scope of this study for single-use and refillable product systems.

Life cycle stages	**Single-use container**	**Keeper & Auxiliary unit containers**
New container manufacturing (Includes raw material extraction, material processing, container manufacturing, manufacturer's packaging, and upstream transport)	Included	Included
Container transport	Included	Included
Container use	Included but not applicable (no consumables required in use phase)	Included (impact of auxiliary unit used to refill keeper container)
End-of-life	Included	Included

Table 2 defines the critical parameters and source data used to assess the potential life cycle environmental benefits of a potential refillable product standard:

Table 2. Critical parameters and source data used to assess the potential life cycle environmental impacts of a potential refillable product standard.

Impacts	Critical parameters	Source
Container Manufacturing Impacts	• Mass of container & material composition, • Manufacturing processes	Amazon tear-down laboratory; Manufacturer-provided bills of materials; Inventory and assumptions from ecoinvent datasets modeled in SimaPro
Container Transport Impacts	• Transport modes & distances	LCA Report*: Average data from Amazon REST*: Assumption of 1000 km truck/lorry freight by road and 25 km in a delivery van
Container use Impacts	• Auxiliary unit counts	Consumer surveys on typical auxiliary unit count reached for each product type and form factor
End-of-life (EOL) impacts	• EOL disposal scenarios, • EOL transport	EPA's 2018 data on EOL scenarios, Generic assumption of 100 km EOL transport

*The transportation distances are different between the LCA report and the REST, as the LCA model was originally developed using transportation mode and distance assumptions from Amazon. It was later decided that the generic assumption of 1000 km truck/lorry freight by road and 25 km in a delivery van would be preferable, and this assumption is used in the REST. This change is expected to be insignificant, as transport impacts are small compared to other parts of the life cycle.

Functional Unit

To perform the analysis, single-use and refillable product systems were selected for their functional equivalence (i.e., the single-use and refillable product systems perform the same function for the user). In other words, the user receives the same performance from the contained product; only the container design and refill behavior are different. Environmental impacts were calculated per liter or per kg of dispensed product (depending on the unit of measure used for the systems). In this way, the number of refills required to realize environmental impact benefits could be calculated.

Average Container Mass

Container mass has a critical influence on lifecycle environmental impacts. The keeper containers often have a higher mass than their single-use counterparts to provide durability, allowing multiple auxiliary unit counts. Table 3 below provides the primary material(s) and mass of each container evaluated in this study. The containers are grouped by product type and form factor. To reflect equivalent performance and function, the environmental performance of containers within a specific product type and form factor

combination is only compared to the single-use baseline of that product type/form factor combination. For example, refillable deodorant stick systems are only compared to the single-use deodorant stick, not to roll-on or spray-on deodorants.

Table 3. Identification of each container evaluated as part of the LCA, including information about the container use type, its primary materials, and its mass. Containers are also categorized by product type and form factor.

Container ID	Product type	Form factor	Container type	Primary material(s)	Container mass (g)
M1-S1	Skin complexion compact	Compact	Single use	Plastic, glass	63.4
M1-B1			Keeper container	Plastic, glass, aluminum	75.31
M1-R1			Auxiliary unit	Steel	8.8
M1-B2			Keeper container	Bamboo, Glass	62.7
M1-R2			Auxiliary unit	Steel	11.6
M1-B3			Keeper container	Zinc	151.43
M1-R3			Auxiliary unit	Steel	6.54
D1-S1	Deodorant	Roll-on	Single use	Plastic	30.4
D1-B1			Keeper container	Plastic	26.5
D1-R1			Auxiliary unit	Plastic	58.1
D2-S1		Stick	Single use	Plastic	38.9
D2-B1			Keeper container	Aluminum	41.2
D2-R1			Auxiliary unit	Aluminum	23.6
D2-B2			Keeper container	Plastic	71.2
D2-R2			Auxiliary unit	Paperboard	5.1
D2-B3			Keeper container	Aluminum, plastic	84.3
D2-R3			Auxiliary unit	Paperboard	4.3
D2-B4			Keeper container	Plastic	65.1
D2-R4			Auxiliary unit	Paperboard	32.8
D3-S1		Spray-on	Single use	Aluminum, Steel	39.7
D3-B1			Keeper container	Plastic	29.6
D3-R1			Auxiliary unit	Plastic	38.3
F1-B7	Facial moisturizer, facial cleanser, liquid soap	Pump bottle	Single use	Plastic	12.6
F1-B4			Keeper container	Plastic	41.6
F1-R4			Auxiliary unit	Recycled plastic	14.6
F1-B5			Keeper container	Glass	458
F1-R5			Auxiliary unit	Paper	0.6
F1-B6			Keeper container	Aluminum, plastic	73.2
F1-R6			Auxiliary unit	Plastic	153
F1-B7			Keeper container	Plastic	12.6
F1-R7			Auxiliary unit	Plastic	21.7
F1-B8			Keeper container	Aluminum, Plastic	65.2
F1-R8			Auxiliary unit	Paperboard	36.3
F1-B9			Keeper container	Glass	267
F1-R9			Auxiliary unit	Plastic	71.7
F1-B10			Keeper container	Plastic	51.8

Container ID	Product type	Form factor	Container type	Primary material(s)	Container mass (g)
F1-R10			Auxiliary unit	Plastic	34.6
F1-B11			Keeper container	Glass	336
F1-R11			Auxiliary unit	Aluminum	52.7
F1-B12			Keeper container	Glass	183
F1-R12			Auxiliary unit	Plastic	14.1
F1-B13			Keeper container	Recycled plastic, plastic	37
F1-R13			Auxiliary unit	Plastic	11.6
F2-B5			Single use	Plastic	62.7
F2-B1			Keeper container	Plastic	74.4
F2-R1			Auxiliary unit	Plastic	8.4
F2-B2			Keeper container	Plastic	72.7
F2-R2		Jar	Auxiliary unit	Plastic	11.1
F2-B3			Keeper container	Glass	137
F2-R3			Auxiliary unit	Plastic	13.3
F2-B5			Keeper container	Plastic	62.7
F2-R5			Auxiliary unit	Plastic	9.7
C1-B9			Single use	Plastic	64.3
C1-B1			Keeper container	Glass	362
C1-R1			Auxiliary unit	Glass	46.3
C1-B2			Keeper container	Recycled plastic, plastic	64.3
C1-R2	Cleaning agent	Spray bottle	Auxiliary unit	Recycled plastic	90.8
C1-B3			Keeper container	Recycled plastic, plastic	64.6
C1-R3			Auxiliary unit	Recycled plastic	43.0
C1-R4			Auxiliary unit	Recycled plastic, plastic	173

SimaPro Data Sets

Inventories from external sources have been used to develop life cycle assessment models of each product type in SimaPro. The main datasets used to represent the extraction, manufacturing, and end-of-life of the various material components of the containers are listed in Table 4 below. These data sets are from the ecoinvent 3.10 database. These materials comprise the initial assessed materials library, a library of materials that will be updated over time by the standard owner to accommodate the addition of materials not in the list below, including any new and innovative materials that are part of future refillable product systems. The assessed materials library will evolve over time to suit the needs of the *CLS: Refillable Certified Standard.*

Table 4. Key information about the datasets used for each material in this LCA.

Material	Material data set used	Processing data set used	Landfill data set used	Incineration data set used	Compost data set used
Corrugated Box	Corrugated board box {RoW}| market for corrugated board box | Cut-off, U	N/A	Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill | Cut-off, U	Waste paperboard {GLO}| treatment of waste paperboard, municipal incineration | Cut-off, U	Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U
Aluminum	Aluminium, wrought alloy {GLO}| market for aluminium, wrought alloy | Cut-off, U	Metal working, average for aluminium product manufacturing {GLO}| market for metal working, average for aluminium product manufacturing | Cut-off, U	Waste aluminium {RoW}| treatment of waste aluminium, sanitary landfill | Cut-off, U	Scrap aluminium {RoW}| treatment of scrap aluminium, municipal incineration | Cut-off, U	N/A
Paper	Kraft paper {RoW}| market for kraft paper | Cut-off, U	N/A	Waste graphical paper {RoW}| treatment of waste graphical paper, sanitary landfill | Cut-off, U	Waste paperboard {GLO}| treatment of waste paperboard, municipal incineration | Cut-off, U	Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U

Material	Material data set used	Processing data set used	Landfill data set used	Incineration data set used	Compost data set used
Polypropylene	Polypropylene, granulate {GLO}| market for polypropylene, granulate | Cut-off, U	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste polypropylene {RoW}| treatment of waste polypropylene, sanitary landfill | Cut-off, U	Waste polypropylene {GLO}| treatment of waste polypropylene, municipal incineration | Cut-off, U	N/A
Paperboard	Containerboard, unspecified {US}| market for containerboard, unspecified | Cut-off, U	N/A	Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill | Cut-off, U	Waste paperboard {GLO}| treatment of waste paperboard, municipal incineration | Cut-off, U	Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U
Adhesive	Polyurethane adhesive {GLO}| market for polyurethane adhesive | Cut-off, U	N/A	Waste polyurethane {RoW}| treatment of waste polyurethane, sanitary landfill | Cut-off, U	Waste polyurethane {GLO}| treatment of waste polyurethane, municipal incineration | Cut-off, U	N/A
LDPE	Polyethylene, low density, granulate {GLO}| market for polyethylene, low density, granulate | Cut-off, U	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste polyethylene {RoW}| treatment of waste polyethylene, sanitary landfill | Cut-off, U	Waste polyethylene {GLO}| treatment of waste polyethylene, municipal incineration | Cut-off, U	N/A
LDPE foam	Polyethylene, low density, granulate {GLO}| market for polyethylene, low density, granulate | Cut-off, U	Polymer foaming {GLO}| market for polymer foaming | Cut-off, U	Waste polyethylene {RoW}| treatment of waste polyethylene, sanitary landfill | Cut-off, U	Waste polyethylene {GLO}| treatment of waste polyethylene, municipal incineration | Cut-off, U	N/A

Material	Material data set used	Processing data set used	Landfill data set used	Incineration data set used	Compost data set used
HDPE	Polyethylene, high density, granulate {GLO}| market for polyethylene, high density, granulate | Cut-off, U	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste polyethylene {RoW}| treatment of waste polyethylene, sanitary landfill | Cut-off, U	Waste polyethylene {GLO}| treatment of waste polyethylene, municipal incineration | Cut-off, U	N/A
Recycled HDPE	Polyethylene, high density, granulate, recycled {RoW}| market for polyethylene, high density, granulate, recycled | Cut-off, U	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste polyethylene {RoW}| treatment of waste polyethylene, sanitary landfill | Cut-off, U	Waste polyethylene {GLO}| treatment of waste polyethylene, municipal incineration | Cut-off, U	N/A
PET-amorphous	Polyethylene terephthalate, granulate, amorphous {GLO}| market for polyethylene terephthalate, granulate, amorphous | Cut-off, U	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste polyethylene terephthalate {CH}| treatment of waste polyethylene terephthalate, municipal incineration FAE | Cut-off, U	N/A
PET-bottle grade	Polyethylene terephthalate, granulate, bottle grade {GLO}| market for polyethylene terephthalate, granulate, bottle grade | Cut-off, U	Blow moulding {GLO}| market for blow moulding | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste polyethylene terephthalate {CH}| treatment of waste polyethylene terephthalate, municipal incineration FAE | Cut-off, U	N/A

Material	Material data set used	Processing data set used	Landfill data set used	Incineration data set used	Compost data set used
Recycled PET – bottle grade	Polyethylene terephthalate, granulate, bottle grade, recycled {RoW}| market for polyethylene terephthalate, granulate, bottle grade, recycled | Cut-off, U	Blow moulding {GLO}| market for blow moulding | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste polyethylene terephthalate {CH}| treatment of waste polyethylene terephthalate, municipal incineration FAE | Cut-off, U	N/A
Neodymium	Neodymium oxide {GLO}| market for neodymium oxide | Cut-off, U	Metal working, average for metal product manufacturing {GLO}| market for metal working, average for metal product manufacturing | Cut-off, U	Inert waste {RoW}| treatment of inert waste, sanitary landfill | Cut-off, U	Scrap steel {RoW}| treatment of scrap steel, municipal incineration | Cut-off, U	N/A
Stainless Steel	Steel, chromium steel 18/8 {GLO}| market for steel, chromium steel 18/8 | Cut-off, U	Metal working, average for chromium steel product manufacturing {GLO}| market for metal working, average for chromium steel product manufacturing | Cut-off, U	Inert waste {RoW}| treatment of inert waste, sanitary landfill | Cut-off, U	Scrap steel {RoW}| treatment of scrap steel, municipal incineration | Cut-off, U	N/A
Glass	Packaging glass, white {GLO}| market for packaging glass, white | Cut-off, U	N/A	Inert waste {RoW}| treatment of inert waste, sanitary landfill | Cut-off, U	Waste glass {GLO}| treatment of waste glass, municipal incineration | Cut-off, U	N/A

Material	Material data set used	Processing data set used	Landfill data set used	Incineration data set used	Compost data set used
Recycled glass	Packaging glass, white {GLO}| market for packaging glass, white, recycled | Cut-off, U (NSF Created – substitutes raw materials used in primary glass with recycled cullet)	N/A	Inert waste {RoW}| treatment of inert waste, sanitary landfill | Cut-off, U	Waste glass {GLO}| treatment of waste glass, municipal incineration | Cut-off, U	N/A
Synthetic rubber	Synthetic rubber {GLO}| market for synthetic rubber | Cut-off, U	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste rubber, unspecified {RoW}| treatment of waste rubber, unspecified, municipal incineration | Cut-off, U	N/A
Synthetic rubber sponge	Synthetic rubber {GLO}| market for synthetic rubber | Cut-off, U	Polymer foaming {GLO}| market for polymer foaming | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste rubber, unspecified {RoW}| treatment of waste rubber, unspecified, municipal incineration | Cut-off, U	N/A
Tissue paper	Tissue paper {GLO}| market for tissue paper | Cut-off, U	N/A	Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill | Cut-off, U	Waste paperboard {GLO}| treatment of waste paperboard, municipal incineration | Cut-off, U	Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U
Bamboo	Flattened bamboo {RoW}| market for flattened bamboo | Cut-off, U	Plywood {RoW}| plywood production | Cut-off, U(per kg)	Waste wood, untreated {RoW}| treatment of waste wood, untreated, sanitary landfill | Cut-off, U	Waste wood, untreated {GLO}| treatment of waste wood, untreated, municipal incineration | Cut-off, U	Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U

Material	Material data set used	Processing data set used	Landfill data set used	Incineration data set used	Compost data set used
Brass	Brass {RoW}| market for brass | Cut-off, U	Turning, brass, CNC, average/US- US-EI U	Inert waste {RoW}| treatment of inert waste, sanitary landfill | Cut-off, U	Copper in car shredder residue {GLO}| treatment of copper in car shredder residue, municipal incineration | Cut-off, U	N/A
Magnet	Permanent magnet, for electric motor {GLO}| market for permanent magnet, for electric motor | Cut-off, U	N/A	Inert waste {RoW}| treatment of inert waste, sanitary landfill | Cut-off, U	Scrap steel {RoW}| treatment of scrap steel, municipal incineration | Cut-off, U	N/A
Zinc	Zinc {GLO}| market for zinc | Cut-off, U	Casting, brass {GLO}| market for casting, brass | Cut-off, U	Inert waste {RoW}| treatment of inert waste, sanitary landfill | Cut-off, U	Zinc in car shredder residue {GLO}| treatment of zinc in car shredder residue, municipal incineration | Cut-off, U	N/A
Recycled plastic (mixed)	Waste plastic, consumer electronics, unsorted {RoW}| market for waste plastic, consumer electronics, unsorted | Cut-off, U	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste polyethylene {GLO}| treatment of waste polyethylene, municipal incineration | Cut-off, U	N/A
Corn starch foam	Maize starch {RoW}| maize starch production | Cut-off, U	Polymer foaming {GLO}| market for polymer foaming | Cut-off, U	Waste wood, untreated {RoW}| treatment of waste wood, untreated, sanitary landfill | Cut-off, U	Waste wood, untreated {GLO}| treatment of waste wood, untreated, municipal incineration | Cut-off, U	Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, U

Material	Material data set used	Processing data set used	Landfill data set used	Incineration data set used	Compost data set used
Silicone	Silicone product {RoW}| market for silicone product | Cut-off, U	Extrusion, plastic pipes {GLO}| market for extrusion, plastic pipes | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste plastic, mixture {GLO}| treatment of waste plastic, mixture, municipal incineration | Cut-off, U	N/A
Nylon	Nylon 6-6 {RoW}| market for nylon 6-6 | Cut-off, U	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste plastic, mixture {GLO}| treatment of waste plastic, mixture, municipal incineration | Cut-off, U	N/A
Polyacetal	Polyoxymethylene (POM)/EU-27	Injection moulding {GLO}| market for injection moulding | Cut-off, U	Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off, U	Waste plastic, mixture {GLO}| treatment of waste plastic, mixture, municipal incineration | Cut-off, U	N/A
Recycled containerboard	Containerboard, fluting medium {RoW}| containerboard production, fluting medium, recycled | Cut-off, U	N/A	N/A	Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill | Cut-off, U	Waste paperboard {GLO}| treatment of waste paperboard, municipal incineration | Cut-off, U

The data sets in Table 5 were used to calculate impacts related to the transport from the warehouse to the customer and from the customer to waste disposal. These data sets are from the ecoinvent 3.10 database.

Table 5. Transportation datasets used in this LCA by mode of transport.

Transport mode	Dataset
Truck freight	Transport, freight, lorry, unspecified {GLO}| market for transport, freight, lorry, unspecified | Cut-off, U
Air freight	Transport, freight, aircraft, unspecified {GLO}| market group for transport, freight, aircraft, unspecified | Cut-off, U
Municipal 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

Data Quality Summary

The quality of data used in life cycle assessment should be as precise, complete, consistent, and representative as possible, aligned with the goals of the study, and balanced with time and budget constraints. A screening-level LCA method, as used in this study, does not require primary data or specific data quality thresholds. Primary foreground inventory data were used for:

- container materials, manufacturer's packaging, and their respective masses;
- averaged transport distances and modes (not specific to the product types);
- validation of consumer behavior expectations (e.g., typical number of auxiliary unit counts)

The primary data is considered good quality. This study uses secondary data from ecoinvent to supplement foreground and background unit processes. The representativeness of this data is considered fair.

Overall, we consider the data used in this study to be of adequate quality to provide useful information as an input to develop a refillable product standard.

Completeness is judged based on the completeness of the inputs and outputs per unit process and the completeness of the unit processes themselves. The goal is to capture sufficient relevant data in this regard. We have included materials, energy, waste, and water flows to the degree we were able to identify them. The completeness of the data is considered good.

Consistency refers to modeling choices and data sources. The goal is to ensure that differences in results reflect actual differences between container systems and are not due to inconsistencies in modeling choices, data sources, emission factors, or other artifacts. This study uses consistent modeling approaches, data sources (within product type categories), and characterization methods. The consistency of this study is considered good.

Reproducibility expresses the degree to which third parties would be able to reproduce the results of the study based on the information contained in this report and supporting calculation workbooks. The goal is to provide enough transparency such that reported results could be reproduced by someone not involved in the original analysis. This ability may be limited by the exclusion of confidential primary data

and access to the same background data sources. The reproducibility of the results in this study is considered very good.

Representativeness expresses the degree to which the data matches the geographical, temporal, and technological conditions of the container systems. Given the variability within container systems and the availability of data, we used the US average waste statistics to model foreground waste handling assumptions and the latest global or regional average data to model background waste handling processes. Representativeness for a general range of containers on the market is considered fair, while the representativeness of this analysis for any specific container would be fair to poor. The introduction of a product system-specific eligibility scanning tool (the REST) makes this evaluation much more representative of specific systems seeking certification.

Impact Categories & Metrics Evaluated

Life cycle assessment provides potential measures of environmental impacts on a variety of aspects. Table 6 lists the impact categories evaluated in this study, their units of measure, descriptions, and the methodology used to evaluate each category (European Commission, Joint Research Centre, 2023).

Table 6. Impact category summary, including the units, descriptions, and impact assessment methodologies used for each impact category.

Impact category	Unit	Description	Impact assessment methodology
Climate change	kg CO_2 eq	Measures the potential for a substance to contribute to global climate change by quantifying its greenhouse gas emissions.	EF v3.1
Water use	m^3 world-eq deprived	Represents the relative available water remaining per area in a watershed, after the demand of humans and aquatic ecosystems has been met. It assesses the potential of water deprivation, to either humans or ecosystems, building on the assumption that the less water remaining available per area, the more likely another user will be deprived.	EF v3.1
Resource use, minerals and metals	kg Sb eq	Evaluates the depletion of natural non-fossil resources from the Earth. Measured in kg antimony equivalents.	EF v3.1
End of life (EOL) waste	kg	Estimates the total amount of waste generation at end-of-life. This sums the mass of the container and associated manufacturer's packaging.	Inventory metric

Results and Discussion

An Excel-based calculator was developed to estimate the environmental impacts associated with the use of refillable product systems when compared with single-use containers. For each product type, results were generated based on the assumptions and data points as listed in earlier sections. The results in this section are illustrative examples of the LCA methodology to demonstrate the impact calculations, breakeven calculations, and calculated MUFI values. The MUFI results are demonstrative of the eligibility calculations performed in the REST, but the REST will calculate a MUFI for each specific product system that seeks eligibility. The only product-specific data carried from this report into the REST is the bill of materials for single-use baseline containers.

Life Cycle Impacts of Single-Use and Refillable Product Systems

Within the project scope and boundaries, various impact categories were evaluated for the life cycles of both single-use containers and their counterpart refillable systems. Table 7 below provides a comparison of single-use container impacts (in relative percentages) with the impacts from keeper containers and auxiliary unit containers. All results are normalized per unit liter or kg of dispensed product. The bills of materials (material types and masses) are provided from either a product teardown laboratory or directly from manufacturers. In one case, a typical container made from recycled content was used as a proxy to build a hypothetical container with the same masses, except with a primary material to evaluate a different scenario. The containers are intentionally unidentified and described generally to protect the anonymity of the manufacturers.

Table 7. Modeled environmental impacts of each keeper container and auxiliary unit as a percentage of single-use container impact for a given product type and form factor.

Product type	Form factor	Container type	Primary material(s)	Climate change (kg CO2 eq)	Water use (m^3 world-eq deprived)	Resource use, minerals and metals (kg Sb eq)	EOL waste (kg)
Skin complexion compact	Compact	Single use	Plastic, glass	100%	100%	100%	100%
		Keeper container	Plastic, glass, aluminum	75%	60%	68%	58%
		Auxiliary unit	Steel	14%	9%	14%	20%
		Keeper container	Bamboo, Glass	39%	45%	20%	97%
		Auxiliary unit	Steel	13%	8%	17%	19%
		Keeper container	Zinc	154%	355%	4578%	289%
		Auxiliary unit	Steel	45%	24%	19%	104%
Deodorant	Roll-on	Single use	Plastic	100%	100%	100%	100%
		Keeper container	Plastic	200%	182%	41097%	220%
		Auxiliary unit	Plastic	39%	32%	20702%	38%
	Stick	Single use	Plastic	100%	100%	100%	100%
		Keeper container	Aluminum	680%	362%	16702%	230%
		Auxiliary unit	Aluminum	379%	199%	9136%	148%
		Keeper container	Plastic	442%	300%	288423%	507%
		Auxiliary unit	Paperboard	42%	17%	188%	102%
		Keeper container	Aluminum, plastic	938%	629%	16825%	492%
		Auxiliary unit	Paperboard	19%	3%	88%	52%
		Keeper container	Plastic	338%	432%	986%	566%
		Auxiliary unit	Paperboard	203%	358%	968%	470%
	Spray-on	Single use	Aluminum, Steel	100%	100%	100%	100%
		Keeper container	Plastic	59%	78%	9%	283%
		Auxiliary unit	Plastic	13%	18%	1%	61%
Facial moisturizer, facial cleanser, liquid	Pump bottle	Single use	Plastic	100%	100%	100%	100%
		Keeper container	Plastic	378%	375%	387%	370%
		Auxiliary unit	Recycled plastic	35%	30%	0%	63%

Product type	Form factor	Container type	Primary material(s)	Climate change (kg CO2 eq)	Water use (m^3 world-eq deprived)	Resource use, minerals and metals (kg Sb eq)	EOL waste (kg)
soap		Keeper container	Glass	2057%	1228%	41%	5806%
		Auxiliary unit	Paper	22%	4%	0%	58%
		Keeper container	Aluminum, plastic	1403%	1017%	63%	940%
		Auxiliary unit	Plastic	132%	140%	1%	204%
		Keeper container	Plastic	100%	100%	100%	100%
		Auxiliary unit	Plastic	84%	82%	1%	139%
		Keeper container	Aluminum, Plastic	1323%	952%	67%	883%
		Auxiliary unit	Paperboard	32%	11%	0%	78%
		Keeper container	Glass	369%	210%	11%	1185%
		Auxiliary unit	Plastic	109%	118%	127%	109%
		Keeper container	Plastic	284%	363%	1%	300%
		Auxiliary unit	Plastic	63%	80%	0%	66%
		Keeper container	Glass	943%	682%	76%	1483%
		Auxiliary unit	Aluminum	476%	331%	21%	406%
		Keeper container	Glass	525%	214%	11%	1785%
		Auxiliary unit	Plastic	63%	128%	8%	58%
		Keeper container	Recycled plastic, plastic	121%	97%	4%	191%
		Auxiliary unit	Plastic	59%	84%	8%	59%
	Jar	Single use	Plastic	100%	100%	100%	100%
		Keeper container	Plastic	142%	155%	158%	123%
		Auxiliary unit	Plastic	16%	23%	0%	14%
		Keeper container	Plastic	141%	152%	133%	135%
		Auxiliary unit	Plastic	27%	30%	0%	34%
		Keeper container	Glass	127%	101%	2%	262%
		Auxiliary unit	Plastic	42%	47%	0%	51%
		Keeper container	Plastic	100%	100%	100%	100%

Product type	Form factor	Container type	Primary material(s)	Climate change (kg CO2 eq)	Water use (m^3 world-eq deprived)	Resource use, minerals and metals (kg Sb eq)	EOL waste (kg)
		Auxiliary unit	Plastic	6%	14%	1%	5%
Cleaning agent	Spray bottle	Single use	Plastic	100%	100%	100%	100%
		Keeper container	Glass	469%	527%	13%	898%
		Auxiliary unit	Glass	61%	39%	2%	119%
		Keeper container	Recycled plastic, plastic	82%	77%	2%	100%
		Auxiliary unit	Recycled plastic	60%	52%	1%	83%
		Keeper container	Recycled plastic, plastic	93%	89%	3%	109%
		Auxiliary unit	Recycled plastic	68%	59%	1%	93%
		Auxiliary unit	Recycled plastic, plastic	67%	69%	1%	83%

From the table above, most of the keeper containers have higher environmental impacts than their single-use counterparts because they are more energy- and material-intensive. However, as long as the auxiliary unit containers have lower impacts than the single-use containers in the same product category, the refillable product system will eventually have a breakeven point at which impacts begin to be avoided. Conversely, if auxiliary unit containers have higher impacts than the single-use containers, the refillable product system will never break even. While most of the auxiliary units above have lower impacts than the single-use containers in the same product system, that is not always the case.

Breakeven Point

A critical parameter in the estimation of the environmental benefits of a refillable product system in comparison to the single-use container is *auxiliary unit counts*. As the number of auxiliary unit counts goes up, the refillable product system will avoid more environmental impacts as long as the impacts for the auxiliary unit container are less than the total single-use impacts. The *breakeven point* is the condition when the impacts generated from using a refillable product system are the same as the total impacts from the use of multiple single-use containers. If more auxiliary unit containers are used than this breakeven point, the refillable product system will start reducing environmental impact compared to the use of single-use containers.
The breakeven point is estimated using the following conceptual formula:

$$\boldsymbol{Breakeven\ Point} = \frac{\boldsymbol{Keeper\ Container\ Impacts}}{\boldsymbol{Single\ use\ Container\ Impacts - Auxiliary\ Unit\ Container\ Impacts}}$$

In practice, the detailed equations needed to calculate the breakeven point and number of auxiliary unit counts need to be adjusted based on the varying container capacities in the evaluated systems. A detailed derivation and example of the equations used are provided in Appendix B.
For each refillable product system, the breakeven point will vary mainly because of the difference in container mass, material composition, and container manufacturing operations. Breakeven points are estimated for each product type. The results are presented in Table 8 below, with calculated values rounded up to the nearest integer. Rows highlighted green indicate that all environmental impacts achieve breakeven in 10 or fewer auxiliary unit counts. Rows highlighted in yellow achieve breakeven with 10-100 auxiliary unit counts in one or more categories, and/or do not reach breakeven on either water use or resource use (minerals and metals). Rows highlighted in orange indicate containers that require more than 100 auxiliary unit counts to reach a breakeven point in any category or do not reach a breakeven point in at least one category required for eligibility (i.e., climate change, waste, or both water use and resource use).

Table 8. Breakeven results for each refillable product system analyzed, as identified by the keeper container and auxiliary unit combination.

Keeper Container ID	Keeper Container Primary Material(s)	Auxiliary Unit ID	Auxiliary Unit Primary Material(s)	Product Type	Form Factor	Breakeven Point (Unit: Number of auxiliary units consumed)			
						Climate change	Water use	Resource use, minerals and metals	EOL waste
M1-B1	Plastic, glass, aluminum	M1-R1	Steel	Skin complexion compact	Compact	0	0	0	0
M1-B2	Bamboo, glass	M1-R2	Steel	Skin complexion compact	Compact	0	0	0	0
M1-B3	Zinc	M1-R3	Steel	Skin complexion compact	Compact	1	4	56	BNR
D1-B1	Plastic	D1-R1	Plastic	Deodorant	Roll-on	1	1	BNR	1
D2-B1	Aluminum	D2-R1	Aluminum	Deodorant	Stick	BNR	BNR	BNR	BNR
D2-B2	Plastic	D2-R2	Paperboard	Deodorant	Stick	6	3	BNR	BNR
D2-B3	Aluminum, plastic	D2-R3	Paperboard	Deodorant	Stick	11	6	1446	9
D2-B4	Plastic	D2-R4	Paperboard	Deodorant	Stick	BNR	BNR	BNR	BNR
D3-B1	Plastic	D3-R1	Plastic	Deodorant	Spray-on	0	0	0	1
F1-B4	Plastic	F1-R4	Recycled plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	3	2	2	4
F1-B5	Glass	F1-R5	Paper	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	7	3	0	34
F1-B6	Aluminum, plastic	F1-R6	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	BNR	BNR	0	BNR
F1-B7	Plastic	F1-R7	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	0	1	0	BNR

Keeper Container ID	Keeper Container Primary Material(s)	Auxiliary Unit ID	Auxiliary Unit Primary Material(s)	Product Type	Form Factor	Breakeven Point (Unit: Number of auxiliary units consumed)			
						Climate change	Water use	Resource use, minerals and metals	EOL waste
F1-B8	Aluminum, plastic	F1-R8	Paperboard	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	7	4	0	14
F1-B9	Glass	F1-R9	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	BNR	BNR	BNR	BNR
F1-B10	Plastic	F1-R10	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	2	5	0	2
F1-B11	Glass	F1-R11	Aluminum	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	BNR	BNR	0	BNR
F1-B12	Glass	F1-R12	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	6	BNR	0	19
F1-B13	Recycled plastic, plastic	F1-R13	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	1	0	0	3
F2-B1	Plastic	F2-R1	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Jar	1	1	1	1
F2-B2	Plastic	F2-R2	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Jar	1	1	1	1
F2-B3	Glass	F2-R3	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Jar	1	1	0	4
F2-B5	Plastic	F2-R5	Plastic	Facial Moisturizer, Facial Cleanser, Liquid	Jar	1	0	1	0

Keeper Container ID	Keeper Container Primary Material(s)	Auxiliary Unit ID	Auxiliary Unit Primary Material(s)	Product Type	Form Factor	Breakeven Point (Unit: Number of auxiliary units consumed)			
						Climate change	Water use	Resource use, minerals and metals	EOL waste
				Soap					
C1-B1	Glass	C1-R1	Glass	Cleaning agent	Spray bottle	10	7	0	BNR
C1-B2	Recycled plastic, plastic	C1-R2	Recycled plastic	Cleaning agent	Spray bottle	0	0	0	1
C1-B3	Recycled plastic, plastic	C1-R3	Recycled plastic	Cleaning agent	Spray bottle	0	0	0	2
C1-B3	Recycled plastic, plastic	C1-R4	Recycled plastic	Cleaning agent	Spray bottle	0	0	0	1

This table represents estimated figures based on the analysis performed in this study.
BNR = Breakeven not reached (i.e., per-refill impacts exceed single-use impacts)

The following are the main observations from the calculation of the breakeven point:

- The breakeven point for the makeup compact depends on both the mass and the materials that make up the containers. The first two refillable systems have similar mass but different materials, and both have lower impacts per container capacity than the single-use baseline container; therefore, no refills are needed to reach breakeven in all categories. The third keeper container is a much heavier container made primarily from zinc and has higher impacts than the single-use baseline. The climate change and water use categories have a relatively quick payback, the resource use has a longer payback, and the EOL waste breakeven point is not reached since the auxiliary unit has slightly higher mass per unit of product than the single-use baseline.
- The deodorant roll-on product has generally low breakeven points for all categories except resource use, which does not break even. This is due to the PET used in the refillable system chosen for analysis, which has relatively higher resource use impacts than PE or PP plastics. There may be roll-on refillable product systems that perform better, but for which the team did not have appropriate bills of materials (BOMs).
- The deodorant stick products require a large number of auxiliary unit counts to achieve breakeven or do not break even at all. This is likely due to the auxiliary units having the same capacity as the original unit since they are solid and constrained by the geometry of the container. Whereas other liquid auxiliary units can generally offer a much larger product quantity per container mass, these products cannot.
- The spray-on deodorant system requires a single refill to reach breakeven in the EOL waste category, but the other categories do not require any refills to reach breakeven.
- The ten moisturizer/soap pump bottle refillable product systems show mixed results against the single-use baseline. Seven of the ten refillable systems require relatively high auxiliary unit counts to break even, or do not reach a breakeven. The four worst performers do not reach breakeven in climate change or EOL waste; three have relatively heavy keeper containers made primarily of glass or aluminum, and the fourth has a plastic keeper container but an auxiliary unit that generates more EOL waste per unit of product than the single-use baseline. The three performers with relatively high breakeven points have keeper containers made with aluminum or glass and auxiliary units made primarily with paper, paperboard, or plastic. The three systems with relatively low auxiliary unit counts to breakeven have keeper containers and auxiliary units made primarily from plastic or recycled plastic.
- The cleaning agent bottle refillable product systems show mixed results against the single-use baseline. Three of the four systems reach breakeven in two or fewer refills. These have keeper containers and auxiliary units made primarily from plastic or recycled plastic, and the auxiliary unit volume capacities are much larger than the keeper container (i.e., the keeper can be refilled multiple times from the same auxiliary unit). One of the four refillable systems does not reach breakeven for EOL waste. This system has both keeper containers and auxiliary units made primarily from glass. In this category, since all of the keeper containers had a substantial recycled content or were made from glass, the single-use baseline is a proxy of the best-performing keeper container with primary plastic in place of the recycled plastic in order to reflect a more typical

single-use container (i.e., the same bill of materials was used, recycled plastic was replaced with primary plastic).

- All four lidded jar refillable systems reach a breakeven point relatively quickly, in four or fewer refills in all categories. Three of these systems are made primarily from plastic (both keeper containers and auxiliary units) and have similar mass; the fourth has a glass keeper container. For this product type, the lightest product was used as a proxy for the single-use baseline since its light weight is similar to single-use containers of this product type.

Minimum Uses for Impact (MUFI)

Since this analysis is meant to inform the development of a *CLS: Refillable Certified Standard* that produces tangible environmental benefits, an alternative minimum number of refills was also calculated to assess product eligibility for certification. This value, named minimum uses for impact (MUFI), is higher than the breakeven point (before rounding) and is based on the number of refills required for a refillable product system to produce 15-30% less environmental impact in the assessed categories than a single-use equivalent over the same number of total uses. The intent of this reduction is to provide confidence that product systems achieve a meaningful reduction in impact compared with single-use alternatives. Some calculations have enough uncertainty that products that barely achieve breakeven may, in practice, have environmental impacts that are negligibly different from single-use alternatives.

The 15-30% impact reduction is determined using an uncertainty adjustment factor, which recognizes the fact that there is more uncertainty in some impact calculations that rely heavily on midpoint indicators and generic data (e.g., climate change) and less uncertainty in impacts that are directly measured (e.g., total EOL waste).

In practice, the MUFI is calculated by adjusting the single-use container impacts in the equation outlined in the Breakeven Point section above by both the 30% impact reduction and the uncertainty adjustment factor. That is shown conceptually in the following equation:

$$\boldsymbol{MUFI} = \frac{\boldsymbol{Keeper\ Container\ Impacts}}{(\boldsymbol{1 - 0.3} \times \boldsymbol{Uncertainty\ Adjustment}) \times \boldsymbol{Single\ use\ Container\ Impacts - Auxiliary\ Unit\ Container\ Impacts}}$$

For the four impact categories evaluated as part of the standard, uncertainty adjustment factors used are defined and described in Table 9 below. These uncertainty adjustment factors may be revisited in future versions of the standard.

Certain products may break even in Table 8 above, but they may never achieve a MUFI. For instance, if one product's auxiliary unit container has climate change impacts that are 25% lower than the single-use container impacts, it may break even using the equation in the previous section, but it may never achieve a viable MUFI. In that case, the breakeven equation would have a denominator of [1 x single-use container impact – 0.75 x single-use container impact] while the MUFI would have a denominator of [0.7 x 1 x single-use container impact – 0.75 x single-use container impact], leading to a negative result, or a product system that does not achieve a viable MUFI (designated as MNR or MUFI not reached in Table 10).

Table 9. Uncertainty adjustment factors and justifications for each impact category.

Impact category	**Uncertainty Adjustment Factor**	**Explanation**
Climate change	100%	Calculated using midpoint indicators and generic data from ecoinvent with product mass to calculated impact. Midpoint indicators are calculated with characterization factors that have uncertainty; and ecoinvent data sources are generic, and thus have a moderate degree of uncertainty.
Water use	100%	
Resource use, minerals and metals	100%	
EOL waste	50%	Calculated directly based on the mass of the product's components. Mass measurement has a high degree of certainty, and the bill of materials for any refillable product system will be confirmed upon audit. Thus, there is a low degree of uncertainty in this calculation.

The calculated MUFI values for the assessed products are shown in Table 10 below. Shading follows the same rules as Table 8, only applied to MUFI values rather than breakeven values.

Table 10. MUFI results for each refillable product system analyzed, as identified by the keeper container and auxiliary unit combination.

Keeper Container ID	Keeper Container Primary Material(s)	Auxiliary Unit ID	Auxiliary Unit Primary Material(s)	Product Type	Form Factor	Minimum Uses for Impact (MUFI) (Unit: Number of auxiliary units consumed)			
						Climate change	Water use	Resource use, minerals and metals	EOL waste
M1-B1	Plastic, glass, aluminum	M1-R1	Steel	Skin complexion compact	Compact	1	0	0	0
M1-B2	Bamboo, glass	M1-R2	Steel	Skin complexion compact	Compact	0	0	0	1
M1-B3	Zinc	M1-R3	Steel	Skin complexion compact	Compact	4	7	89	MNR
D1-B1	Plastic	D1-R1	Plastic	Deodorant	Roll-on	1	1	MNR	1
D2-B1	Aluminum	D2-R1	Aluminum	Deodorant	Stick	MNR	MNR	MNR	MNR
D2-B2	Plastic	D2-R2	Paperboard	Deodorant	Stick	14	5	MNR	MNR
D2-B3	Aluminum, plastic	D2-R3	Paperboard	Deodorant	Stick	18	9	MNR	13
D2-B4	Plastic	D2-R4	Paperboard	Deodorant	Stick	MNR	MNR	MNR	MNR
D3-B1	Plastic	D3-R1	Plastic	Deodorant	Spray-on	0	1	0	2
F1-B4	Plastic	F1-R4	Recycled plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	5	4	3	7
F1-B5	Glass	F1-R5	Paper	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	11	5	0	53
F1-B6	Aluminum, plastic	F1-R6	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	MNR	MNR	0	MNR
F1-B7	Plastic	F1-R7	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	MNR	MNR	1	MNR

Keeper Container ID	Keeper Container Primary Material(s)	Auxiliary Unit ID	Auxiliary Unit Primary Material(s)	Product Type	Form Factor	Minimum Uses for Impact (MUFI) (Unit: Number of auxiliary units consumed)			
						Climate change	Water use	Resource use, minerals and metals	EOL waste
F1-B8	Aluminum, plastic	F1-R8	Paperboard	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	13	6	0	46
F1-B9	Glass	F1-R9	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	MNR	MNR	MNR	MNR
F1-B10	Plastic	F1-R10	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	10	MNR	0	4
F1-B11	Glass	F1-R11	Aluminum	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	MNR	MNR	1	MNR
F1-B12	Glass	F1-R12	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	29	MNR	0	30
F1-B13	Recycled plastic, plastic	F1-R13	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Pump bottle	5	MNR	0	5
F2-B1	Plastic	F2-R1	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Jar	2	2	2	1
F2-B2	Plastic	F2-R2	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Jar	2	3	1	1
F2-B3	Glass	F2-R3	Plastic	Facial Moisturizer, Facial Cleanser, Liquid Soap	Jar	3	2	0	6
F2-B5	Plastic	F2-R5	Plastic	Facial Moisturizer, Facial Cleanser, Liquid	Jar	1	1	1	1

Keeper Container ID	Keeper Container Primary Material(s)	Auxiliary Unit ID	Auxiliary Unit Primary Material(s)	Product Type	Form Factor	Minimum Uses for Impact (MUFI) (Unit: Number of auxiliary units consumed)			
						Climate change	Water use	Resource use, minerals and metals	EOL waste
				Soap					
C1-B1	Glass	C1-R1	Glass	Cleaning agent	Spray bottle	43	15	0	MNR
C1-B2	Recycled plastic, plastic	C1-R2	Recycled plastic	Cleaning agent	Spray bottle	1	1	0	4
C1-B3	Recycled plastic, plastic	C1-R3	Recycled plastic	Cleaning agent	Spray bottle	11	2	0	MNR
C1-B3	Recycled plastic, plastic	C1-R4	Recycled plastic	Cleaning agent	Spray bottle	2	3	0	3

This table represents estimated figures based on the analysis performed in this study.
MNR = MUFI not reached (i.e., per-refill impacts exceed 70-85% of single-use impacts)

Assumptions and Limitations

Assumptions are used throughout the LCA screening process. Major assumptions and limitations are stated below:

- Manufacturing operations and inventory for each product type were developed using average typical manufacturing processes from the ecoinvent database. Actual container manufacturing data would improve the accuracy of results.
- End-of-life scenarios are developed from US EPA data. The disposal scenarios follow a cut-off approach where the container is disposed of in a landfill, incinerated, and/or recycled at the end of the service life. The sensitivity analysis below explores the potential impact of changes in end-of-life assumptions.
- The impact of container contents (e.g., the actual deodorant inside the refillable container) is not considered in this report. Because of this, the results are limited to product systems where the single-use container, keeper container, and auxiliary unit containers all have the same contents. This excludes products like concentrates, where the impact per functional unit of the concentrate may differ from that of the diluted or unconcentrated product. This restricts eligibility but does not impact the results herein.
- Use-phase impacts related to potential washing or other maintenance of keeper containers are not accounted for. Many refillable product systems do not require washing between uses (i.e., if a cleaning spray is being replaced with an identical cleaning spray), but this could be explored if the scope of the standard were expanded to include additional refillable products that may require washing. Including use-phase washing would increase the MUFI and breakeven points for applicable products.
- Manufacturer BOMs were limited to manufacturers willing to voluntarily share detailed product information. This limited the variety of single-use, keeper, and auxiliary unit containers that could be used to inform this LCA and the standard. Additional single-use container BOMs, in particular, could strengthen the single-use baselines used to calculate MUFIs in the REST.
- Single-use container baselines are based on a single BOM for each product type. The baseline was chosen as a product that was deemed to be sufficiently representative and, if possible, perceived to be conservative (e.g., relatively lower impact and/or streamlined materials). Choosing a conservative (low-impact) container means that the refillable product systems are evaluated more stringently and that they must demonstrate impact reduction against single-use containers that are already materially efficient and relatively low impact. This strengthens the eligibility determination made based on MUFI, but may limit eligibility.
- The expected quantity of product dispensed by an average consumer in a refillable system is based on consumer survey data. While we consider these to be reasonable representations of consumer behavior, there is considerable uncertainty and variation in these values. As this is a key input to calculate the MUFI threshold for each refillable product system, future analyses should consider whether additional data sources are available to inform these assumptions.

End-of-Life Waste Pathway Sensitivity Analysis

End-of-life waste pathways vary across countries and regions within countries. Notably, the EU incinerates, recycles, and composts a higher proportion of waste compared to the US, which has a higher proportion of landfill waste. To determine how the different waste scenarios affect the impact results, we calculated separate impact results using waste statistics from the US and EU for each container and calculated the difference in results for each impact category.

For the baseline results, we used statistics from the US EPA's Facts and Figures about Materials, Waste, and Recycling for Nondurable Goods (US EPA, 2017). For the EU results, we used municipal waste statistics from Eurostat (Eurostat, 2026). These statistics are summarized in Table 11.

Table 11. Summary of waste disposal statistics from the US and EU average sources.

Geography	Recycled	Composted	Combustion	Landfilled
US Average	28%	0%	14%	58%
EU Average	30%	19%	26%	24%

For all containers analyzed, we calculated the percent difference of the EU result compared to the US result and generated histograms of those differences to see the relative distribution across the containers. The histograms for each impact category are shown in Figure 2.

- Climate change EU results vary from -24% to +33% compared to US results, with 76% of containers between -10% and +14%. This is due to the differences in greenhouse gas emissions for different material/EOL pathway combinations. For example, biobased materials have a higher climate change impact in landfills due to anaerobic decomposition into methane, compared to carbon dioxide emissions via incineration, making the landfill impacts higher. The opposite is true for plastics, where there is very little decomposition in a landfill and very low greenhouse gas emissions compared to the carbon dioxide generated via incineration. Except for spray-on deodorant, all single-use baseline products are primarily made from plastic, thus the EU scenario would have higher climate change impacts for end-of-life. For refillable product systems made from plastic, the impacts of both systems are likely higher in the EU calculation, and thus the breakeven point will likely be similar (i.e., both the numerator and denominator are adjusted by similar amounts). For refillable product systems made from biobased materials, end-of-life impacts in the US are higher, requiring more auxiliary unit counts to break even. Thus, the US result is more conservative.
- Water EU results vary from +2% to +103% compared to US results, with 91% of containers between +2% and +26%. This is due to higher water use in average incineration and composting operations compared to landfill operations. The containers with the largest differences are those made primarily from paperboard, paper, steel, unrecyclable plastic, or glass. If the single-use and refillable product systems have similar types of materials, then the water impacts of both are likely higher in the EU calculation, and thus the breakeven point will be similar (i.e., both the numerator and denominator are adjusted by similar amounts). However, if the refillable system has one of the above materials and is compared to a single-use baseline of plastic (plastic is typical of single-use containers), then the breakeven point may require slightly more auxiliary unit counts. In that case, the EU result is more conservative.

- Resource use EU results vary from 0% to +1.3% compared to US results, with 91% of containers between 0% and +0.3%. This provides confidence that resource use results for containers used in the US and EU markets are likely to be similar.
- Since the mass of containers is the same, the EOL waste is the same in both the EU and US scenarios, so this result does not change.

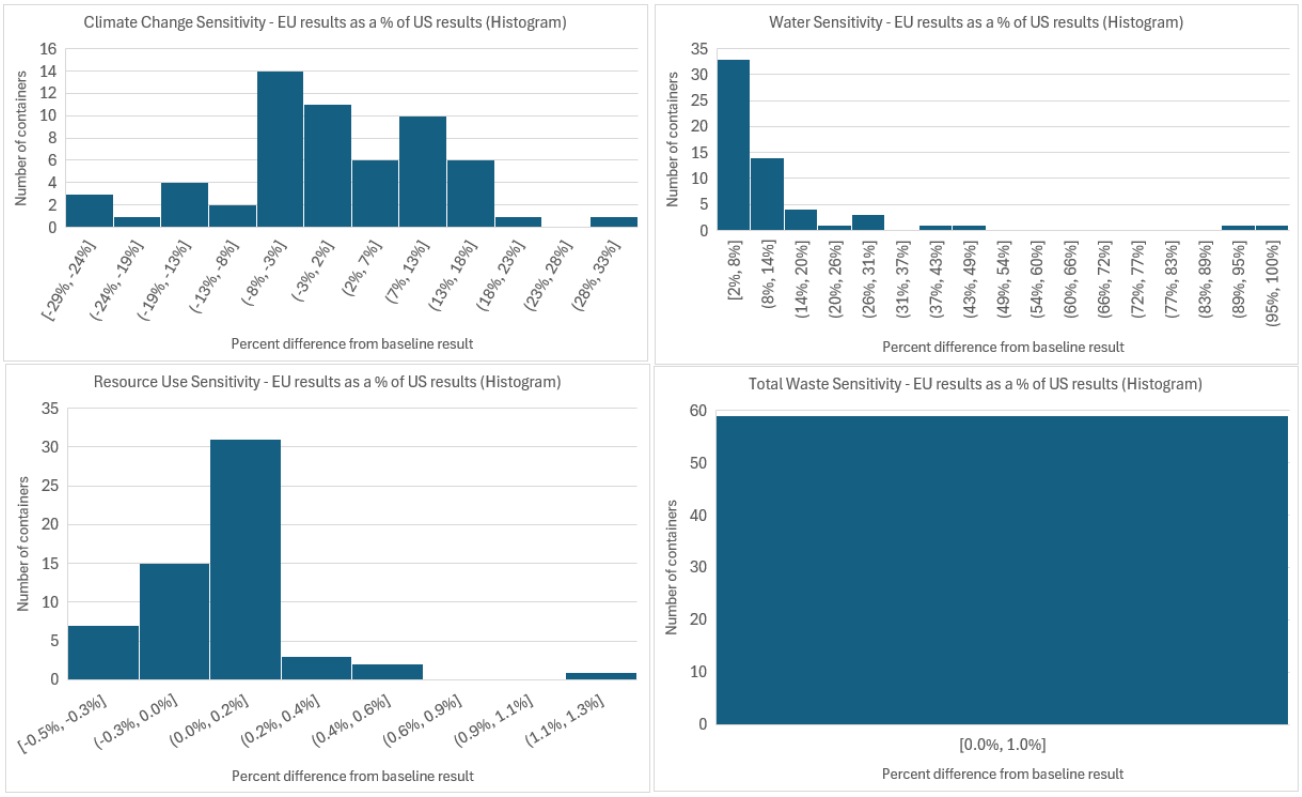

Figure 2. Histogram results comparing the percent difference of the EU result compared to the US result for each impact category.

Refillable Eligibility Scanning Tool (REST) Overview

Proxies such as the efficiency ratio were not found to have a clear correlation with MUFI during the development of the LCA. Thus, we could not set clear thresholds (e.g., minimum efficiency ratios) for any metrics that would clearly indicate desirable environmental performance. Ultimately, it was decided that the most robust way to determine eligibility would be to directly perform a simplified life cycle assessment for each product system using a spreadsheet-based tool that could be used by the certifying body based on product, container, and manufacturer's packaging BOMs.

The REST performs simplified life cycle assessments of refillable keeper containers, auxiliary units, and their respective manufacturer's packaging for the purposes of calculating a MUFI value for a given product system (a specific pairing of keeper container and auxiliary unit). The REST also performs a series of quality control checks, including basic data entry checks, a user prompt (in this case, to the CB auditor) to confirm recycled content verification requirements have been met, and a validation that at least 95% of the container and manufacturer's packaging mass has been entered. Once all quality control checks have been met, the REST outputs a calculated MUFI for a given product system. Capacity and efficiency ratios are also calculated, but are not intended to serve as a proxy for impact.

One calculated MUFI is computed for each impact category required by the standard: (1) climate change, (2) resource use, minerals and metals, (3) water use, and (4) EOL waste. Then, a final MUFI is selected as the maximum MUFI of those calculated for climate change, EOL waste, and the lower MUFI of either water use or resource use. If a product system does not reach a MUFI for one of water use or resource use, then it may still be eligible. If a product system does not reach a MUFI for both, or does not reach a MUFI for climate change or EOL waste, then it is not eligible. This is based on the priority of impact categories outlined in the standard.

A MUFI threshold is also established for each refillable product system in the REST. The MUFI threshold is calculated using the keeper container capacity, auxiliary unit capacity, and the quantity of product dispensed at the MUFI threshold Q_{MUFI}. A Q_{MUFI} is established for each product type, subtype, and form factor in the *CLS: Refillable Certified Standard* as well as in Appendix F of this document, which details the methodology for setting Q_{MUFI} for each product type and subtype. The MUFI threshold will generally differ for each unique refillable product system because keeper container and auxiliary unit capacities can vary substantially. So, the Q_{MUFI} is common across all refillable product systems of a given product sub-type and form factor, while the MUFI threshold varies depending on the magnitude of keeper and auxiliary unit capacities. The MUFI threshold is computed as follows:

$$MUFI\ Threshold = \frac{Q_{MUFI} - C_K *}{C_A}$$

**C_K is set to 0 if the keeper container is empty at the point of delivery to the consumer*

In this equation, Q_{MUFI} is the quantity of dispensed product at the MUFI Threshold, C_K is the capacity of the keeper container, and C_A is the capacity of the auxiliary unit. This equation allows for the calculation of a dynamic MUFI Threshold that takes into consideration the size of keeper and auxiliary unit containers, which establishes a more consistent set of criteria through which refillable product systems with different size containers can be evaluated.

The calculated MUFI value will then be compared against the MUFI threshold calculated for that product

system. For a refillable product system to be eligible, the calculated MUFI must be lower than the MUFI threshold, which demonstrates that the product is expected to reach the required auxiliary unit count based on consumer behavior data.

The REST offers several advantages when compared with using proxies to determine eligibility:

- Case-by-case eligibility is determined based on the system-specific impacts of each component of a refillable product system and their bills of materials.
- Using system-specific impacts, as calculated using simplified life cycle assessment, expands eligibility when compared with a proxy system that may not have full correlation between the proxy and eligibility.
- The REST provides a clear output of the final product system's calculated MUFI, MUFI threshold, and MUFI eligibility result.
- The REST provides several quality control checks on the CB auditor's calculations and inputs.
- The REST may be updated over time to include additional materials, which will expand eligibility.

The REST's key disadvantages are interrelated: The tool requires more work from the CB auditor, who must input BOM data; it requires the provision of a BOM from the manufacturer; and it requires management by the scheme owner. We feel that the additional effort is far outweighed by the added accuracy and precision of this approach.

Recommendations

This study is largely based on container teardown data, bills of materials, and average secondary data. Data points should be updated as more data becomes available (e.g., via customer surveys). Some of the recommendations to make this study more robust are listed below:

- Mass of the containers (both single-use and refillable systems) and refill patterns significantly change the end environmental impacts. Existing data should be compiled and consumer surveys conducted to obtain accurate data values.
- Additional BOMs of all container types (single-use, keeper containers, and auxiliary units) could be used to uncover additional patterns that may inform updates to the standard or similar efforts.
- Additional BOMs of single-use containers could strengthen the representativeness of the single-use baseline used in the REST for comparison with refillable product systems.
- Higher-fidelity global data for specific manufacturing processes, if available, could enable highly customized calculations for different global regions and the disparity in their manufacturing environmental impacts.
- The inclusion of end-of-life treatment data for a large number of global regions could expand eligibility to different regions where products might be sold.
- Customer surveys can be used to better understand the end-of-life scenarios for both single-use and refillable product systems.
- Performing detailed life cycle assessments on upstream impacts and more downstream end-of-life scenarios will make the study more robust.

Appendices

Note: Some appendices were developed during earlier stages of this work and may be based on earlier versions of the LCA model. Values shown in these appendices may therefore differ from the results presented in the body of this report, which reflect the final version of the model.

Appendix A: Relevant studies

The following table summarizes the external studies evaluated for refillable systems prior to much of the analysis contained in this report. None of the studies were directly aligned in system boundary or product type, and no data from these studies were directly used in the analysis above. Most conclude that the specific refillable systems studied can offer environmental benefits.

Table 12. Summary of external studies used to inform the refillable LCA.

Title	Year	Summary	Reference
Life Cycle Assessment of a Plant-Based, Regionally Marketed Shampoo and Analysis of Refill Options	2021	The cradle-to-grave study of shampoo is conducted for four packaging scenarios. The study includes shampoo ingredients and hot water for showering, and unsurprisingly shows that heating the water during the shower is the largest source of impacts. However, Figure 3 does demonstrate that refills can offer impact reductions from different packaging. Packaging quantities for each scenario are provided in Table 2.	(Kröhnert & Stucki, 2021)
Coty Launches the First Ever Refillable Perfume Achieving Cradle to Cradle Certification	2022	This is a press release for refillable fragrance with a cited LCA that backs up impact reductions. The LCA compared 5x 50ml single-use bottles with a larger 100 ml refillable bottle (keeper container) and a 150 ml refill bottle (auxiliary unit). The LCA and its data are not publicly available.	(Coty Inc., 2022)
Life cycle impact assessment of beverage packaging systems: focus on the collection of post-consumer bottles	2016	The study explores multiple end-of-life collection systems for beverage bottles along with refillable beverage bottles. Identifies important parameters to analysis of refillable beverage bottles: number of refills, transport distance, efficiency of cleaning between refills, if needed.	(Simon et al., 2016)
Reusability and recyclability of plastic cosmetic packaging: A life cycle assessment	2022	An analysis of a refillable blush powder compact case. Provides a bill of materials for the product, though no consideration of packaging of the initial compact and refills are included. Concludes that refills have environmental benefits.	(Gatt & Refalo, 2022)
Guidance for Reusable Packaging	2022	Provides a good definition of refillable packaging, examples of companies that offer it, and the importance of knowing theoretical reuse versus reuse in practice (e.g., just because a bottle can be refilled 100 times doesn't mean it will be).	(Olga Kachook, 2022)

Appendix B: Calculation of breakeven point

The calculation of the breakeven point in refillable product systems versus their baseline single-use products requires nuanced adjustments based on varying container capacities. This appendix provides detail on how the breakeven point and number of auxiliary unit counts required to achieve the breakeven point were calculated.

In a refillable product system, the breakeven point is reached when the environmental impacts are the same as the single-use containers per unit of product dispensed from the containers.

First, the following useful terms are defined:

C_S = single-use container capacity

I_S = environmental impact of a single-use container

C_K = keeper container capacity

I_K = environmental impact of a keeper container

C_A = auxiliary unit capacity

I_A = environmental impact of an auxiliary unit

I_E = environmental impact at breakeven

Q_E = the quantity of product dispensed at the breakeven point

n_a = number of auxiliary unit containers

n_s = number of single-use containers

At the breakeven point, the single-use impact-per-unit-capacity multiplied by the quantity of product dispensed at breakeven will equal the breakeven impact. The breakeven impact of the refillable product system will equal the impact of the keeper container plus the impact-per-unit-capacity of the auxiliary unit multiplied by the difference of the quantity of product dispensed at breakeven and the keeper container capacity (since most keeper containers come with a prefilled amount of product). This is written as:

$$\frac{I_S}{C_S} Q_E = I_E \quad \text{and} \quad I_B + \frac{I_A}{C_A}(Q_E - C_K) = I_E$$

Therefore, $$\frac{I_S}{C_S} Q_E = I_K + \frac{I_A}{C_A}(Q_E - C_K)$$

$$\frac{I_S}{C_S} Q_E - \frac{I_A}{C_A} Q_E = I_K - \frac{I_A}{C_A} C_K$$

$$Q_E \left(\frac{I_S}{C_S} - \frac{I_A}{C_A}\right) = I_K - \frac{I_A}{C_A} C_K$$

$$Q_E = \frac{\left(I_K - \frac{I_A}{C_A} C_K\right)}{\left(\frac{I_S}{C_S} - \frac{I_A}{C_A}\right)}$$

The following example is provided for the refillable product system F1-B8 (keeper container) and F1-R8 (auxiliary unit) and single-use container F1-B7. In this system, the following properties are known:

C_S = 0.975926 L

I_S = 0.237 kg CO_2e

C_K = 0.354882 L
I_K = 1.17 kg CO_2e
C_A = 0.946353 L
I_A = 0.0771 kg CO_2e

The quantity of product dispensed at breakeven is therefore: $Q_E = \frac{(I_K - \frac{I_A}{C_A} C_K)}{\left(\frac{I_S}{C_S} - \frac{I_A}{C_A}\right)}$ =

$$\frac{(1.17 - \frac{0.0771}{0.946353} \times 0.354882)}{\left(\frac{0.237}{0.975926} - \frac{0.0771}{0.946353}\right)} = 7.06\ L$$

The number of single-use containers used to dispense 7.06 L of product is:

$$n_S = \frac{Q_E}{C_S} = \frac{7.06\ L}{0.975926\ L} = 7.23\ single\ use\ containers$$

The number of auxiliary units used to dispense 7.06 L of product is:

$$n_A = \frac{(Q_E - C_K)}{C_A} = \frac{7.06\ L\ -\ 0.354882\ L}{0.946353\ L} = 7.08\ auxiliary\ units$$

Checking the impacts for the indicated number of containers (they should be equal):
Single use: 7.23 containers * 0.2375 kg CO_2e = **1.72 kg CO_2e**
Refillable: 1 keeper container * 1.17 kg CO_2e + 7.08 auxiliary units * 0.0771 kg CO_2e = **1.72 kg CO_2e**

This means the refillable product system will reach a breakeven point for GWP when the contents of 7.08 auxiliary units have been consumed, and will have less impact, per unit of product dispensed, after eight auxiliary units have been used. The breakeven point for this system (with respect to GWP) is 8 (rounded up from 7.08).

Appendix C: Capacity ratio analysis

The containers in this study are made from a variety of materials. To provide a better understanding of how the various materials compare and to identify potential constraints or limitations of materials or mass of materials for decision-making, we developed a sensitivity analysis on the capacity ratio, or the ratio of the mass of the container to the capacity of the container, of the various materials. The capacity ratio is calculated as follows:

$$Capacity\ Ratio = \frac{m_c}{C}$$

Where m_c is the mass of the container in grams and C is the capacity of the container (either liters or kilograms, depending on the predominant unit used in each product type). First, we identified the major materials in the various containers by considering all materials greater than 12.5% of the mass of each container. This eliminated minor materials and left 18 materials that are commonly used in containers, including a variety of metal, plastic, glass, and biobased materials. Next, we calculated the capacity ratio for each material in each container. This is simply the mass of material in the container divided by the capacity of the container, in grams per unit capacity (g/liter or g/kg). This ratio allows analysis of realistic material quantities in the containers. We then found the minimum, maximum, and average capacity ratio of each material. The following table shows these statistics. Due to varying numbers of containers with each material, some materials have narrow ranges, and some have wide ranges.

Table 13. Capacity ratio analysis descriptive statistics.

Material	Capacity ratio (g/liter or g/kg)		
	Min.	Max.	Avg.
Aluminum	49	1357	425
Bamboo	4468	4468	4468
Corn starch foam	347	347	347
Corrugated Box	46	8073	1117
Glass	95	2231	1019
HDPE	7	4212	363
LDPE	15	139	39
Paper	42	3161	726
Paperboard	28	1902	418
PET-amorphous	2287	3846	3067
PET-bottle grade	10	1780	487
Polypropylene	6	753	243
Recycled containerboard	54	407	179
Recycled HDPE	22	22	22
Recycled PET, bottle grade	44	350	105
Recycled plastic (mixed)	25	25	25
Stainless Steel	861	1505	1137
Recycled glass	508	660	584

Using this information, we then used the material-specific impact factors for the upstream materials, manufacturing, and end-of-life to calculate the minimum, maximum, and average environmental impact for each impact category. The following figures show the range of impacts for each material. The bottom

of the orange bar is the minimum, the intersection of the orange and green bars is the average, and the top of the green bar is the maximum. All materials are separately reported and scaled to their relative mass in the container (manufacturer's packaging included).



Figure 3. Range of potential impacts for each material analyzed in this capacity ratio sensitivity analysis.

This demonstrates that some materials are generally less impactful than others in individual categories, and there is also overlapping performance among several materials in each category. For example, most materials perform better than stainless steel in the resource use category, though there is overlapping performance in the same category for many of the materials. This analysis could help decision makers better understand capacity ratio limitations for specific materials when developing a product standard for keeper containers.

Appendix D: Efficiency ratio analysis

The initial life cycle assessment results of refillable product systems compared to their baseline single-use containers are mixed, with some unclear trends that might enable the identification of boundaries or thresholds within the CLS: Refillable Certified Standard, currently in development. A further attempt to identify trends adds the concept of efficiency ratio along with the existing LCA results. This analysis is described herein.

The container efficiency ratio (η_c) is the ratio of the product amount (q_d) (by either weight or volume, depending on how the product is sold) to the container mass (m_c) (see equation 4).

	$\boldsymbol{\eta_c = \frac{q_d}{m_c}}$	(Equation 4)

The container and packaging efficiency ratio (η_{c+k}) is the ratio of the product amount (q_d) (by either weight or volume, depending on how the product is sold) to the mass of the combined container plus its associated manufacturer's packaging (m_{c+k}) (see equation 5).

	$\boldsymbol{\eta_{c+k} = \frac{q_d}{m_{c+k}}}$	(Equation 5)

The more product that can be carried per container/packaging weight, the higher the efficiency ratio. The logical expectation is that, for containers of the same materials, a higher efficiency ratio would show better environmental performance.

To conduct this analysis, we calculated the efficiency ratios for the same containers that were analyzed in the LCA: single-use, keeper container, and auxiliary unit containers. We calculated the efficiency ratios two ways – with and without non-container manufacturer's packaging materials – in order to see if more insight could be gleaned. The equations for each of these ratios are shown in the following equations. These are the same as equations 4 and 5 above, except with subscripts s, b, and r, to denote single-use, keeper container, and auxiliary unit containers, respectively.

Single-use efficiency ratio (container)	$\boldsymbol{\eta_{c_s} = \frac{q_d}{m_c}}$	(Equation 6)		Single-use efficiency ratio (container+ manufacturer's packaging)	$\boldsymbol{\eta_{(c+k)_s} = \frac{q_d}{m_{c+k}}}$	(Equation 9)
Keeper container efficiency ratio (container)	$\boldsymbol{\eta_{c_b} = \frac{q_d}{m_c}}$	(Equation 7)		Keeper container efficiency ratio (container+ manufacturer's packaging)	$\boldsymbol{\eta_{(c+k)_b} = \frac{q_d}{m_{c+k}}}$	(Equation 10)
Auxiliary unit efficiency	$\boldsymbol{\eta_{c_r} = \frac{q_d}{m_c}}$	(Equation 8)		Auxiliary unit efficiency ratio	$\boldsymbol{\eta_{(c+k)_r} = \frac{q_d}{m_{c+k}}}$	(Equation 11)

ratio (container)				(container+ manufacturer's packaging)		

The calculated efficiency ratios are shown in the following table. The rows are highlighted with the same colors used in the breakeven and MUFI results tables above. See above for specific color meanings, but generally, green rows are the best environmental performers, yellow are middling performers, and orange are relatively poor performers.

Table 14. Calculated efficiency ratios for each container type by product. The colors on the graphs are the same as those applied in the breakeven and MUFI tables in the body of the report.

		container only			container + packaging		
Container ID	**Product**	**Single-use eff. Ratio (ml/g or g/g)**	**Keeper container eff. Ratio**	**Auxiliary unit eff. Ratio**	**Single-use eff. Ratio (ml/g or g/g)**	**Keeper container eff. Ratio**	**Auxiliary unit eff. Ratio**
M1-R1	Makeup compact (Steel)	0.1	0.1	1.1	0.1	0.1	0.4
M1-R2	Makeup compact (Steel)	0.1	0.2	1.0	0.1	0.1	0.4
M1-R3	Makeup compact (Steel)	0.1	0.0	0.9	0.1	0.0	0.1
D1-R1	Deod. roll-on (Plastic)	3.4	2.8	9.0	3.2	1.5	8.6
D2-R1	Deod. stick (Aluminum)	2.2	1.1	2.0	2.2	1.0	1.5
D2-R2	Deod. stick (Paperboard)	2.2	0.6	7.8	2.2	0.4	2.1
D2-R3	Deod. stick (Paperboard)	2.2	0.5	9.2	2.2	0.4	4.2
D2-R4	Deod. stick (Paperboard)	2.2	1.3	2.3	2.2	0.4	0.5
D3-R1	Deod. spray-on (Plastic)	2.7	3.4	13.1	2.7	1.0	4.4
F1-R4	Moisturizer/ soap - pump bottle (Recycled plastic)	25.8	5.5	32.4	21.1	5.5	32.4
F1-R5	Moisturizer/ soap - pump bottle (Paper)	25.8	0.6	1774.4	21.1	0.4	35.4
F1-R6	Moisturizer/ soap - pump bottle (Plastic)	25.8	4.8	24.8	21.1	2.2	10.1
F1-R7	Moisturizer/ soap - pump bottle (Plastic)	25.8	25.8	46.3	21.1	21.1	14.7
F1-R8	Moisturizer/ soap - pump bottle (Paperboard)	25.8	5.4	26.1	21.1	2.3	26.1
F1-R9	Moisturizer/ soap - pump bottle (Plastic)	25.8	1.8	26.4	21.1	1.7	18.8
F1-R10	Moisturizer/ soap - pump bottle (Plastic)	25.8	6.9	30.8	21.1	6.8	30.8
F1-R11	Moisturizer/ soap - pump bottle (Aluminum)	25.8	3.2	20.2	21.1	1.4	5.0
F1-R12	Moisturizer/ soap - pump bottle (Plastic)	25.8	1.3	35.5	21.1	1.1	35.5
F1-R13	Moisturizer/ soap - pump bottle (Plastic)	25.8	10.7	34.5	21.1	10.7	34.5
F2-R1	Moisturizer/ soap - jar (Plastic)	0.8	0.6	5.7	0.8	0.6	5.7
F2-R2	Moisturizer/ soap - jar (Plastic)	0.8	0.7	4.5	0.8	0.6	2.4
F2-R3	Moisturizer/ soap - jar (Plastic)	0.8	0.4	3.8	0.8	0.3	1.6
F2-R5	Moisturizer/ soap - jar (Plastic)	0.8	0.8	15.5	0.8	0.8	15.5
C1-R1	Cleaning agent - spray bottle (Glass)	12.9	1.3	10.2	5.2	0.6	4.4
C1-R2	Cleaning agent - spray bottle (Recycled plastic)	12.9	12.9	22.0	5.2	5.2	6.2
C1-R3	Cleaning agent - spray bottle (Recycled plastic)	12.9	10.5	15.8	5.2	4.8	5.6
C1-R4	Cleaning agent - spray bottle (Recycled plastic,	12.9	10.5	21.9	5.2	4.8	6.2

	plastic)						

By themselves, the efficiency ratios are not very informative. A further step is needed – to compare the auxiliary unit efficiency ratios to the single-use efficiency ratios. This is essentially a ratio of ratios, as shown in the following equations, similarly accounting for both container-only and container plus packaging scenarios, respectively.

	$\boldsymbol{\eta_{(\frac{r}{s})_c} = \frac{\eta_{c_r}}{\eta_{c_s}}}$	(Equation 12)
	$\boldsymbol{\eta_{(\frac{r}{s})_{c+k}} = \frac{\eta_{(c+k)_r}}{\eta_{(c+k)_s}}}$	(Equation 13)

We might expect that the systems that have better environmental performance would have a larger refill efficiency ratio compared to the single-use efficiency ratio, i.e., larger values for $\eta_{(\frac{r}{s})_c}$ and $\eta_{(\frac{r}{s})_{c+k}}$. The results of this comparison are shown in the following table.

Table 15. Comparison of refill efficiency ratios to single-use efficiency ratios. The colors on the graphs are the same as those applied in the breakeven and MUFI tables in the body of the report.

Container ID	**Product**	$\eta_{(\frac{r}{s})_c}$	$\eta_{(\frac{r}{s})_{c+k}}$
M1-R1	Makeup compact (Steel)	14.0	4.9
M1-R2	Makeup compact (Steel)	11.7	5.2
M1-R3	Makeup compact (Steel)	11.0	1.0
D1-R1	Deod. roll-on (Plastic)	2.7	2.7
D2-R1	Deod. stick (Aluminum)	0.9	0.7
D2-R2	Deod. stick (Paperboard)	3.6	1.0
D2-R3	Deod. stick (Paperboard)	4.2	1.9
D2-R4	Deod. stick (Paperboard)	1.0	0.2
D3-R1	Deod. spray-on (Plastic)	4.8	1.6
F1-R4	Moisturizer/ soap - pump bottle (Recycled plastic)	1.3	1.5
F1-R5	Moisturizer/ soap - pump bottle (Paper)	68.9	1.7
F1-R6	Moisturizer/ soap - pump bottle (Plastic)	1.0	0.5
F1-R7	Moisturizer/ soap - pump bottle (Plastic)	1.8	0.7
F1-R8	Moisturizer/ soap - pump bottle (Paperboard)	1.0	1.2
F1-R9	Moisturizer/ soap - pump bottle (Plastic)	1.0	0.9
F1-R10	Moisturizer/ soap - pump bottle (Plastic)	1.2	1.5
F1-R11	Moisturizer/ soap - pump bottle (Aluminum)	0.8	0.2
F1-R12	Moisturizer/ soap - pump bottle (Plastic)	1.4	1.7
F1-R13	Moisturizer/ soap - pump bottle (Plastic)	1.3	1.6
F2-R1	Moisturizer/ soap - jar (Plastic)	7.2	7.2
F2-R2	Moisturizer/ soap - jar (Plastic)	5.7	3.0
F2-R3	Moisturizer/ soap - jar (Plastic)	4.7	2.0
F2-R5	Moisturizer/ soap - jar (Plastic)	19.4	19.4

C1-R1	Cleaning agent - spray bottle (Glass)	0.8	0.8
C1-R2	Cleaning agent - spray bottle (Recycled plastic)	1.7	1.2
C1-R3	Cleaning agent - spray bottle (Recycled plastic)	1.2	1.1
C1-R4	Cleaning agent - spray bottle (Recycled plastic, plastic)	1.7	1.2

Even with this comparison, it is still difficult to identify trends visually. A helpful step to organize this result would be to show the results per container material type while preserving the relative environmental performance color indication. This reorganization is shown below. The first chart includes the container and manufacturer's packaging materials. It excludes the large outlier (19.4) in the plastic column to better visualize the remaining values.

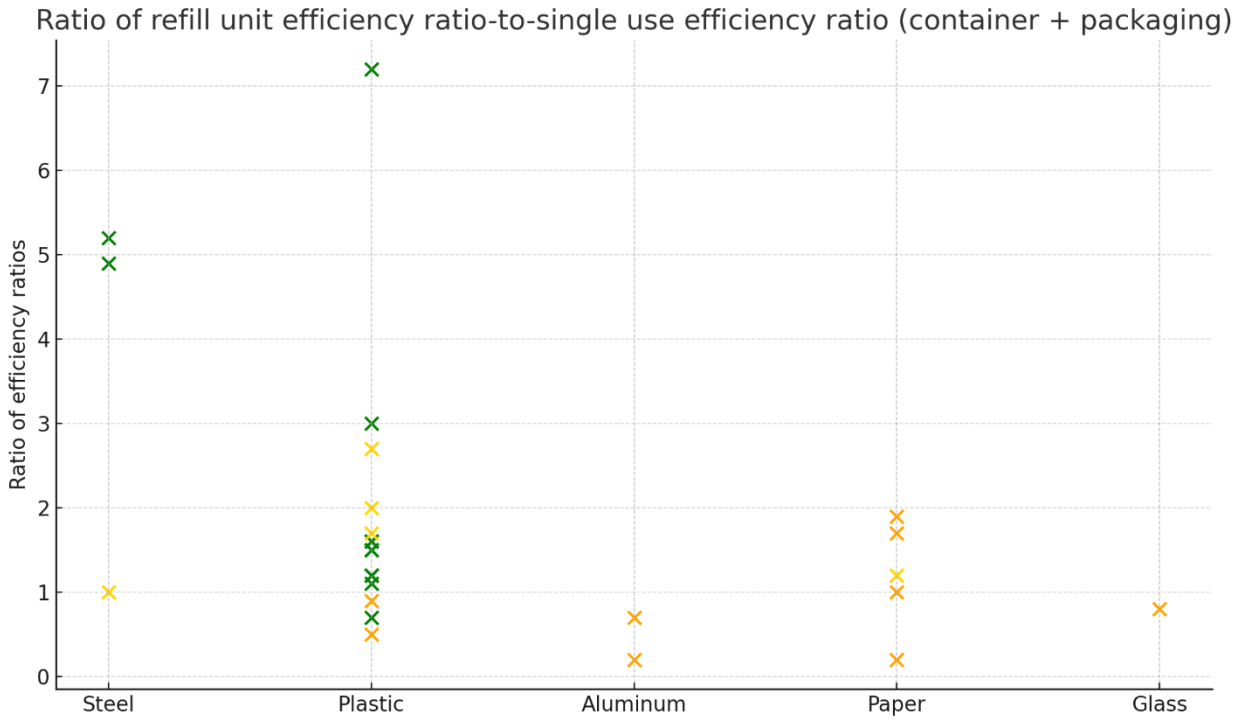

Figure 4. A visual representation of the ratio of refill unit efficiency ratio to single-use efficiency ratio by material type, including both container and manufacturer's packaging material quantities. The colors on the graphs are the same as those applied in the breakeven and MUFI tables in the body of the report.

The next chart includes only the container materials. It excludes one large outlier (68.9) in the paper column to better visualize the remaining results.

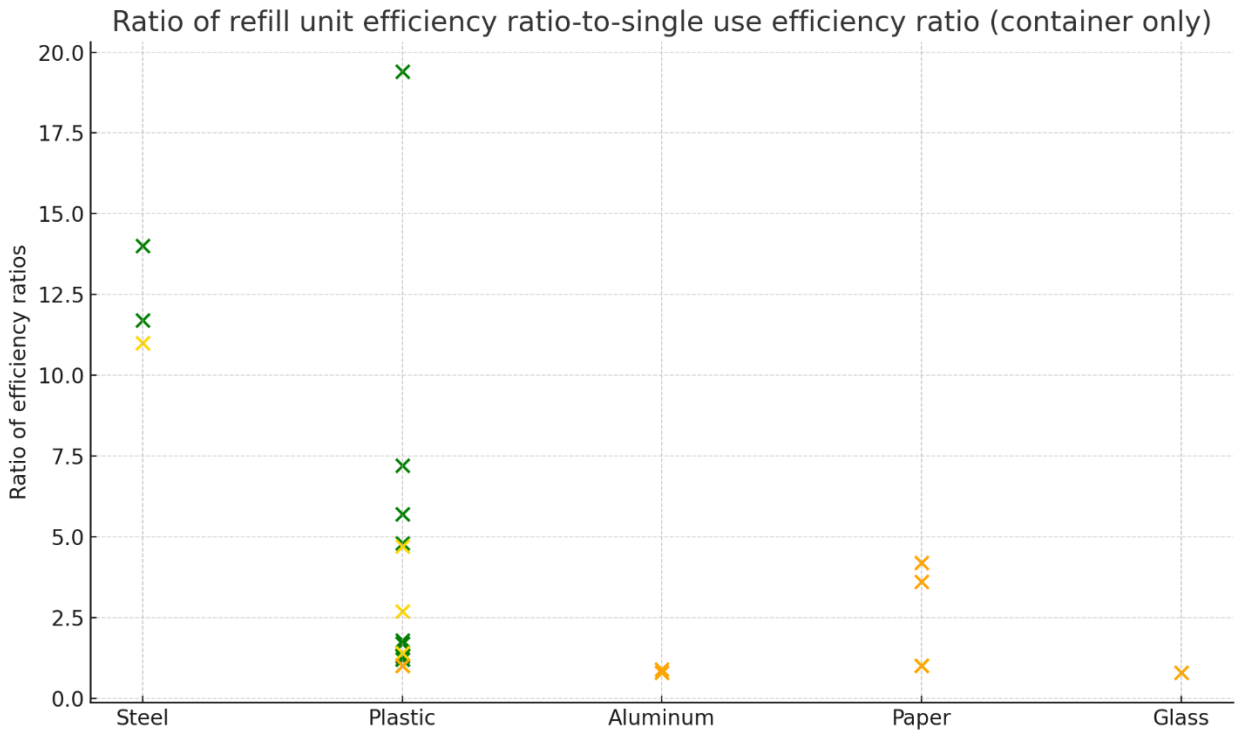

Figure 5. A visual representation of the ratio of refill unit efficiency ratio to single-use efficiency ratio by material type, including just container material quantities. The colors on the graphs are the same as those applied in the breakeven and MUFI tables in the body of the report.

As expected, for containers of the same material, the better environmental performers generally have higher ratios of refill efficiency ratio to single-use efficiency ratio. However, this is not always the case. For example, some middling and poor-performing paper and plastic systems have higher ratios than better-performing systems. For other materials, there are not enough data points to inform a clear threshold of better performance that might be used in the product standard. For example, the steel container systems (considering both the container and manufacturer's packaging) show that the middling performer has a ratio (1.0) much less than the better performers (4.9 and 5.2), but the gap is so wide that there is no way to determine where the threshold might be within that gap. If we look at the container only results, the gap between the middling performer (11.0) and the low-end better performer (11.7) is so small that it is not clear whether the gap is even meaningful, and it's similarly difficult to identify a threshold. Other materials have similar issues or simply lack the data to differentiate.

The efficiency ratio analysis helps confirm our high-level expectations that better environmental performers have higher efficiency ratios compared to their corresponding single-use efficiency ratios, but the material-specific results are not enough to confidently identify thresholds that might be used in the *CLS: Refillable Certified Standard*. The lack of conclusive takeaways from this efficiency ratio analysis led us to determine that, at this time and with the available data, efficiency ratio would not be a valuable proxy for product system eligibility. This led us to develop the Refillable Eligibility Scanning Tool (REST), detailed in the body of the report.

Appendix E: REST Input/Output Sheet Screenshot with Simplified Worked Example

Refillable Product System Eligibility Scanning Tool

NOTES: Light blue cells are required user inputs | Pink cells may be optionally edited

No units are selectable by the user. They are all pre-populated based on the product and container type chosen in Step 1 or they are consistent across all product and container types.

It is expected that CBs will perform unit conversions as needed, or that product manufacturers/suppliers will provide converted values.

The tool does not consider impacts of the product/contents, only the containers, so the bills of materials should only apply to keeper containers, auxiliary unit containers, and manufacturer's packaging.

Step 1: Identify your Refillable Product System

Keeper Container ID:	NSF-k-001
Auxiliary Unit ID:	NSF-a-001
Refillable Product System ID:	NSF-k-001 / NSF-a-001

Please develop a unique identifier for the keeper container and auxiliary unit.

Step 2: Choose Product and Container Type

Product type:	Cleaning agent
Product subtype:	Glass cleaner
Container type:	Spray bottle

Step 3: Input Keeper Container Capacity, Product Mass, Product BOM, Manufacturer's Packaging Mass, and Manufacturer's Packaging BOM

General Information

Keeper Container capacity:	500	milliliters	NOTE: Units will populate once step 2 is complete
Keeper Container Mass (excluding product contents and ancillary packaging):	80	grams	
Keeper Container Manufacturer's Packaging Mass:	0	grams	
Is the Keeper Container shipped full of consumable contents (yes) or empty (no)?	No		

Bill of Materials Input

Keeper Container (excluding packaging)

(These are default values which should be manually overwritten if justified.) | *(These are default values which should be manually overwritten with "Yes" or "No" if justified.)*

Component Name or ID	Material Composition	Mass (grams)	Reused material?	% Recycled content	% Renewable content	Separable at end of life? *(see instructions tab for guidance)*	Designed for reuse at end of life?	Designed to be recyclable at end of life?	Designed to be composted at end of life?
	HDPE	80	No	0%	0%	Yes	No	No	No
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No	

Step 4: Input Auxiliary Unit Capacity, Auxiliary Unit BOM, Auxiliary Unit Manufacturer's Packaging Mass, and Auxiliary Unit Manufacturer's Packaging BOM

General Information

Auxiliary Unit capacity:	2000.0	milliliters	NOTE: Units will populate once step 2 is complete
Auxiliary Unit Mass (excluding product contents and ancillary packaging):	75	grams	
Auxiliary Unit Manufacturer's Packaging Mass:	0	grams	

Bill of Materials Input

Auxiliary Unit (excluding packaging)

(These are default values which should be manually overwritten if justified.) | *(These are default values which should be manually overwritten with "Yes" or "No" if justified.)*

Component Name or ID	Auxiliary Unit Composition	Mass (grams)	Reused material?	% Recycled content	% Renewable content	Separable at end of life? (see instructions tab for guidance)	Designed for reuse at end of life?	Designed to be recyclable at end of life?	Designed to be composted at end of life?
	LDPE	75	No	0.0%	0.0%	Yes	No	No	No
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No		
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	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	Total reported container mass:	75							

Auxiliary Unit Manufacturer's Packaging

(These are default values which should be manually overwritten if justified.) | *(These are default values which should be manually overwritten with "Yes" or "No" if justified.)*

Component Name or ID	Auxiliary Unit Manufacturer's Packaging Materials	Mass (grams)	Reused material?	% Recycled content	% Renewable content	Separable at end of life? (see instructions tab for guidance)	Designed for reuse at end of life?	Designed to be recyclable at end of life?	Designed to be composted at end of life?
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No		
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	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	<select>		No			<select>	No		
	Total reported packaging mass:	0							

Step 5: Review Checks

Automatic Review Checks:	CHECK
Is "Is the Keeper Container shipped full of consumable contents" input with a yes or no answer?	Yes
Is product type, subtype, container type selected by user?	Yes
Is keeper container capacity input by user?	Yes
Is keeper container mass input by user? (Both container and packaging)	Yes
Is auxiliary unit capacity input by user?	Yes
Is auxiliary container mass input by user? (Both container and packaging)	Yes
Are keeper materials selected for nonzero mass values?	Yes
Are auxiliary materials selected for nonzero mass values?	Yes
Are all material quantities non-negative (greater than or equal to zero)?	Yes
Is 95% of total mass threshold met for keeper container BOM (including packaging)?	Yes
Is 95% of total mass threshold met for auxiliary unit BOM (including packaging)?	Yes
Is sum of keeper container materials less than or equal to the reported container mass?	Yes
Is sum of keeper container packaging materials less than or equal to the reported packaging mass?	Yes
Is sum of auxiliary unit materials less than or equal to the reported auxiliary unit mass?	Yes
Is sum of auxiliary unit packaging materials less than or equal to the reported packaging mass?	Yes
Are all 'separable & recyclable / compostable" selections made?	Yes
If keeper impacts < single-use impacts, are auxiliary impacts <= single use impacts?	Yes

Review Checks Requiring User Input		
Is any recycled content verified according to the auditing requirements?	Yes	User Input
Are all relevant checks met, allowing results to be shown in Step 5 below?	Yes	
	(If this is "No", results will not be shown)	

Step 6: Eligibility Results

Reported Masses

Keeper Container Mass Reported (container + packaging):	100.0%
Auxiliary Unit Mass Reported (container + packaging):	100.0%

Calculated MUFI Results

	Climate change	Resource use, minerals, and metals	Water use	EOL waste
Calculated Component MUFIs:	1	1	2	1

Single Calculated MUFI:	**1**	
Quantity of Product at MUFI Threshold	**4377**	**milliliters**
MUFI Threshold:	**2.2**	**auxiliary units (unit of measure for MUFI threshold)**

Eligibility Result: Meets MUFI Threshold

Refill Me: 4 times *(This number indicates that the keeper container must be fully refilled at least 4 times to meet the single calculated MUFI*

Step 7: ISO Circularity Indicator Results [reporting purposes; not used for eligibility]

Reported Indicators

	Keeper container	Auxiliary container
Reused content (%)	0.0%	0.0%
Recycled content (%)	0.0%	0.0%
Renewable content (%)	0.0%	0.0%
Designed reusability (%)	0.0%	0.0%
Designed recyclability (%)	0.0%	0.0%
Designed biological recirculation (%)	0.0%	0.0%

Appendix: Optional Results for Data Collection Only

Product System characteristics

	Capacity ratio	Efficiency ratio
Keeper container:	6.3	
Auxiliary Unit:	26.7	5.1

Appendix F: Methodology for setting Minimum Uses for Impact (MUFI) thresholds

Consumer behavior requirement for the refillable standard

F.1. Purpose

This methodology defines how consumer survey data are used to set Minimum Uses for Impact (MUFI) thresholds for refillable products. The MUFI threshold is a behavioral screening value: it represents a reasonable minimum level of lifetime use that the evidence indicates consumers can be expected to achieve. The threshold is not intended to represent average consumer use and is not itself intended to serve as an environmental break-even point or take the place of a calculated MUFI. Its role is to identify products whose design or format is associated with a sufficiently low expected lifetime use that they should not qualify against the consumer behavior requirement.

F.2. Evidence base and measurement

The thresholds are derived from a consumer survey analysis. The analysis estimates expected lifetime use for each relevant product group.

- For cleaning products, cleansing products, moisturizers and deodorants, lifetime use is expressed as the total volume of product dispensed, in US fluid ounces (US fl oz).
- For makeup, lifetime use is expressed as the number of refills used.

Volume dispensed is used for the non-makeup categories because refill size is itself an important driver of the number of refills a consumer may use. Using total volume therefore provides a more consistent behavioral measure across products supplied in different refill sizes.

F.3. Statistical basis for the threshold

The lower quartile (25th percentile) of the survey-derived expected lifetime use distribution is used as the basis for the MUFI threshold. This deliberately sets the threshold below the median: approximately three quarters of the observations used to derive the estimate are at or above the lower-quartile value.

F.4. Product segmentation

Consumer behavior is assessed against two characteristics: product subtype (e.g., for cleansing products, face cleanser vs hand cleanser) and keeper container form factor (e.g., pump bottle vs squeeze bottle). The survey results are analyzed for these characteristics separately rather than as a full cross-break of every subtype-by-format combination.

A full cross-break was not adopted because it would create a large number of individual thresholds, many based on small samples. That would add complexity and maintenance burden to the standard, make future expansion to additional product types more difficult, and increase the risk that individual thresholds would be unstable or appear arbitrary.

Product subtype remains the primary classification because it is readily recognizable to brands and consumers and, in the original analysis, generally differentiated expected behavior more strongly than keeper format. Keeper format is nevertheless retained as a downward adjustment because subsequent analysis found evidence that format can independently affect expected lifetime use.

F.5. Calculation of the final MUFI threshold

Each product is assigned to a product subtype and, where applicable, a keeper container form factor. The final

threshold is the lower of the two relevant lower-quartile values:

Final MUFI threshold = lower of (product subtype lower quartile) and (product type x keeper format lower quartile)

Taking the lower value avoids setting a threshold above the level suggested by either independently relevant aspect of the product. It therefore preserves the intended function of MUFI as a conservative screen for consumer behavior rather than a prediction of the exact lifetime use of a particular subtype-by-format combination.

Makeup is assessed by product subtype only because the available analysis does not provide an equivalent keeper-format breakdown. Survey response categories such as “other” and “not sure” are not used as certification categories in the final threshold tables.

F.6. Final MUFI threshold values

The values below are the final thresholds produced by applying the method above. For the volume-based categories, values are expressed as total lifetime product dispensed in US fl oz. “N/A” indicates that the subtype/format combination is not used in the threshold matrix. It should be noted that not all of the data in the table below is used in the current iteration of the Standard, but that it will likely be used to inform Standard extensions into some of these product subtypes and container types.

The Q_{MUFI} for makeup was established in terms of the number of refills of the makeup compact rather than a number of US fluid ounces. The team determined that each refill would contain approximately 9 grams of makeup, based on available refillable makeup products. Thus, the REST utilizes the number of refills below multiplied by 9 grams per refill.

Table 16. Final MUFI thresholds by product subtype and keeper format (US fl oz)

Product subtype	Spray	Pump	Squeeze	Screw cap	Jar	Stick	Roll-on
Dish soap	190	289	289	234	N/A	N/A	N/A
Floor cleaner	190	221	221	221	N/A	N/A	N/A
Glass cleaner	148	148	148	148	N/A	N/A	N/A
Hand soap	N/A	250	188	232	109	N/A	N/A
Body wash	N/A	181	181	181	109	N/A	N/A
Facial cleanser	N/A	71	71	71	71	N/A	N/A
Hand lotion	56	56	39	N/A	21	N/A	N/A
Body lotion	56	56	39	N/A	21	N/A	N/A
Facial moisturizer	16	16	16	N/A	16	N/A	N/A
Solid stick deodorant	N/A	N/A	N/A	N/A	N/A	52	N/A
Gel stick deodorant	N/A	N/A	N/A	N/A	N/A	56	N/A
Roll-on liquid deodorant	N/A	N/A	N/A	N/A	N/A	N/A	68
Spray-on deodorant	110	N/A	N/A	N/A	N/A	N/A	N/A

Note: The table contains the combined final MUFI values. It should be used directly rather than applying a second subtype/format adjustment.

Table 17. Final MUFI thresholds for makeup (number of refills)

Product subtype	MUFI threshold
Foundation	4
Pressed powder	5
Blush, bronzer, highlighter	4
Eyeshadow	5
Concealer	4

F.7. Review and extension of the thresholds

The same approach can be applied when new product subtypes or keeper formats are added, or when new consumer evidence becomes available: use the lower quartile of the relevant behavioral measure and apply the lower of the subtype and keeper-format values.

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