Understanding Packaging (UP) Scorecard Methodology

[Beta Version 0.4]

A free, easy-to-use web-based tool to assess the sustainability impacts
of common food packaging and serviceware choices

Methodologies developed by the Single-Use Material Decelerator (SUM'D)

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This is a beta version of the tool. Future versions of the UP Scorecard with new features and additional improvements will be published on www.UPscorecard.org.

About the UP Scorecard and SUM’D

The Understanding Packaging (UP) Scorecard is a free, easy-to-use web-based tool to assess the sustainability impacts of common foodware and food packaging choices. It tackles the challenge of finding the most sustainable choice for a specific use case by providing the food service industry (and other users) with consistent and comprehensive environmental and health impact data to make an informed decision.

The UP Scorecard is being further developed and managed by the Single-Use Material Decelerator (SUM’D), which is a passionate and dedicated team of leading food service companies, NGOs, and technical experts. For more information about SUM’D, its members, and the UP Scorecard, visit the UP Scorecard’s website.

Citation Guidelines

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License Information

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1 Scorecard Overview

The Understanding Packaging Scorecard provides sustainability scores for generic container systems and foodwares that are commonly used in the food service industry (referred to in this document as "products"). For each product, the scorecard calculates scores in six impact areas (referred to in this document as "metrics"), and a summary score.

Two of the six metrics are qualitative material and system ratings (Recoverability, Sustainable Sourcing); one is an indicator of the possible presence of harmful substances in the food contact material used (Chemicals of Concern); and three are life cycle impact metrics (Climate Change, Water (blue) Use, and Plastic Pollution). This document provides an overview of the six metrics, their calculation steps, and discussion on the scientific understanding and data used to develop them.

1.1 Overview of Metrics

Plastic Pollution

Indicator: g of plastic leakage to the environment

The Plastic Pollution metric estimates the amount of plastic that enters the environment. It includes plastic pollution to land and aquatic ecosystems. Leakage from the following five life cycle stages is estimated:

- Loss during resin raw material manufacture, handling, and transport (e.g. as "nurdles")
- Loss in the supply chain during conversion from resin to containers
- Loss as litter during or after use of container
- Handling and management after use, including sorting and reclamation
- Loss during disposal

We estimate leakage rates at each stage and report the aggregate contribution to plastic pollution, in units of mass. Different plastic resins are assumed to leak at the same rate for a particular life cycle stage. As location-specific (e.g. state, county, or city) data representing litter rates and waste management practices become more available, the estimates of plastic leakage can be updated to account for these data. Details in §Life Cycle Model and §Plastic Pollution.

Chemicals of Concern

Indicator: scale from 2 - 20 based on chemicals of concern and material inertness
The Chemicals of Concern (CoC) metric is intended to encourage suppliers to better understand the chemical impact of their products and to empower purchasers to eliminate chemicals of high concern from their portfolios and ask for safer ingredients. To provide a starting point and pathway to safer foodware and packaging, a matrixed approach was developed that considers the avoidance of chemicals of concern in the packaging material, the inertness of the material, and the properties of the food being packaged. These scores are then combined to calculate a total CoC score for each food contact material on the scorecard's results page. Where only limited or highly uncertain data were available to inform the score, this is visually communicated to the user on the scorecard's results page. Details in §Chemicals of Concern.

Recoverability

Indicator: scale from 1 to 5
The Recoverability metric is a qualitative rating that represents the potential for the material to be reused, recycled or composted. This metric considers compostability, packaging design for recyclability, and material persistence. All materials are ranked in one of five performance tiers. The tiers, and placement of materials within the tiers, were developed through interviews with experts outside the project team.

This metric provides a complement to the *cutoff* (i.e. Recycled Content) method used for the life cycle metrics. While the cutoff method does provide for lower impacts due to the avoidance of disposal processes (landfilling and/or incineration without energy recovery), it does not give avoided burden credits for recycling. The Recoverability metric does, however, provide higher scores for materials that are designed to be recycled. Thus, the tool addresses both “ends” of the recycling system: the use of Recycled Content as raw material inputs, and the ability to recover those materials after their use as food service products. Details in §Recoverability.

Climate

Indicator: g CO_2 equivalents (CO_2e)
The Climate indicator estimates the mass of carbon dioxide equivalent emissions of the product and is assessed using the IPCC 2013 radiative forcing factors, as implemented by the Ecoinvent Centre. The implementation includes 45 substances characterized in terms of their relative radiative forcing potential in comparison to carbon dioxide. Details in §Life Cycle Model and §Climate Change & Blue Water Use.

Sustainable Sourcing

Indicator: scale from 1 to 5

Many experts interviewed for this project spoke to the importance of sustainable sourcing when considering the environmental tradeoffs of different packaging materials. Two priorities emerged from these discussions: increase the use of post consumer recycled content and, for bio-based materials, reward sustainable agriculture and forestry practices. In addition to reducing lifecycle water consumption and greenhouse gas emissions, mixing post consumer recycled content into the packaging material closes the loop and creates demand for additional recycling while reducing the need to extract virgin materials. Because of the concern about chemical contamination from recovered materials, the Sustainable sourcing metric only rewards recycled content in some types of products: metals (aluminum and steel), glass, and PET bottles. Details in §Sustainable Sourcing.

Water Use

Indicator: Liters of consumed water

To assess water use by the product system, we followed the methodology of the Global Water Footprint Standard (Hoekstra et al., 2011). We computed “blue water footprint,” which reports consumptive use of surface and ground water throughout the product supply chain, including actions that result in the transfer of water between reservoirs. The blue water footprint is reported in units of physical volume of water consumed, and it does not reflect water scarcity or any other spatial or geographic factors of water use. Blue water also excludes natural rainwater for irrigation (“green water”) and ignores the emission of pollutants or contaminants into water (“gray water”). Details in §Life Cycle Model and §Climate Change & Blue Water Use.

1.2 Material definitions and transformations

The general modeling framework is illustrated in Figure 1.1. Foodwares and packaging can be made of a diverse range of materials, and new materials are being developed all the time. To deal with this complexity, the model maps between three distinct types of materials: Component, Base, and Activity.

A. Component materials represent a part of a product that is designed to be separable by the user. For example, a generic single-use beverage bottle may have three components, each classified with a component material: the bottle (PET, stretch-blow molded), the closure (HDPE, injection molded), and the label (PP film with ink and adhesive). Some component materials are homogenous single materials, while others are multi-material and heterogenous.

B. Base materials represent homogeneous functional materials.

C. Activity materials represent distinctions between materials, depending on recycled content.

Examples of the material mappings are shown in Figure 1.2. First, when necessary, *component* materials are "separated" into their *base* materials. This mapping is performed by multiplying the mass of the *component* material by the mass fraction for the corresponding *base* materials (Figure 1.2B). Next, *base* materials are mapped to final *activity* materials. The base-to-activity material mapping is rule-based. Some of these mapping rules are generic and could apply to many types of base materials, while some rules are base-material specific.

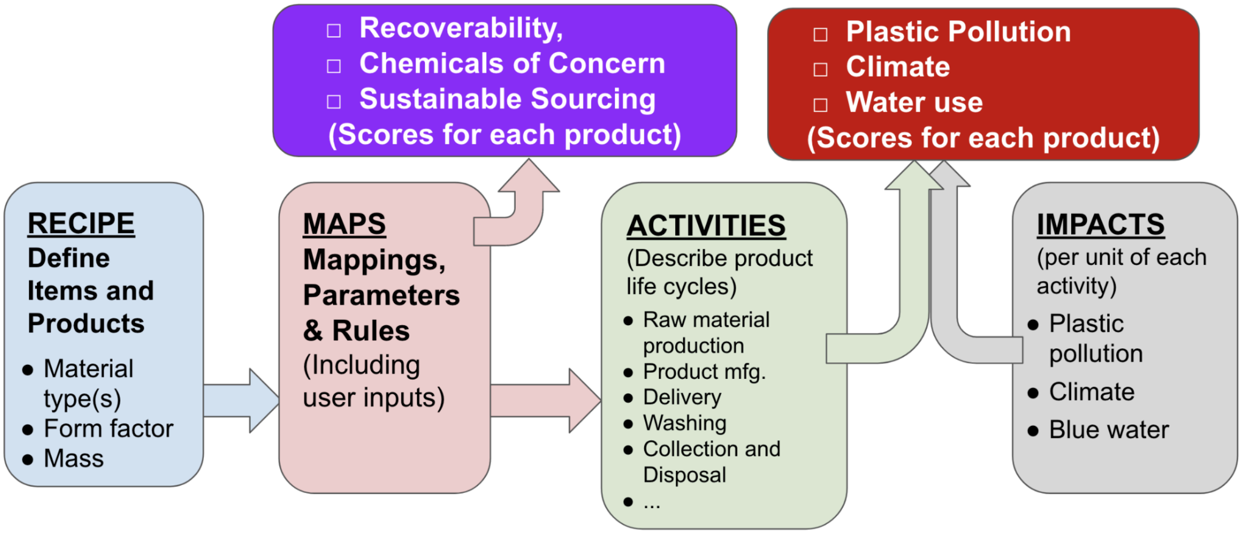
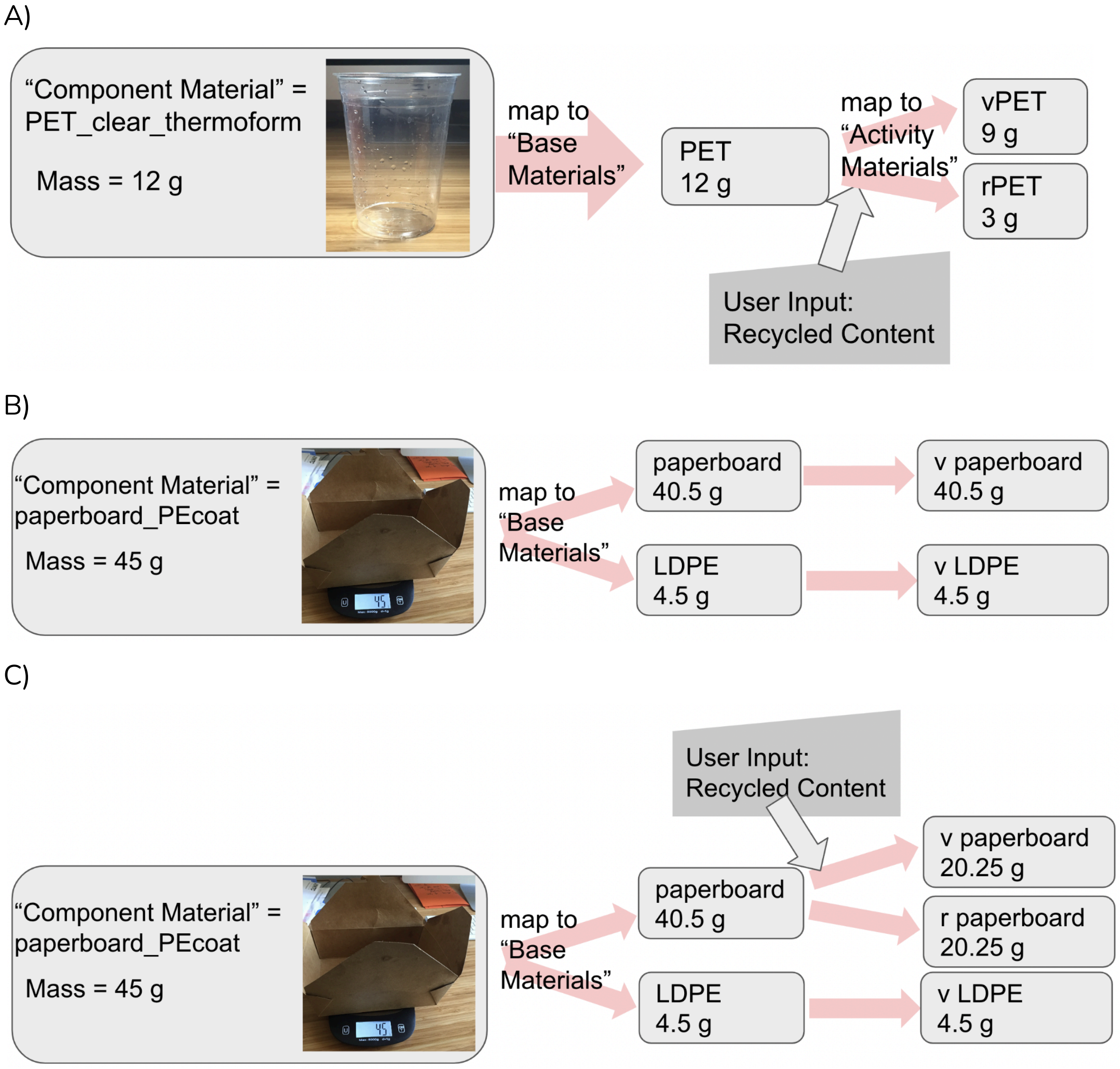


Figure 1.1. Overview of the modeling framework. The metric scores in the purple box (top, left) depend on material types as well as user inputs to specify details about the product and about recovery infrastructure available to the user. The Scores in the red box (top, right) are life cycle impacts and rely on rule-based mapping from materials to activities. The life cycle model estimates impacts of each activity.

Figure 1.2. Examples of mapping from *component* materials (left), to *base* materials (center) to *activity* materials (right). All three examples show mappings for a product with only one component. A) Shows a mapping where the *component* material and *base* material are the same. In the example shown, the mapping from base material to activity depends on user input. B) Shows a *component* material that must be mapped to two different base materials. In this case, recycled content is not allowed, so the mapping from each base material to an activity does not depend on user input. C) Shows a *component* material as in B), but for which paperboard is allowed to have recycled content, so the map from Base to Activity Material depends on user input. Note: “v” denotes virgin material, while “r” denotes recycled material.



1.3 Scorecard Framework

Products are defined by Product Recipes, which provide the model input. Each row represents one component of a product. As described above, components of a product are characterized by a mass of a predefined *component* material.

The UP Scorecard can be used in one of two modes: a “Product Comparison” mode, and a “Portfolio Score” mode. In Product Comparison mode, the user selects products that all have the same function, and the scores are calculated relative to a standard serving size (so that all products provide the same amount of the function, e.g. 1 liter of cold liquid for drinking).

In Portfolio Mode, the user selects products from any and all use cases and is prompted to indicate the number of each product purchased (and used). This is meant to represent the foodwares used by an establishment during a given time period. Scores are calculated based on the products and quantity specified by the user (see next Section). For reusable products, the “number of each product” could indicate the purchase, end of life, and all reuses of a product, or it could indicate only one use of the reusable product. In v0.4, the user enters the number of reusable products purchased, and all uses are assumed to be represented by the portfolio.

In either mode, the general user flow is as follows: First, the user selects a region where the product/portfolio will be used. Then, they select a use case (product family), and all products that are members of the use case are shown as selections to the user. Use cases are listed in Table 1.1, along with the standard serving sizes.

The Scorecard allows for user-control of the following parameters:

- Number of uses for a reusable product system (*numuse*)
- Recycled content in a product system (*RC*)
- Transport distance from manufacturing to retail; four possible transport modes (*truck_trans_retail*, *train_trans_retail*, *boat_trans_retail*, *plane_trans_retail*)
- Recovery rate (*recover*), based on:
    - Availability of Composting and Recycling infrastructure
    - Whether product is optimized for recovery
    - Whether product is certified to be compostable
- Presence of Chemicals of Concern, based on:
    - Compliance with a tiered list of CoC
    - Verification of declaration of compliance

Table 1.1. Use Cases and the functional unit used to characterize the service provided by the products within the use case.

Use Case	**Characteristic Unit**
Cold Cups	1 liter of container volume
Cold Cup Lids	100 sq. cm of lid area
Hot Cups	1 liter of container volume
Hot Cup Lids	100 sq. cm of lid area
Straws	1 item
Beverage Containers	1 liter of container volume
Cold Take Out	1 liter of container volume
Hot Take Out	1 liter of container volume
Plates and Trays	200 sq. cm of serving area
Utensils	1 item
Bowls	1 liter of container volume
Ramekins	1 liter of container volume
Lids for Bowls and Ramekins	100 sq. cm of lid area

2. Scoring

In this section, the concepts that guide scoring are described. Then, in the following subsections, the step-by-step processes for generating scores are listed.

To make comparisons within the scorecard, it is necessary to compare two products that provide different amounts of some function (for example, cups that have different volumes). So, we need to decide how to account for this difference in size when we compare their impacts. In the jargon of life cycle assessment (LCA), setting a "functional unit" allows one to define a standard quantity of a product or service. In some cases, defining a standard quantity is straightforward, and relatively uncontroversial. In other cases, there is no perfect way to define the standard amount. In the UP Scorecard, a standard amount is defined for each use case, as listed in Table 1.1 (above).

The UP Scorecard calculates Raw Scores and Normalized Scores for each of the six metrics. The Raw Scores indicate the impact associated with a product or portfolio of products. The Normalized Scores provide an indication about how good an option is, relative to the alternatives (for the Climate, Plastic Pollution, and Water Use metrics), or relative to the minimum and maximum possible per-service score.. As discussed in the previous section, the UP Scorecard operates in two distinct modes: a Product Comparison mode and a Portfolio Scoring mode:

- Product Comparison mode
    - Raw Scores represent the impact of using a product to supply a standard amount of a service (e.g. 1 liter of cup volume; see Table 1.1). In this mode, a "product" is not necessarily just one item. For example, if a cup has a volume of 100 mL, the raw scores for that cup, in Product Comparison mode, represent the use of 10 of those cups.
    - Normalized Scores provide a scale from worst to best product
- Portfolio Scoring mode
    - Raw Scores represent the impact of using a product. In this mode, a "product" is just the item itself. The user enters the quantity of each product in the portfolio
    - Normalized Scores provide a scale from worst to best for each metric, and for a Portfolio Summary score.

In Product Comparison mode, the Raw Scores for the quantitative metrics (Climate, Plastic Pollution, Water Use) represent the impact associated with providing a standard amount of service, using the product. This is done to provide a fair comparison between products of different sizes. For example, what if you want to compare the climate impact of a 100 mL PP clear plastic cup Vs. a 500 mL all-paper cup? In Product Comparison mode, we do not simply compare one of each cup. Instead, we compare using each product to provide the standard amount of service for cups (1000 mL; see Table 1.1). The comparison would be between *ten* of the 100 mL PP cups Vs. *two* of the 500 mL paper cups. We give this 'functional raw score' variable the name *raw_standard_score*.

In Portfolio mode, Raw Scores for the quantitative metrics are based on the impacts of the products - the actual products specified, and the quantity of each. We give this 'product raw score' the variable name *raw_product_score*. The conversion between these two scores is shown in Table 2.1.

Table 2.1. Conversion between *raw_product_score* and *raw_standard_score*. The standard score represents the provision of a predefined amount of service (for example, 1 liter of cup volume), while the product score represents all uses of a particular product.

Metrics	**Calculation of *raw_product_score***
Climate, Plastic Pollution, Water	$= raw\_standard\_score * numuse * \frac{\text{Product Size}}{\text{Standard Size}}$
Recoverability, Sustainable Sourcing, Chemicals of Concern	$= raw\_standard\_score * numuse$

Note: *numuse* = number of uses; for single-use products, *numuse* = 1.

To compare reusable and single-use products, we must rely on the number of uses for a particular reusable product. The number or reuses represents the number of times a product is used during its lifetime. For single use products, the scorecard assumes it is used only once before end-of-life (so number of uses = 1, and the total function it can provide is equal to its volume). For pre-defined reusable products, the number of uses has a default value (based on the material and usecase), but the user can customize this parameter.

Consider an example of scoring in Comparison mode, which includes a single-use and a reusable item. If one single-use 0.5 liter aluminum can has a climate impact of 200 g CO_2e, then the raw climate score for the can shown in Comparison mode is 400 g CO_2e (two 0.5 liter cans, providing 1 liter of total function). For reusable products, the scores shown in Comparison mode represent only the number of uses of the reusable product that are necessary to provide the standard serving. For example, if a 0.5 liter reusable bottle has a per-use life-cycle climate impact of 110 g CO_2e per use, then the raw climate score for the reusable bottle shown in Comparison mode is 220 g CO_2e (two uses of the 0.5 liter reusable bottle, providing 1 liter of function).

In Product Comparison mode, a single *summary* score is calculated for each product, based on the Normalized Scores for that product (see Section 2.2). Like the normalized scores, the Summary scores are between 1 and 100. A summary score is also calculated for the portfolios in Portfolio Scoring mode.

The methodologies for generating the raw standard scores for each metric are described in their respective Sections 4 through 8, further below in this document. Then, raw product scores are calculated (Table 2.1 above). For single-use items, the raw product score represents the production, logistics, use, and end-of-life of one product. For reusable items, the raw product score represents one use of the product (including the appropriate share of the production, logistics, and end-of-life of the reusable product). The number of uses parameter provides the scale between the per-use scores and the product scores (all-uses) for reusable products. Details of the life cycle model used to calculate the quantitative impacts (climate, plastic pollution, water use), including details about reusable items and washing, are in Section 3.

2.1 Normalized Scores

In both Product Comparison mode and Portfolio mode, *Normalized scores* are calculated for each metric, derived from the Raw Scores. Normalized scores all have a range from 1 to 100, where 100 is best. In both Comparison and Portfolio modes, the normalization depends on the range of ‘best to worst’ raw scores.

The goal of the Normalized Scores, for both Product Comparison and Portfolio modes, is to provide an indication about how well a product or portfolio of products performs, relative to other options that are available. A low Normalized Score means the option is among the worst performing; a high normalized score means the option is among the best performing.

For Comparison Mode, the normalization is calculated using *raw_standard_score*, and the MIN and MAX values specified in Table 2.1. The normalization range is defined by the best and worst possible scores (for qualitative metrics, which have a predefined maximum and minimum), or on the worst performing default product (for quantitative metrics). The maximum and minimum per-product (use) scores are shown in Table 2.2.

For Portfolio Mode, the normalized score is calculated similarly to the Comparison Mode. The difference is that the normalization range for quantitative metrics is determined using the lowest raw score among default products (instead of zero, as with normalization in Comparison mode).

Table 2.2 Characteristics of each of the raw product scores for the six metrics. These MIN and MAX values define the normalization range for calculating Normalized Scores in the Product Comparison mode. The lifecycle methodology does not assign credits for avoided impacts, so the plastic pollution, climate, and water impacts are bounded by zero for the minimum (see §Discussions for more about the LCA accounting used). Lower raw scores are always better across all metrics.

Metric	Type	MIN	MAX
plastic pollution	number	0	MAX of all default products in Usecase
chemicals of concern	integer	2	20
recoverability	integer	1	5
climate	number	0	MAX of all default products in Usecase
material sourcing	integer	1	5
H2O	number	0	MAX of all default products in Usecase

2.2 Product Comparison mode: Step-by-step

The following instructions describe how raw, normalized, and summary scores are calculated in Product Comparison mode.

1. For each product, and for each metric, calculate the *raw_standard_score*, as described in Sections 4 through 8, further below in this document. This score represents the impacts per standard amount of service

2. For the quantitative metrics (Climate, Plastic Pollution, Water Use), find the MAX *raw_standard_score* across all default products within the use case (regardless of which products the user selected for viewing)
    a. The MAX is based on all the products in a use case, not just the ones selected by the user for viewing

3. For each metric, define its scoring weight (w_i)
    By default, all six metrics are weighted equally, so w = 1/6 = 0.1667

4. For each product, and for each metric, calculate the *normalized score*, based on the *raw_standard_score* and and the MIN and MAX (described in Table 2.1):

    normalized score = 1 + 99 * (MAX - *raw_standard_score*) / (MAX - MIN)

5. For each product, calculate *summary* score:

$$\textit{summary score} = \sum_{i=1}^{M} w_i * s_i ,$$

where
M = # of metrics (6)
w_i = weight specified for each metric (in #3)
s_i = normalized score for each metric calculated above (in #4)

Display results

- The scorecard reports the *normalized* score for each metric as well as the *raw score* for each quantitative metric (Climate, Plastic Pollution, Water Use)
- The colors shown in the scorecard results are based on the *normalized* scores. There are five colors, which correspond to five equal-spaced bins between 1 and 100 (since the normalized scores are all between 1 and 100)
    ○
- Products are listed in the scorecard results in the order of highest to lowest *summary* score.

2.3 Portfolio Scoring mode: Step-by-step

Calculate Scores

The following instructions describe how raw and normalized scores are calculated in Portfolio Scoring mode.

1. For each product, and for each metric, calculate the raw product score (*raw_product_score*). This score represents the total raw score per product, including all of its uses (for reusable products). These are calculated from the *raw_standard_score*, according to Table 2.1.

2. For each metric, calculate the raw portfolio score (*RawPortfolioMetric*) for the user-defined portfolio

   $$= \sum raw\_product\_score(\text{p}) \ * \ quantity(\text{p}),$$

   for all products (p) in the portfolio, where *quantity*(p) is the number of each product in the portfolio.

3. For each metric, and for each product (p) in the portfolio, identify the best and worst score possible. For the three quantitative metrics (Climate, Plastic Pollution, Water Use), the best and worst scores are selected among all default products defined in the UP Scorecard, within the usecase. For the three qualitative metrics, the per-use best and worst scores are given in Table 2.2.

4. For each metric, calculate the Normalized Portfolio Metric Score for the user-defined portfolio:

   $$1 + 99 * ((\, HighestPossibleMetric - RawPortfolioMetric) \,/\, (\, HighestPossibleMetric - LowestPossibleMetric\,)\,)$$

   where *HighestPossibleMetric* and *LowestPossibleMetric* were calculated in #3.

5. Based on the quantity (and number of uses) of each product in the portfolio, define two alternative portfolios that provide the same number of product uses as the user-defined portfolio, but that use the ‘best’ and ‘worst’ products within each usecase. Best and Worst products are defined by the Summary Score for each product (see previous subsection §2.2).

6. Calculate Raw and Normalized scores for the alternative ‘Best’ and ‘Worst’ portfolios (same procedure as for the user-defined portfolios, step #4).

Display results

- The scorecard reports the *normalized* score for each metric as well as the *raw score* for each quantitative metric (Climate, Plastic Pollution, Water Use)
- The colors shown in the scorecard results are based on the *normalized* scores. There are five colors, which correspond to five equal-spaced bins between 1 and 100 (since the normalized scores are all between 1 and 100)

3 Life Cycle Model

3.1 Overview and LCA Model Framework

The Climate, Water Use, and Plastic Pollution metrics are life cycle indicators, meaning that impacts from throughout the product life cycle are included. Processes include raw material production (virgin material and post-consumer recycled content), transport from manufacturing to use, washing and transport for washing (for reusables), litter, collection after use, and disposal.

The LCA model is relatively simple. There are 129 activities (as of v0.4) that are used as "building blocks" to model each product. The set of activities (with amounts) that comprise the model of a product serves as a 'bill of materials and services' required for the use of that product. Some activities represent the supply of material, while others represent material transformations, transport, and disposal. These activities provide a life cycle model with an intermediate level of complexity that allows real-time score updates when parameters are changed, as well as a high level of transparency.

Each activity is modeled as a process that uses material and energy inputs. The ecoinvent database is used as the primary source of LCA data. Please see the Activities Documentation for details about the data sources and assumptions used to estimate the impacts associated with each activity. The process models are implemented using the appropriate regional electricity generation mix. In addition, region-specific values for recycled content , recovery rates, and disposal processes are used. (see §Regionalized Activity Impacts for details)

For each product, the LCA model calculates the numerical score for the three life cycle metrics (Plastic Pollution, Climate Change, Water Use). The model uses the product definitions and the Scorecard's user interface elements (UI) as input, and performs various mappings and lookups to build up the model. Simplified examples of mappings are shown in Figure 1.1 and described in §Material definitions and transformations.

The current list of the activities, with characteristic units and data sources used to generate impacts (Climate impact, Water Use, and Plastic Pollution), are in the Activities Documentation. Impacts per unit of activity are shown in Activity Impacts.

3.2 System Boundary & Recycling

When a foodware item is recycled into a “new” material or product, it is necessary to decide where the life cycle for the first product ends and the second one begins. In the approach used for the Scorecard, the impacts from recycling (sorting, transport, and reclamation) are assigned to the product that *makes use of* the recovered material. With this accounting method (known as the *cutoff* method or *recycled content* method), the processes involved in recycling and reclamation are treated more like a raw material supply system than a waste management system. If the impacts of recycling and reclamation are lower than the impacts of primary (virgin) material production, then a product with recycled content will typically also have a lower impact (and vice versa). See §Discussion of the cutoff LCA Accounting Method for more information.

The Scorecard only considers the health and environmental performance of the foodwares. Neither cost nor aesthetics are considered, and all products within a given use case are assumed to have comparable performance. The food or beverage inside the container is excluded from the scorecard.

3.3 Modeling Details

3.3.1 Reusable Food Service Wares

All single-use products are compared to a reusable case. The reusable options for each use case are shown in Table 3.1, with the default number of uses (including loss and breakage) and number of items that fit on a standard commercial washing rack. The resources required for a washing cycle are shown in Table 3.2. Washing is assumed to occur offsite, and so transport is required, as shown in §Transport and Collection.

Table 3.1. Reusable product systems included in the Scorecard Tool.

Use case	Reusable system	Number of uses	Items per commercial dishwasher rack
Cup, hot	Ceramic mug; Glass mug; Stainless steel mug w/PP lid	30; 30; 50	25; 25; 25
Cup, cold	Glass; Plastic (PP); S. Steel	25; 40; 40	25; 25; 25
Plate & tray	Ceramic	30	14
Bowl	Ceramic; Plastic (PP)	30; 40	16; 21
Ramekin	Ceramic	30	36
Bottled drinks	S. Steel w/PP lid	100	25
Takeout	Glass; Plastic (PP)	40; 50	14
Utensil	S. steel	50	240
Straw	S. steel	50	320
Lid, bowl	Plastic (HDPE)	50	39
Lid, cup	Plastic (PP)	50	50

Table 3.2. Inventory for washing reusable products. Dishwasher is assumed to be a high temperature commercial “Stationary Single Tank Door” type, as specified in (USEPA, 2020).

Flow	Unit	Amount	Source
Electricity: wash	kWh / wash cycle	0.35	(USEPA, 2020)
Electricity: standby	kWh / wash cycle	0.55	(USEPA, 2020); assuming 1 hr
Water	L / wash cycle	3.37	(USEPA, 2020)
Detergent	g / wash cycle	20	Adapted from (Franklin Associates, 2009; Quantis et al., 2010)
Natural gas for water heating	cu m / wash cycle	0.024	(Franklin Associates, 2009)

3.3.2 Recycled Content and Material Recovery Rates

Recycled Content (RC) and Recycling Rates are based on regional averages from best available statistics. The default values for different regions are shown in the Recycled Content and Recovery Tables. Recycled content includes only post-consumer material.

In the UP scorecard, the user can customize recycled content and whether collection and recovery is available for a particular type of material.

3.3.3 Disposal: Landfill and Incineration

Material that is not recovered for recycling or composting is disposed of, either in a sanitary landfill or via incineration, or is exported. The mix of material that goes to landfill, incineration, and export is determined from regional statistics (see Disposal Tables). While most incineration facilities do recover heat for steam and electricity, the revenue earned from energy sales is not typically sufficient to operate incineration plants. Facilities must rely on tipping fees (paid by the waste generator or hauler) for economic sustainability (Liu et al., 2020). Thus, we adopt the methodology used by ecoinvent (cutoff method), whereby the primary “product” of incineration facilities is the service of waste management, and not the energy byproduct (ecoinvent [v3.7.1], 2020). All impacts from incineration are assigned to the product being burned.

3.3.4 Bio-based materials

Bioplastic

PET is produced from two main raw materials: ethylene glycol (EG) and terephthalic acid (TPA). About 30% of the mass of PET comes from EG, and 70% from TPA. Synthesis of bio-based EG from bio-ethanol is a well-developed process and bioEG is available at a large scale. However, TPA produced from bio-derived materials is currently not available on a large scale (Volanti et al., 2019). Thus, the bioPET that we are modeling is 30% bio-based, with 70% of its mass coming from fossil-based TPA. The bioEG production process inventory data comes from GREET (2020), and we assume that ethanol is produced from corn grain.

Land use emissions due to bio-based materials

Primary fiber-based materials (directly from the field or forest) are assigned a land-use requirement, per kg of material. The values, methods, and sources for land use requirements are shown in Table 3.4. These land-use requirements are used to calculate GHG emissions due to land use and land use change (LUC). Impacts due to land use only apply to primary materials - those that are sourced directly from the field or forest. Recycled materials are not assigned land use impact.

For corn-based products (PLA, bio ethylene glycol), our estimate of GHG emissions associated with land use is 100 g CO_2e per square meter of annual land occupation (m^2a). This value was chosen to be a compromise between the estimate of GREET, which reports about 74 g CO_2e / m^2a (GREET, 2020), and the estimate by the California Air Resources Board, which reports about 196 g CO_2e / m^2a (CARB, 2015).

Land use impacts for other non-grain-based products (wood, wood pulp, bamboo) are estimated based on a fraction of the impacts for grain. This fractional multiplier is shown in Table 3.4 in column "LUC mult". In general, the multiplier for grains, trees, grasses, and harvested by-products is 100%, 10%, 5%, and 1%, respectively.

Table 3.4. Land requirements for bio-based materials.

Material	Land required (m^2a/ kg)	Source & Methods	Crop	LUC mult
bio ethylene glycol	3.065	(GREET, 2020). Uses 3.3 g corn grain / g bioEG; corn grain ethanol as feedstock; assumes harvest of 172 bu grain / acre (10.8 t / ha)	maize grain	1.0
PLA	1.186	(GREET, 2020). Uses corn grain as feedstock; 1.28 g corn grain / g PLA; assumes harvest of 172 bu grain / acre (10.8 t/ha)	maize grain	1.0
softwood	3.633	(ecoinvent [v3.7.1], 2020). Land use from "softwood forestry, pine, sustainable forest management - GLO". Weighted average of Birch, Spruce, Pine. // Assumes wood yield is 90% of harvested logs.	softwood (mix)	0.1
paper	6.017	same as "pulp from softwood"	softwood (mix)	0.1
paperboard	6.017	same as "paper"	softwood (mix)	0.1
cartonboard	6.017	same as "paper"	hardwood (mix)	0.1
pulp from softwood	6.017	(ecoinvent [v3.7.1], 2020). Land use from "softwood forestry, pine, sustainable forest management - GLO". Weighted average of Birch, Spruce, Pine. // Pulp yield from (ecoinvent	softwood (mix)	0.1

		[v3.7.1], 2020) “sulfate pulp production, from softwood, unbleached - GLO”		
bamboo	0.231	Adapted from (Chang et al., 2018; Zea Escamilla & Habert, 2014) // Assumes bamboo yield is 80% of harvested culm	bamboo	0.05
pulp from bamboo	0.264	Adapted from (Chang et al., 2018; Zea Escamilla & Habert, 2014) // Assumes pulp yield is 70% of harvested culm	bamboo	0.05

Biogenic Carbon content of Recycled Content and Recovered Material

The default assumption regarding bio-based materials is that biogenic carbon (bioC) in these products will not be sequestered indefinitely, and that the carbon that was withdrawn from the atmosphere (during plant growth) will be re-emitted to the atmosphere during decomposition. For this reason, we do not assign credit to primary (virgin) bio-based materials for atmospheric carbon removal. Likewise, we do not count emissions of biogenic CO_2 during decomposition toward the climate impact. However, if a material contains bioC that will not decompose within 100 years, this fraction of carbon is considered sequestered, and the product system is given a proportional credit for the carbon sequestration.

To maintain carbon-accounting consistency for recycled content, the bioC fraction of the recycled inputs must be tracked in order to correctly determine the bioC content of the container. In addition, the bioC of material that leaves the product system boundary should be reported in case it is used as raw material in another product system.

3.3.5 Glass Production & Recycling

The resource requirements for production of glass bottles depends strongly on the amount of recycled content (cullet) used. We approximate this relationship by extrapolating between two ecoinvent glass production models: the global default with 0% cullet, and the European average with 60.5% cullet (Figure 3.1). Extrapolating through these two points gives a linear relationship that approximates available data, including the Glass Packaging Institute study for North America (GPI et al., 2010). Water impacts were also modeled through extrapolation.

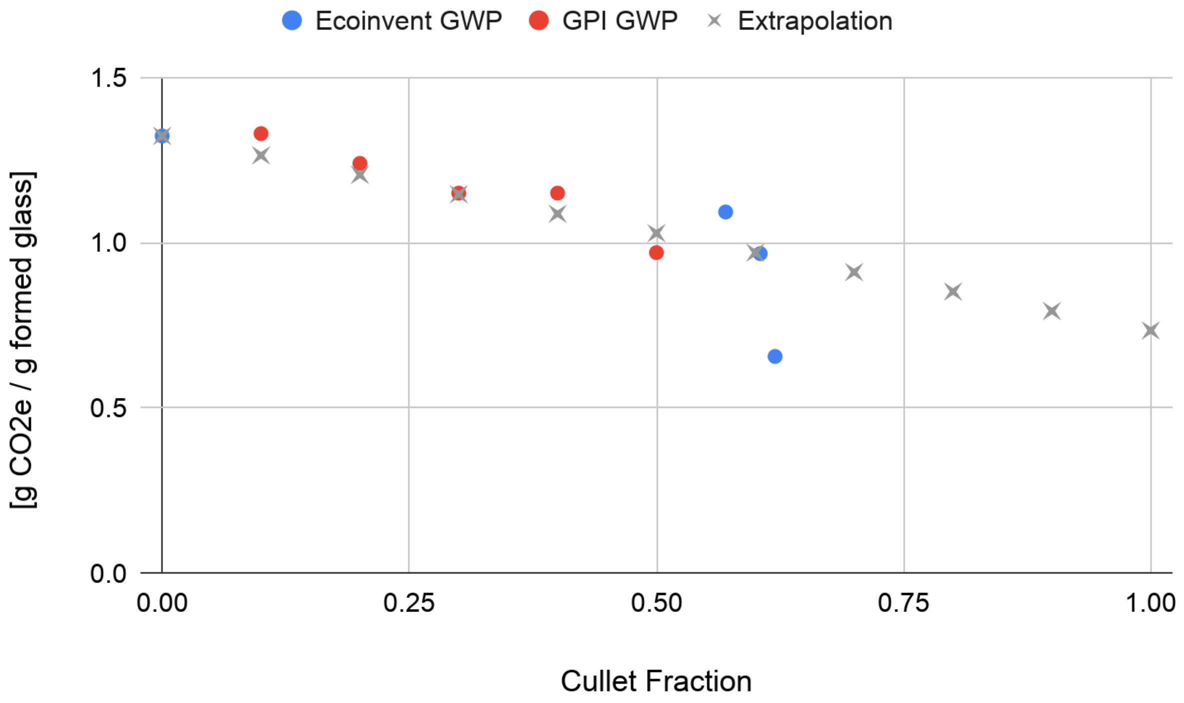


Figure 3.1. Variable carbon dioxide equivalent (CO_2e) emissions of glass production by cullet fraction, computed via extrapolation

Whether glass in single-stream recyclables is a resource or contaminant depends on the particular case. With the proper equipment and processes, glass can be recovered from MRFs, to be sold and reused. However, many facilities do not have the infrastructure to separate glass from single-stream sources. In these cases, MRFs view glass as a contaminant, and so some jurisdictions have begun to eliminate glass from their list of acceptable items. For these reasons, recycling rates for glass are variable.

3.3.6 Transport and Collection

Transport processes include raw materials to the foodware factory gate, a product delivery stage to the retail location, collection from retail to sorting or disposal, sorting to landfill, sorting to remanufacturing, and remanufacturing to factory gate. In practice, these distances are all dependent on the location of the user of a material. The distances in Table 3.5 are used for the baseline case. The “Bottling to retail” transport leg can be updated with case-specific information by the user.

Table 3.5. Assumed transport distances. Purchasing decisions will have the most impact on “Forming to retail” distances, so this parameter is user-editable in the scorecard interface. Distances for “Sorting to disposal” and “Sorting to reclamation” are adapted from (APR & Franklin Assoc., 2018); other distances are assumed.

Transport Leg	Mode	Distance (km)
Washing (for reusables; round trip)	truck	0
Raw material to preform or forming factory	truck	100
	train	1000
	ocean	0
Preform to forming factory	truck	50
Forming to retail	truck	500
	train	0
	ocean	0
Collection (use to transfer station)	truck	50
Transfer station to disposal	truck	350
	train	0
Sorting to disposal	truck	100
Sorting to reclamation	truck	350
	train	0

3.3.7 Blue Water Use

For processes drawn from the ecoinvent database (version 3.7; cutoff methodology), we implemented the model in a way that is consistent with the Blue water footprint (Hoekstra et al., 2011). Ecoinvent uses a harmonized list of “elementary” flows, which are flows exchanged between industrial processes and the natural environment. The aggregated totals are computed over all processes through matrix inversion. While most of the individual processes within ecoinvent are carefully water-balanced, ecoinvent’s conventions for reporting water consumption and water emissions are not consistent with certain aspects of the water footprint standard, particularly the requirement that water moved between reservoirs counts as blue water consumption. However, an indicator that considers all water withdrawals as blue water consumption will over-report impacts for processes that use and return significant amounts of water to the same reservoir, such as turbines and cooling water.

To approximate blue water consumption over activities in the ecoinvent database, we assigned characterization factors to some of the ecoinvent elementary flows representing water exchange between industrial processes and the natural environment. Flows that represented water withdrawal from surface or groundwater reservoirs were assigned a positive factor of 1, while flows that represented water return to these reservoirs were given a factor of -1, thus reducing the size of the footprint. Outflows of water to air or to the ocean were given zero characterization. The ecoinvent water flows and their characterizations are shown in Table 3.6.

This approach correctly computes water footprint for the most important processes in the model, including the polymer production and container forming processes. For some activities, the approach under-reports blue water footprint by ignoring water that is moved between reservoirs within one activity, or water withdrawn in one activity that is carried within a product and emitted in a different activity. However, we did not identify any significant instances of under-counting in the current study.

Table 3.6. Blue water footprint characterization factors for ecoinvent flows

Inputs - Ecoinvent Flow Name	Blue Water Characterization
Water, cooling, unspecified natural origin	1
Water, salt, sole	1
Water, well, in ground	1
Water, salt, ocean	0
Water, river	1
Water, turbine use, unspecified natural origin	1
Water, unspecified natural origin	1
Water, lake	1
Outputs - Ecoinvent Flow Name and compartment	
Water, to water	-1
Water, to air	0
Water, urban air	0
Water, surface water	-1
Water, rural air	0
Water, to lower stratosphere and upper troposphere	0
Water, to air, low population density, long-term	0

Water, to water, ground-	-1
Water, ocean	0

3.5 Regionalized Activity Impacts

For activities that represent raw materials supply and product forming processes, the Climate and Water Use impacts are calculated using region-specific electricity mixes. This is accomplished by connecting common foreground process inventories to region-specific electricity grids when calculating impacts of each activity. For example, the process of thermoforming plastic is assumed to use the same amount of electricity in all regions, but the generation mix of the electricity supply is distinct for each region. Thus, the impact of the thermoforming activity will be different by region. The activities that use regional electricity grids are denoted in the *region status* column in Activities Documentation. In addition, region-specific values for recycled content, recovery rates, and disposal processes are used.

As described above, a common process inventory is used for most activities. The main exception is primary aluminum, which is modeled according to the regional models prepared by the International Aluminum Institute (IAI) and provided in ecoinvent. For US conditions, the Canadian mix is used (Canada is the dominant aluminum producer in North America); for Europe and China, the appropriate regional mixes are used; for Brazil, the South America mix is used. For Japan, Indonesia, and the global average, the rest-of-world mix is used.

Polymer production uses inventory data published by Plastics Europe (as included in ecoinvent). For these processes, regionally-specific grid models are applied for the final production activities, as long as the electricity use is reported in the inventory. For major commodity precursor chemicals, including ethylene (input to PET and PE), xylene (input to PET), and propylene (input to PP), the inventory data are pre-aggregated in ecoinvent, and did not report electricity consumption. However, the regional electricity grid is applied to the polymerization stage of material production. For PET, the production of terephthalic acid, ethylene glycol, and the final production stage (PET) are all modeled using the regional grid specification. The materials tetrafluoroethylene (used as a proxy for PFAS), polystyrene, and nylon are also pre-aggregated in ecoinvent, so these materials have the same impacts in all regions.

Forming processes and use phase activities (e.g. washing) use the regionally appropriate grids. Likewise this is done for recycling activities (e.g. collection and sorting), except for aluminum recycling, which use a global average process for scrap preparation.

For primary paper production, regional grids are applied to the final production process only. Upstream inputs (mainly sulfate pulp) are not modified because of the lack of suitable information about commodity flows and the relatively low significance of electricity in the upstream activities. We utilized the ecoinvent default sulfate pulp model, which is a mix based on the estimated global market for paper production.

The electricity grids are implemented as defined in ecoinvent, for the following regions:

- Individual countries (e.g. United States, Brazil, Indonesia, China, Japan)
- Europe: ENTSO-E region (European Network of Transmission System Operators), representing electricity grids in 35 countries
- Global average

The activity impacts for each region are shown in Activity Impacts.

3.6 Discussions

3.6.1 Discussion of the “Cutoff” LCA accounting method

At the foodware item’s end of life, the item is collected and transported to its next stage of life. These impacts are assigned to the packaging system. If the item then enters final disposal, the burdens of landfill or incineration are also considered within the packaging item’s system boundary. If, however, the used foodware material enters a recycling process, then the material is considered to leave the foodware system. This is referred to as a *cut off*, and the material enters the first stage of its next life cycle carrying *zero burden*. In practice, this will be delivery to a sorting or material recovery facility.

The same principle applies to composting, anaerobic digestion, and incineration with energy recovery: if the foodware item supplies material or energy to a *subsequent* product system, then the burdens of the recovery and processing activities are also assigned to that subsequent product. So, if composted foodware is used for landscaping, emissions from composting are assigned to the finished compost used in landscaping. Likewise, if an incineration plant delivers energy services, then the burdens of these activities are assigned to the user (or seller) of the energy. If, on the other hand, composting or incineration are used simply to dispose of the product, their burdens are assigned to the food packaging item.

Even though no “credits” are given to the foodware item in these cases of open-loop recycling, some benefits do accrue when material is diverted away from disposal and to recycling and composting: The impacts from disposal (landfilling and incineration without energy recovery) are avoided when material is recovered.

The cutoff approach we use has the benefit of being relatively simple and fair. With a credit-based approach, the “generator” of the material for recycling gets credit for displacing virgin material production. In the case of open loop recycling (the user of recycled material is in a different business than the generator of the material), the credit approach requires that the user of recycled material be assigned the burdens of using 100% virgin material, when in fact they are using recycled content. Not only is this dubious from the perspective of the recycled content user, but it also introduces significant difficulty for maintaining compatible models of different product systems.

While the cutoff method does have the benefit of simplicity and relative fairness, perhaps its main shortcoming is the assumption that, without the recycled content, a product manufacturer would make the product, but with virgin content. Put another way, the cutoff method assumes that recycled content is of sufficient quality to replace virgin content. In some downcycling applications, this is probably not a justifiable assumption. However, in the realm of food packaging and food wares, we believe that it is reasonable to assume that the product would have been produced whether recycled content was available or not.

3.6.2 Discussion of Plastic Pollution

For this study, we reviewed literature on plastic entry into the environment and determined plausible rates of plastic pollution for each life cycle stage. Although the topic of plastic pollution has become more prominent in the past few years, there remains very little direct evidence of leakage rates in the scientific literature. Jambeck et al. (2015) focused on waste management of post-consumer plastics to develop their widely-cited estimate of 4.8-12.7 million tonnes of plastic entering the oceans per year. To develop this figure they applied a blanket assumption that 2% of plastic products were littered by consumers. The Plastic Leak Project Methodological Guide (Quantis & ea, 2020) adapts this assumption by suggesting different litter rates by item size form factor.

A crucial study performed by Eunomia on behalf of Fidra, an environmental charity in the UK (Eunomia et al., 2016), focused on “nurdles,” or pre-production pellets of resin that typically have a diameter of 2-5mm. The study reports that there are “very few reliable estimates of pellet loss in Scotland and the UK, and no direct measurements at all." The authors found a handful of regional studies throughout the world with estimates ranging from 0.001-1.0% of total production lost to the environment, but scant or no direct observational data to support many of these estimates. They ultimately concluded that between 0.001-0.01% of pellets (10-100 mg/kg or parts per million) could be lost at each stage of handling and transport, but emphasize that the data foundation of this estimate is minimal.

An additional study performed direct observations of pellets in waterways around a polyethylene factory in Sweden (Karlsson et al., 2018). The study found that between 300-3000 kg of plastic particles per year were emitted into the environment by the facility. Normalizing by the facility's production capacity of 750,000 tonnes per year results in an estimated range of 0.26-4 parts per million. The authors observed that plastic between 300 microns and 2 mm in diameter made up two thirds of the observed mass flow, emphasizing the importance of considering leakage below nurdle size. Given the limitations of the study, as well as the relatively stronger regulatory environment in Sweden, we adopted a compromise estimate of 70 parts per million for pellet leakage during production, and 100 parts per million for leakage during each processing stage (container production and secondary material reclamation).

Plastic leakage rates and data sources are listed in §Plastic Pollution.

3.6.3 Discussion of bio-based materials

A primary motivation for the use of bio-plastics is the potential for reducing greenhouse gas emissions by using biomass as a material feedstock, and to reduce dependence on fossil fuels. Since the carbon content of biomass is collected directly from the atmosphere, any recalcitrant carbon in bio-plastic that is sourced from biomass is credited with sequestering atmospheric CO_2.

When plants grow, they convert CO_2 in the atmosphere to many carbon-containing compounds (cellulose, sugars, proteins, fats, etc). Thus, the growth of biomass results in removal of carbon from the atmosphere. If a long-lasting material contains biogenic carbon, it may be assigned a "sequestration credit" to reflect the reality that the biogenic carbon was removed recently from the atmosphere by the plant (as opposed to fossil carbon, which was extracted from a pool of carbon that was already sequestered from the atmosphere). Long-lived material could include uses like wood, paper, or cardboard (which could last for hundreds of years depending on the use case). Long-lived could also refer to a single-use bioPET material in a landfill (which is mostly inert to decomposition over the span of 100 years).

3.6.4 Discussion of emissions due to land use

Emissions from indirect land use change (iLUC) result from market-mediated conversion of forest (or other ecosystems with significant carbon contained in standing biomass or soils) to agriculture. For example, if a policy or decision leads to increased demand for corn (as with the biofuel mandate in the US), this may lead to increased acreage producing corn, and reduced acreage in the US producing soybeans. In turn, land elsewhere in the world may be dedicated to soybeans, thereby increasing pressure to convert land to agriculture. A similar situation may occur with forest products, where an intensively managed forest for harvest contains less ecosystem carbon than a mature diverse forest. Impacts due to land use only apply to primary materials - those that are sourced directly from the field or forest. Recycled materials are not assigned land use impact.

The iLUC process is highly uncertain, and it is nearly impossible to reliably attribute a policy or action with any particular land-clearing event. Nonetheless, many economic models, as well as remote sensing studies, indicate the iLUC effect is real.

4 Metric: Chemicals of Concern

4.1 Overview

The presence of toxic chemicals in food packaging associated with harm to humans and the environment is well documented. Additives used in paper, pulp and plastic products that are intended to improve performance can have an unintended consequence of contaminating food or beverages as well as dispersing harmful chemicals in the environment during either production or end of life (i.e., via. composting, recycling, or incineration).

In a life cycle assessment model, however, the ability to quantify the potential hazards to human health due to ingestion of chemicals leached from packaging is highly uncertain. However, this subject has gained increasing research attention. Uncertainties arise at all points: about the ability to identify chemicals present in food packaging, their likelihood of migrating and contaminating the food or beverage product, their levels in the food, and the ability to characterize or assess the possible adverse effects of different chemicals and their mixtures (Ernstoff et al., 2019; Hahladakis et al., 2018).

Given these complexities, the Chemicals of Concern (CoC) indicator should be viewed differently from the other scorecard indicators. The goals of the CoC indicator are:

- To increase transparency along the supply chain with regards to chemical additives in food contact materials;
- To provide a pathway toward safer chemistry in food contact materials;
- To ensure harmful substances are limited or eliminated;
- To close information gaps by assessing and verifying safer materials for circular applications that also addresses chemical safety beyond current legal requirements; and
- To encourage and amplify sustainable product innovation.

This work is meant to provide a starting point in discussions between food service organizations and their suppliers, and it should not be viewed as the final word on the possible risks from chemicals of concern. As further explained below, the methodology developed and described here for the UP Scorecard is intended to be further improved in future scorecard updates, pending the availability of currently limited data, as well as constructive and evidence-based feedback received from scorecard users and their suppliers.

4.2 Context

A recent peer-reviewed article in *Environmental Health* titled, “Impacts of Food Contact Chemicals on Human Health: A Consensus Statement" (Muncke et al., 2020) was written by 33 international scientists, and 200+ environmental groups signed a declaration of concern supporting the statement (“A Declaration of Concern and Call to Action Regarding Plastics, Packaging, and Human Health,” 2020). The peer-reviewed article identifies current challenges and sets out a clear path to where the industry is heading. The authors point out that

- Inadequate global regulations of chemicals in food packaging pose a growing risk to human health;
- There are critical gaps in information needed to assess human and environmental hazards and risks, and safeguard public health;
- Efforts to achieve a circular economy must consider chemical hazards.

With increasing evidence and awareness about the adverse health implications of food packaging, comprehensive legislative and regulatory changes are expected in the coming years. The voluntary actions taken by companies to improve their scorecard results will help them stay ahead of legislative and regulatory requirements and be perceived as leaders in the industry.

The reduction/elimination of known chemicals of concern in foodware and packaging products and processes through a tiered chemicals of concern list is part of a transition toward the ultimate goal of safe and circular products and systems.

What are Chemicals of Concern?

Informed by authoritative bodies (e.g. ECHA, UNEP/WHO), a chemical of concern is a chemical substance that has one or more of the following hazard properties:

- Carcinogenic, mutagenic, toxic to reproduction (CMR)
- Endocrine disruption
- Persistent, bioaccumulative and toxic (PBT)
- Very persistent and very bioaccumulative (vPvB)

Thereby, the levels of chemicals of concern present in a food contact material or migrating into the food are not considered for the following main reasons:

1. Highly hazardous chemicals that are of concern should not be used in food contact materials, regardless of their levels. This responds to the common understanding of safety, meaning that food packaging should not contain hazardous chemicals.
2. For certain chemicals of concern (mutagens, carcinogens, endocrine disruptors) a safe exposure level may not exist (for example, due to limited data), or it may not be practically enforceable (for example, because the analytical detection limit is not sufficiently low). For these chemicals it is more practical to discourage their use in food packaging, because the low thresholds cannot be controlled. It also is a practicality that avoids costly and complex testing.
3. Chemicals transfer in mixtures from packaging into food or the environment, and so, assuming safe thresholds for single chemicals does not address mixture toxicity. Therefore, eliminating all CoCs also addresses mixture toxicity concerns.

It is important to note that this metric only addresses intentionally used chemicals and chemicals well-known to be present in materials. During packaging production, other non-intentionally added substances may be formed or introduced (e.g. from using recycled content). These are not explicitly addressed by this metric but are considered to a limited extent by estimating the potential for chemical migration from a material taking into account its inertness and the properties of the food it is in contact with.

The scorecard is intended to encourage suppliers to better understand their chemical impact and to empower purchasers to ask for safer ingredients as well as encourage the use of the Principles of Green Chemistry to inspire innovation (Anastas & Eghbali, 2010). Designing and producing materials around these principles can be used at any stage in the supply chain to improve sustainability as well as protect the consumer, employee, community, and the environment.

To provide a starting point and pathway to safer foodware and packaging, a matrix approach was developed that calculates two separate scores to:

1. Consider the avoidance of chemicals of concern and reward verification of claims
2. Consider the migration potential for any present chemicals of concern to migrate from the product into food and the environment; based on the inertness of the food contact material, and interactions the foodware and packaged food can have with the material.

These two scores are then combined to calculate a total CoC score presented for each packaging item on the scorecard's results page. Where data is limited or lacking, this is visually communicated to the user on the scorecard's results page.

4.3 Presence of Food Chemicals of Concern Score

Toward the goal of safe and circular foodware and packaging, purchasers are seeking to avoid certain chemicals of concern in the products they procure. Therefore, the first of the two indicators within the scorecard's CoC methodology is based on the Food Chemicals of Concern (FCOC) List, which was developed to capture known chemicals of concern present in foodware and packaging materials. The chemicals of concern within this list are prioritized and grouped into three tiers, where Tier 1 presents a shortlist of priority chemicals of concern to avoid, based on broad stakeholder agreement, and Tiers 2 and 3 present more extensive sets of chemicals that should not be used in the manufacture of food contact materials.

In many cases, the chemicals included in these tiers go beyond current legal and regulatory requirements, which could help suppliers and purchasers stay ahead of emerging regulation and consumer concerns. However, in an event of a possible conflict, legal requirements must be followed.

The inclusion of substances on the FCOC List is based on research and information provided by leading NGO and industry associations including Environmental Defense Fund (EDF), the Food

Safety Alliance for Packaging (FSAP), and Food Packaging Forum (FPF). Where guidance from separate organizations overlapped, they were summarized to reflect the most general among the overlapping identified chemicals of concern, both in terms of the chemicals' scope and the group of chemicals covered (e.g., all lead compounds versus just lead sulfates).

To reflect the best science available, the FCOC List will be periodically updated in future versions of the scorecard.

Table 4.1 defines the requirements for the scorecard user to place a foodware or packaging product within each of the three tiers describing the product's compliance with the FCOC List. Unless noted otherwise, the FCOC List applies to the presence of the intentionally added chemicals in the product.

Table 4.1. Tiered compliance with the FCOC List for a foodware or packaging product

Tier	Description
0	Not compliant for chemicals of concern identified in Tier 1.
1	Does not intentionally contain any of the chemicals of concern identified by Environmental Defense Fund (EDF) (Environmental Defense Fund, 2021). EDF has identified chemicals in food packaging and food handling equipment where the potential health impacts from their migration into food raises serious concerns. These chemicals in virgin materials may also contaminate the recycling stream and undermine their recyclability. Does not intentionally contain any per- and polyfluoroalkyl substance (PFAS) according to the OECD definition (OECD, 2021): "PFASs are defined as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e. with a few noted exceptions, any chemical with at least a perfluorinated methyl group (–CF3) or a perfluorinated methylene group (–CF2–) is a PFAS."
2	Does not intentionally contain any of the chemicals of concern identified in Tier 1 plus chemicals of concern identified by the Food Safety Alliance for Packaging (FSAP) brand owners' working group document: Food Packaging Stewardship Considerations v1.0 (Food Safety Alliance for Packaging, 2018) that have been screened against the Food Packaging Forum's (FPF) Food Contact Chemicals database (FCCdb) for relevance (Food Packaging Forum, 2021).

3	Does not intentionally contain any of the chemicals of concern identified in Tiers 1 and 2 or any of the priority food contact chemicals identified in the Food Contact Chemical database (FCCdb) developed by the FPF (Food Packaging Forum, 2021).

Once a tier of compliance has been established for a product, a progressive approach to verify the claims of this compliance has also been established to offer the scorecard user increased confidence in the data they are using for decision making. Table 4.2 shows a set of four levels from which a user can choose, when describing the level of disclosure to validate self-documented compliance with one of the tiers from Table 4.1.

Table 4.2. Levels of disclosure for claimed tier compliance of a foodware or packaging product

Level	Description
0	Supplier is unable to provide information about in-scope chemicals of concern in the materials within the foodware or packaging product
1	Supplier self-reports compliance of all in-scope chemicals of concern within the tier
2	Supplier provides a statement on their website or a written (preferably publicly available) declaration from an officer level representative of the company to demonstrate compliance with all in scope chemicals of concern within the tier
3	Supplier provides third party verified certificates of analysis (CoA) and/or approved certification program equivalent (preferably publicly available) for all in-scope chemicals of concern within the tier

The assigned tier (Table 4.1) and level of disclosure (Table 4.2) for a foodware or packaging product are used together by the scorecard to identify the resulting score for the Presence of Chemicals of Concern, as shown in the matrix in Table 4.3.

Table 4.3. Matrix defining a foodware or packaging product's score within the methodology for the presence of chemicals of concern based on FCOC List compliance and the level of disclosure

		Disclosure			
		Level 0	Level 1	Level 2	Level 3

FCOC List Compliance	Tier 0	10	10	10	10
	Tier 1	10	9	8	7
	Tier 2	10	8	6	4
	Tier 3	10	7	4	1

For example, a product with Tier 1 FCOC List compliance based on Level 1 self-declaration would receive 9 points and be assigned a ‘below average’ score (as categorized in Table 4.4). In contrast, a product that is compliant with Tier 3 of the FCOC List and has Level 3 third-party verified results would receive 1 point and a dark green rating indicating ‘best’.

Table 4.4. Categorization of the CoC presence score as determined in Table 4.3

CoC Presence Score	Score Indicator
10	Worst
8-9	Below average
6-7	Moderate
4	Better
1	Best

Unless the user inputs information to describe a packaging article's compliance within a tier of the FCOC List and a disclosure level, the article by default is automatically assigned to have Tier 0 compliance and a Level 0 disclosure (resulting in a CoC presence score of 10).

4.4 Migration Potential Score

Apart from considering the intentional presence of chemicals of concern in a foodware or packaging product, the second aspect of this methodology considers the propensity for any present chemicals of concern to migrate from the product into the food. This chemical migration is responsible for the resulting chemical exposure to the consumer that could result in adverse health effects. While chemicals in a product can migrate from it during all stages of its life cycle (including manufacturing and end of life), the focus within this methodology is placed on considering the migration of chemicals into food during the product's use phase.

Hundreds of different chemicals of concern across the three tiers can be present at different levels in the thousands of different food contact material (FCM) compositions that exist on the market and can be used in foodware and packaging products. Also, specific products within the same category may vary considerably. This is in addition to the thousands of non-intentionally added substances (NIAS) that could be present, are often not analytically identifiable, and could also be of concern. As very limited to no quantitative information exists in the public domain to describe the migration of these chemicals from most products during their different uses and applications, a qualitative and generalized approach has to be applied to take into consideration this human exposure potential, focusing on the generic properties of the different direct food contact materials and the role that the properties of the food itself can play in increasing migration.

This is done by considering 1) the inertness of the FCM in the foodware or packaging product that is in direct contact with the food and 2) the properties of the food in contact with the foodware or packaging material.

Material Inertness

The inertness of a material can be described by proxy through testing its overall migration rate, which is the total amount of chemicals that migrate into the food. While standardized tests do exist for determining overall migration from an FCM, very little data exist in the public domain to quantitatively describe this for most FCMs, and the resources required to test this for the thousands of different FCMs on the market are far beyond the scope of this project.

Therefore, to qualify the inertness of the different generic foodware and packaging products in the scorecard, a set of seven scientific FCM experts with testing expertise were consulted. They were each asked to independently qualitatively score the overall migration potential from a set of 34 generic FCMs included in §Appendix Table 10.1 from 'very low' to 'very high'. When determining their score for each material, the experts were asked to always consider a standard food contact area (6 dm^2/kg food) and the worst-case food conditions that could increase the overall migration (e.g. high temperature, acidic, high fat content, etc.). To translate the results from this expert consultation into a numerical score, a point scale was implemented from 10 (highest overall migration; least inert) to 1 (lowest overall migration; most inert).

The results from the consultation showed that the experts have varying opinions on the overall migration potentials of most materials. However, a consensus was reached for a small subset of the materials: glass, stainless steel, and ceramic were identified as having the lowest overall migration potential (highly inert), while recycled paper and board was identified as having the highest overall migration potential (least inert). For all of the other materials in Table 10.1, no consensus could be reached. Recycled paper and board was therefore assigned a score of 10, and glass, stainless steel, and ceramic were assigned scores of 1. Without additional scientific data to inform the overall migration potential of the other materials in Table 10.1, a precautionary approach is taken that assumes the worst-case and assigns a score of 10 for these other materials. As this is a highly uncertain assumption, all CoC results presented for products in the scorecard based on these FCMs are clearly marked as being uncertain using a hashed circle on the scorecard's results page. Future versions of the scorecard will aim to improve this approach following additional expert input and data provided by product manufacturers. See the section on §Looking ahead below for more discussion regarding this.

Using the assigned scores for each FCM shown in §Appendix Table 10.1, these are translated over to each of the foodware and packaging products considered in the scorecard and shown in §Appendix Table 10.2 based on the primary FCM they contain that is in direct contact with the food.

Food and Material Interaction

In addition to the inertness of the food contact material, the conditions of use and the chemistry of the foodstuff also have an influence on the migration of chemicals out of a food contact material used for foodware or packaging. To address these interactions between food and FCM, this metric adapts an evaluation scheme developed and published by (Geueke et al., 2022) for the Association of the Swiss Organic Agriculture Organisations (Bio Suisse). The approach creates a food and material interaction score based on six factors that influence chemical migration for a product including: typical storage time, storage temperature, fat content of the food, acidity of the food, aggregate state of the food, and the volume of the foodware of food packaging as an indicator of the surface-to-volume ratio.

For a product, one of five values is chosen that most accurately describes each of the six factors as shown in Table 4.5. These values each correspond to a score from 1 (worst, leading to highest migration) to 5 (best, leading to least migration).

Table 4.5. Scoring scheme evaluating six factors of food and material interactions leading to higher or lower potential for chemical migration based on typical storage conditions and physical-chemical properties of the foodstuffs.

Storage time		**Storage temperature**		**Fat content (of foodstuff)**		**Acidity (of foodstuff)**		**Aggregate state of the food**		**Typical packaging size**	
<4 days	1	<0°C	1	0-2%	1	pH >7	1	Solid food with punctual contact	1	>1 L or >1 kg	1
4-7 days	2	0-8°C	2	3-10%	2	pH 5-6.9	2	Solid food with full contact	2	0.5-1 L or 0.5-1 kg	2
8-14 days	3	9-18°C	3	11-20%	3	pH 3-4.9	3	Semi-solid food	3	0.25-0.49 L or 0.25-0.49 kg	3
15-30 days	4	>18°C	4	21-30%	4	pH <3	4	Liquid food	4	0.1-0.249 L or 0.1-0.249 kg	4

>30 days	5	Any heating >40°C in the packaging	5	>30%	5	Not applicable	5	Not applicable	5	<0.1 L or <0.1 kg	5

A high fat content, for example, increases the transfer of fat soluble chemicals from the food ware or packaging into the food. Similarly, acidic foods and beverages can also raise the migration levels of certain chemicals. It also makes a difference whether solid or liquid foods are in contact with the foodware or packaging material. When migration into solid foods occurs, the chemicals are mainly measured in the portion of the foods that is in close distance to the FCM, whereas chemicals are more evenly distributed in liquid foods and can therefore reach higher overall concentrations over time.

High storage temperatures and long contact times can further increase the migration rates and final concentrations of chemicals. The surface-to-volume ratio between the packaging (surface) and the food (volume) influences the migration behavior. This means that a small packaging item releases relatively higher amounts of chemicals per unit of food because the surface-to-volume ratio is higher in smaller sized packaging.

The Food and Material Interaction Score for a foodstuff and its storage conditions is the sum of the individual scores (a value of 1 to 5) for each of the six factors in Table 4.5. This results in a raw score within a range of 6 to 28. This raw score is then linearly transformed into the corresponding value within the range of 1 to 10, in order to match the range of the Inertness Score.

The Inertness Score and the Food and Material Interaction Score are given equal weight in defining the Migration Potential Score (Equation 4.1).

(Equation 4.1) $$Migration\ Potential\ Score = \frac{Inertness\ Score + Food\ and\ Material\ Interaction\ Score}{2}$$

4.5 Overall Chemicals of Concern Score

With separate scores calculated for 1) the presence of intentionally added chemicals of concern and reliability of the information provided and 2) the Migration Potential Score, these are used together as shown in Eqn. 4.2 to calculate the overall raw food chemicals of concern (CoC) score that are presented in the scorecard results section for a product. With each of the involved sub-scores having a scale from 1 to 10, the overall CoC raw score for a product exists within the range of 2 (best score) to 20 (worst score).

(Equation 4.2) $$CoC\ Overall\ Raw\ Score = Presence\ Score + Migration\ Potential\ Score$$

As an example, a user is scoring a steel water bottle. It achieves a CoC Presence Score of 6 due to the material's compliance with FCOC List Tier 2 and a demonstrated Level 2 disclosure as proof. According to Table 6, the bottle has an Inertness Score of 1. When filled with water, it receives a raw Food and Material Interaction Score of 18, which is then linearly transformed (within a range of 1 to 10) to a score of 5.9. Therefore, the Overall Raw CoC Score for the steel bottle is: 6 + (1+5.9)/2 = 9.45. Linearly transforming it to be within the range of 1 to 100, it will be presented for the CoC metric on the UP Scorecard results page as a score of 47.

4.6 Looking Ahead

The methodology described here and being applied in the Understanding Packaging Scorecard is to the authors' understanding the first published attempt made to scientifically and systematically consider chemicals of concern together with other environmental impact criteria when evaluating foodware and packaging for human and environmental health impacts. While the current CoC methodology can certainly still be improved, it is nevertheless an important step forward in helping stakeholders, many for the very first time, begin to consider the presence of hazardous chemicals in foodware and packaging in their decision making.

The Single-Use Material Decelerator (SUM'D) plans to continue developing this methodology for release in future versions of the scorecard. Among others, the following ongoing work has been planned to reflect the best science available:

- The FCOC List will be periodically updated to incorporate additional chemicals of concern that are added to the source reference lists over time.
- The uncertainty of the inertness scores for many of the FCMs will be reduced through further coordinated input from FCM testing experts as well as through pending results from the Food Packaging Forum's FCCH Project (Food Packaging Forum, 2019), which is extracting FCM migration data from thousands of scientific papers.
- The methodology will be expanded to better address concerns associated with preventing contamination of the recycling stream and the environment.
- Ultimately, avoidance of CoCs, while an important starting point, can lead to regrettable substitution. Future versions aim to incorporate full chemical hazard assessment and optimization options to help companies move beyond avoidance of chemicals of concern and declarations of "free of" and instead encourage suppliers to offer verified safe and circular options. By providing a progressive approach and signaling future needs, the authors recognize that systemic change and innovation in the supply chain will take time.

Constructive evidence-based feedback and recommendations on data sources that could help further develop this methodology are welcome. To provide such information, please contact info@UPscorecard.org. Future versions of the scorecard and updates about its ongoing development will be provided on www.UPscorecard.org.

5 Metric: Climate Change & Blue Water Use

Climate

Indicator: g CO_2 equivalents (CO_2e)

The Climate indicator estimates the kg of carbon dioxide equivalent emissions of the product and is assessed using the IPCC 2013 radiative forcing factors, as implemented by the Ecoinvent Centre. The implementation includes 45 substances characterized in terms of their relative radiative forcing potential in comparison to carbon dioxide.

Water Use

Indicator: Liters of consumed water

To assess water use by the product system, we followed the methodology of the Global Water Footprint Standard (Hoekstra et al., 2011). We computed "blue water footprint," which reports consumptive use of surface and groundwater throughout the product supply chain, including actions that result in the transfer of water between reservoirs. The blue water footprint is reported in units of physical volume of water consumed, and it does not reflect water scarcity or any other spatial or geographic factors of water use. Blue water also excludes natural rainwater for irrigation ("green water") and ignores the emission of pollutants or contaminants into water ("gray water").

5.1 System Boundary & Recycling

The Climate, Water Use, and Plastic Pollution metrics are life-cycle indicators, meaning that the impacts from throughout the product supply chain, product use, and end-of-life disposal are included. These processes include raw material production, container manufacturing, delivery to a food service facility, use, washing (for reusable products), waste collection, landfilling, incineration, sorting, reclamation, and recycling. Please see the §Life Cycle Model for details on the life cycle methodology.

When a foodware item is recycled into a "new" material or product, it is necessary to decide where the life cycle for the first product ends and the second one begins. In the approach used for the Scorecard, the impacts from recycling (sorting, transport, and reclamation) or other reclamation processes are assigned to the product that *makes use of* the recovered material.

With this accounting method (the *cutoff* method), the processes involved in recycling and reclamation are treated more like a raw material supply system than a waste management system. If the impacts of recycling and reclamation are lower than the impacts of primary (virgin) material production, then a product with recycled content will typically also have a lower impact (and vice versa). See §Discussion of the cutoff LCA Accounting Method for more information.

6 Metric: Plastic Pollution

indicator: g of plastic leakage to the environment

The raw plastic score is calculated for each product system.

The Plastic Pollution metric estimates the amount of plastic that enters the environment, and includes plastic pollution to land and aquatic ecosystems. Leakage from the following five life cycle stages is estimated (Table 6.1):

- Loss during resin raw material manufacture, handling, and transport (e.g. as “nurdles”)
- Loss in the supply chain during conversion from resin to containers
- Loss of material into the environment via littering during (or after) use, but before collection
- Handling and management after use, including sorting and reclamation
- Loss due to export

Different plastic resins are assumed to leak at the same rate for a particular life cycle stage. Littering during use (whether intentional or accidental) is the largest source of plastic pollution modeled, by at least an order of magnitude. Each product component is assigned to a litter class, which has a characteristic leakage rate as shown in Table 6.2.

As location-specific (e.g. state, county, or city) data representing litter rates and waste management practices become more available, the estimates of plastic leakage can be updated to account for these data.

Table 6.1. Stage-specific plastic leakage rate estimates used in the SUM methodology

Leakage source	activity group	units	Scorecard value	value (low)	value (high)	sources for low & high
Virgin resin production	rawmat	mg leaked / kg flow	70	7	70	(Eunomia et al., 2016; Karlsson et al., 2018)
Sort & Remanufacture	rawmat	mg leaked / kg flow	100	3	94	"processors" from (Eunomia et al., 2016)
Food ware mfg.	form_prod	mg leaked / kg flow	100	3	94	"processors" from (Eunomia et al., 2016)
Use	use_litter	mg leaked / kg flow	10,000 - 50,000	5,000	50,000	(Jambeck et al., 2015; Quantis & ea, 2020)
Collection & Disposal	dispose	mg leaked / kg flow	100			assumption
Export	disposal	mg leaked / kg flow	100,000	0	500,000	(Borrelle et al., 2020; Lebreton & Andrady, 2019)

Table 6.2. Component classes with characteristic litter rates. Each row (a component of a specific product) in the Product Recipes is assigned to one of these litter classes. Litter rates adapted from (Quantis & ea, 2020).

Component class	Litter rate	activity_id
Small (< 2 cm)	0.05	plastic_use_small
Medium (2 - 5 cm)	0.02	plastic_use_med
Large (> 5 cm)	0.01	plastic_use_large
Unknown/Default	0.02	plastic_use_default
Foam items (all sizes)	0.05	plastic_use_foam

7 Metric: Recoverability

7.1 Overview

indicator: rating scale from 1 to 5

A raw score for the Recoverability (*recov*) metric is determined via lookups for each product system. The lookup depends on the values set in the user interface of the scorecard on two pages:

- Relevant switches on the “Compost and Recycling” page
- “Optimized for Recycling” switch and “Compostable certified” check boxes on the “Customize” page

The Recoverability metric rewards the selection of materials that can be recovered for commercial use or converted to a beneficial material by natural processes (Figure 7.1). The indicator considers a material’s potential to be reused, recycled, composted or naturally degraded to beneficial materials.

Figure 7.1. Description of the 5 levels of the recoverability rating scale

Optimal - Recoverability is not needed [1]	● Reusable packaging and foodwares reduce the proliferation of disposable materials and prevent the need for material recovery.
Recoverable in commerce and the natural environment	● Compostable: Fiber-based, not lined; products that could reasonably be expected to have added per- and polyfluoroalkyl substances (PFAS) must be BPI or CMA certified. ● Recyclable: Fiber-based, clean and dry after use, optimized for recycling using Walmart’s guidelines
Recoverable in commerce but not in the natural environment	● Recyclable: Optimized for recycling. Glass, aluminum and bottles and jugs made from #1 PET and #2 HDPE are assumed to be optimized by default ● Compostable: BPI, CMA certified
Recoverable in the natural environment but not in	● Compostable (as in light green above), but composting not available

commerce	
Not recoverable in commerce or natural environment [5]	- All materials that are not accepted for recycling or composting (except materials in orange above) - Includes fiber-based materials that might be contaminated with added PFAS

Scores are defined by class of material, as shown in Table 7.1. Each material class has a score that applies if material is recovered (recycled, composted, etc), and another score if the material is sent to disposal (landfill or incineration). In order to be considered “recovered”, two distinct criteria must be met:

1. the product’s design is “optimized” for recovery, and
2. the infrastructure to recycle or compost (or other) the material must be available.

The criteria for whether a product is considered to be “optimized” for recovery are specified by material and form factor, as shown in the section on §Criteria for recycling optimization below. These criteria are from the Walmart Recycling Playbook (Walmart Inc., 2019), which was developed with the Association of Plastic Recyclers and the Sustainable Packaging Coalition.

Upon launch of the scorecard, only a select few products are assumed to be optimized for recovery by default. These include uncoated fiber products, PET beverage bottles, HDPE bottles, metals, and glass. The user can change this setting on the scorecard’s “Customize” page for each product.

The availability of recycling and composting infrastructure is specified for material classes. Infrastructure is assumed to be available by default for a few material classes, including recycling for paper dry, clean paper items, PET and HDPE bottles, and glass and metals. The user can change these settings on the scorecard’s “Compost and Recycle” page.

Table 7.1. Recoverability scores assigned to material classes

Recovery class (material)	Description of material	Score if recov = YES	Score if recov = NO
reuse	Reusable packaging or foodwares (take back – sanitize – reuse)	1	1
fiber_no_coat	All-fiber products with no coating/barrier not likely to have	2	4

	PFAS added (wood utensils, paper bags, corrugated boxes)		
fiber_plastic_coat	Wax / poly-coated paper and corrugate (incl. cartons and gable-tops)	3	5
fiber_biopoly_coat	Fiber-based, biopolymer (e.g. PLA) coated	3	5
alum_can	Aluminum cans and bottles	3	5
alum_foil	Aluminum trays and foil	3	5
glass	Glass (containers, jars)	3	5
HDPE_bottle	HDPE bottles and jugs	3	5
PET_bottle	PET bottles	3	5
steel	Steel / Tin (containers, cans)	3	5
PLA	PLA films and rigid	3	5
HDPE_other_rigid	Rigid HDPE (non-bottle/jug)	3	5
PET_other_rigid	Rigid PET (non-bottle/jug)	3	5
PE_film	PE bags and film	3	5
plastic_blend	Polymer blends (any bio + petro or multi-polymer blends)	3	5
composite	Multi-layer / composites (blister packs, aseptics, mylar, etc)	3	5
other_film	Non-PE films, bags, and pouches	3	5
other_rigid	All rigid plastic not made from PET and HDPE containers (PP, LDPE, PS, PVC, etc)	3	5
multi_part	Multi-component/attachments (pumps, metal and plastic, etc)	3	5
foam	Foams (expanded polystyrene (EPS) or other expanded formats)	3	5
small	All items of any material type(s) less than 2" in any dimension	3	5
other	Silicone, rubber, leather, ceramic	3	5
PFAS	Any fiber container with PFAS added	5	5

7.2 Criteria for recycling optimization

The following tables describe conditions for a product to be considered optimized (and thus eligible) to be recovered for recycling. These criteria are from the Recycling Playbook developed by Walmart with the Association of Plastic Recyclers and the Sustainable Packaging Coalition (Walmart Inc., 2019).

Table 7.2. Glass optimized for recovery. Product is considered “Optimized” if it meets criteria in green and avoids those in red. See Wal-Mart’s Recycling Playbook for further detail (Walmart Inc., 2019).

Design optimizes recovery	
Material	Glass container
Color	Clear (colorless), amber, green and blue
Label	Direct print, paper
Design challenges recovery	
Labels	Easy to remove or avoided
Attachments and closures	Avoid anything molded into the glass or ceramic attachments/closures
Non-container glass	Avoid leaded glass (eg crystal) or heat resistant glass (eg Pyrex)

Note: Adapted from *The Recycling Playbook* (Walmart Inc., 2019).

Table 7.3. Metal optimized for recovery. Product is considered “Optimized” if it meets criteria in green and avoids those in red. See Wal-Mart’s Recycling Playbook for further detail.

Design optimizes recovery	
Material	Aluminum, steel
Label	Lacquer printing on container
Attachments, closures	Same as metal package
Design challenges recovery	
Full body sleeves	Avoid using or ensure compatible with removal during recycling

Mixed materials	Avoid using non-metal materials (e.g., no plastic)
Metal trays and pans	Avoid
Attachments and closures	Avoid: Plastic, stickers
Labels	Avoid: Stickers, full body plastic sleeves

Note: Adapted from *The Recycling Playbook* (Walmart Inc., 2019).

Table 7.4. Fiber products optimized for recovery. Product is considered “Optimized” if it meets criteria in green and avoids those in red. See Wal-Mart’s Recycling Playbook for further detail (Walmart Inc., 2019).

Design optimizes recovery	
Material	Natural fiber or recycled fiber
Wet Strength Additives	Compatibility with recycling processing as confirmed by Western Michigan University testing
Coatings	Use no coatings or use clay coatings
Adhesives	Minimal adhesives and tape or hydrophobic adhesives
Attachments	Made from fiber/recycled fiber
Labels and graphics	Paper or direct printed
Design challenges recovery	
Color, Layers, or Additives	Avoid: Plastic/polymer treatments or layers on fiber-based components,wax, UV coatings, metalized films, foils, wet strength additives that haven’t passed Western Michigan University testing, dark colors, fragrances
Attachments and adhesives	Avoid metal, magnetic closures, electronics, RFIDs, PET, PLA, PP, PS, PVC, hot melt adhesives (unless passes Western Michigan University testing)
Labels	Avoid metal foil, metalized printing, PET, PLA, PP, PS, PVC

Note: Adapted from *The Recycling Playbook* (Walmart Inc., 2019).

Table 7.5. Carton products optimized for recovery. Product is considered “Optimized” if it meets criteria in green and avoids those in red. See Wal-Mart’s Recycling Playbook for further detail (Walmart Inc., 2019).

Design optimizes recovery	
Material	Primarily paper with a thin layer of polyethylene
Design challenges recovery	
Mixed materials	Avoid using non-paper materials other than materials used in the carton itself (e.g. no metal attachments/closures)

Note: Adapted from *The Recycling Playbook* (Walmart Inc., 2019).

Table 7.6. Polyethylene Terephthalate (PET) optimized for recovery. Product is considered “Optimized” if it meets criteria in green and avoids those in red. See APR design guide for additional detail (APR, 2021).

Design optimizes recovery	
Resin	PET and PET variants w/ crystalline melting point between 225 and 255C; bio-based OK
Resin Color	Clear, transparent light blue, transparent green
Resin Additives	No degradable or biodegradability additives
Labels	PP or PE (that float when printed)
Attachments	Clear if PET; colored is OK for PP or PE
Closures, Pumps and Sprays	PP or PE
Cap Liner	Made from PE, EVA or TEP or no liner
Tamper Evidence	Easily fully removable, PET, PP or PE
Dimensions	Larger than 2” in two dimensions and largely 3-dimensional (vs flat with one dimension <2”)
Design challenges recovery	
Resin	Avoid PETG, other non-compatible resins mixed in (some EvOH levels are ok)

Resin Color or Additives	Avoid transparent colors other than blue or green, opaque colors, dark colors, optical brighteners, degradable additives or biodegradability additives
Attachments/Closures	Avoid metal, foils, PS, PVC, PLA, TEP/silicon with density > 1, RFIDs
Labels	● Avoid paper, PVC, PLA ● Avoid inks, PS, label structure that sinks in water, metals, pressure sensitive labels, adhesives and direct print other than date coding unless the product passes APR test requirements.
Barriers, layers and coatings	Avoid non-PET barriers, layers and brighteners unless the product passes APR test requirements.

Note: Adapted from the Design Guide for Foodservice Plastics Recyclability (APR, 2021)

Table 7.7. Polypropylene (PP) optimized for recovery. Product is considered “Optimized” if it meets criteria in green and avoids those in red. See APR design guide for additional detail (APR, 2021).

Design optimizes recovery	
Resin	Unpigmented, translucent or opaque
Barrier layers, coatings and additives	EVOH layers
Labels, inks and adhesives	PP, PE; in-mold labels of a compatible polymer; metals, PLA and PS labels that release when washing
Attachments	PLA, PP; plastic attachments that sink in water
Tamper Evidence	PE and PETG tamper evident safety sleeves and seals
Dimensions	
Design challenges recovery	
Tamper Evidence	PVC tamper evident seals
Attachments/Closures	Non-PP attachments unless product passes APR testing
Labels	● Paper ● Inks, direct printing other than date code unless product passes APR testing ● Adhesives ● Metal, PLA or PS labels that don’t release during washing

	- PVC
Barriers, layers and coatings	- Degradable additives - Non PP layers other than EVOH unless product passes APR testing

Note: Adapted from the Design Guide for Foodservice Plastics Recyclability (APR, 2021)

Table 7.8. Polystyrene (PS) optimized for recovery (not EPS). Product is considered “Optimized” if it meets criteria in green and avoids those in red. See APR design guide for additional detail (APR, 2021).

Design optimizes recovery	
Resin	Clear unpigmented
Labels, inks and adhesives	- PS - PP or PE labels that float in water - High melting temperature plastic labels such as PET
Attachments	Clear PS attachments
Design challenges recovery	
Tamper Evidence	Tamper evident sleeves and seals unless product passess APR testing
Attachments/Closures	Non-PS attachments or metals unless product passes APR testing
Labels, inks and adhesives	- Label structures that sink in water - Paper, PVC or PLA - Inks, adhesives or direct printing other than date coding unless product passes APR testing

Note: Adapted from the Design Guide for Foodservice Plastics Recyclability (APR, 2021)

Table 7.9. Expanded polystyrene (EPS) Optimized for recovery. Product is considered “Optimized” if it meets criteria in green and avoids those in red. See APR design guide for additional detail (APR, 2021).

Design optimizes recovery	
Resin	Unpigmented, white, light pink or light blue
Labels, inks and	- PS

adhesives	● High melting temperature plastic labels such as PET ● Direct printing on EPS
Attachments	Clear PS attachments
Design challenges recovery	
Tamper Evidence	Tamper evident sleeves and seals unless product passess APR testing
Attachments/Closures	● Metal or PVC attachments ● Non-PS attachments or metals unless product passes APR testing
Labels, inks and adhesives	● Paper, PE, PVC or PLA labels ● Adhesives unless product passes APR testing
Barrier layers, coatings and additives	Degradable additives unless product passes APR testing

Note: Adapted from the Design Guide for Foodservice Plastics Recyclability (APR, 2021)

Table 7.10. HDPE products optimized for recovery. Product is considered “Optimized” if it meets criteria in green and avoids those in red. See Wal-Mart’s Recycling Playbook for further detail (Walmart Inc., 2019).

Design optimizes recovery	
Resin	HDPE density 0.94-.96
Resin Color	Unpigmented, translucent, opaque colors (not dark)
Resin Additives	No degradable or biodegradability additives
Layers	PE or EVOH less than 3%
Labels	PE, PP
Attachments, Closures, Pumps and Sprays	PE, PLA or PS
Cap Liner	PE, EVA or TPE
Tamper Evidence	PE, PETG
Design challenges recovery	
Resin	Avoid other resins mixed in

Resin Color or Additives	Avoid dark colors with L value less than 40 or near-infrared (NIR) reflectance less than or equal to 10% (can't be sorted), for non-mechanical oil products (which aren't collected for recycling), Optical brighteners, Degradable additives (no biodegradability additives)
Attachments/Closures	Avoid metal, foils, PP, PVC, floating silicone polymer, RFIDs
Labels	Avoid the following for: ● Materials for any type of label: paper, PVC ● Materials just for non-wash releasable labels: PLA, PS, metal foils ● Label coverage: Those that are not APR Preferred, does not pass APR's near infrared (NIR) sorting Potential Test, greater than 60% label coverage of the container side wall section

Note: Adapted from *The Recycling Playbook* (Walmart Inc., 2019).

Table 7.11. PE film products optimized for recovery (includes HDPE, LDPE, LLDPE films). Product is considered "Optimized" if it meets criteria in green and avoids those in red. See Association of Plastic Recyclers Design Guide for more information (APR, 2021).

Design optimizes recovery	
Base polymer	PE (HDPE, LDPE, LDPE)
Barrier layers, coatings and additives	● "Workhorse" additives historically used without issue ● Any non-PE layers pass APR testing ● Degradable additives or other unlisted additives pass APR testing
Color	Unpigmented, white, buff or lightly colored
Labels, inks and adhesives	● Direct printing ● Polyethylene labels
Attachments	Non-polyethylene attachments pass APR testing
Base polymer	
Barrier layers, coatings and additives	● Metalized layers ● PVC and PVDC layers and coatings
Color	Dark colors, particularly blues and greens
Labels, inks and adhesives	Paper labels, metal foil labels
Attachments	Metal and metal containing

Note: Adapted from the Design Guide for Foodservice Plastics Recyclability (APR, 2021)

Table 7.12. Products made of materials which are not generally recycled. For these materials, there is no criteria for optimization.

Design challenges recovery	
Materials	Not typically recycled. Please select “Optimized” only if you are confident that the material will be recovered and reused.

8 Metric: Sustainable Sourcing

Indicator: rating scale from 1 to 5

A raw score for the Sustainable Sourcing metric is determined via lookups for each product system. The scoring criteria is shown in Table 8.1.

Many experts interviewed for this project spoke to the importance of sustainable sourcing when considering the environmental tradeoffs of different packaging materials. Two priorities emerged from these discussions:

1. Increase the use of post consumer recycled content
2. For bio-based materials, reward sustainable agriculture and forestry practices.

In addition to potentially reducing life cycle water consumption and greenhouse gas emissions, mixing post consumer recycled content into the packaging material closes the loop and creates demand for additional recycling while reducing the need to extract virgin materials. The use of higher recycled content is also rewarded by the Climate and Water Indicators. On the other hand, using recycled content also increases the potential for contamination and may negatively impact the Chemicals of Concern Indicator. Because of the concern about chemical contamination from recovered materials, the Sustainable sourcing metric only rewards recycled content in some types of products: metals (aluminum and steel), glass, and PET bottles (Geueke et al., 2018).

The following third party certifications are recognized to reward sustainable biomass production:

- "Best" certifications:
    - Bonsucro (Bonscuro, 2021)
    - Forest Stewardship Council (FSC, 2021)
    - Roundtable on Sustainable Biomass (RSB, 2021)
- "Good" certifications:
    - Sustainable Forestry Initiative (SFI, 2021)

Table 8.1. Sustainable Sourcing indicator criteria

Rating	Criteria
1	Reusable
2	Sustainably certified biomass by a “best” certification or more than 50% post-consumer recycled content
3	Sustainably certified biomass by a “good” certification or more than 25% post-consumer recycled content
4	Less than 25% post-consumer recycled content or uncertified biomass
5	zero recycled content

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10. Appendix

Table 10.1. Assigned inertness scores within the Chemicals of Concern (CoC) metric for each generic food contact material based on expert review. Materials that reached an expert consensus are bolded. Scoring scale ranges from 10 (least inert) to 1 (most inert)

Food Contact Material	Assigned Inertness Score	Expert consensus reached?
Aluminum, uncoated	10	No
Amorphous polyethylene terephthalate (APET)	10	No
Bagasse (dry fiber from sugarcane/sorghum)	10	No
Bamboo	10	No
Bamboo-melamine	10	No
Biaxially oriented polypropylene (BOPP)	10	No
Cellulose	10	No
Ceramic	**1**	**Yes**
Cork	10	No
Crystallized polylactic acid (CPLA)	10	No
Expanded polystyrene (EPS)	10	No
Glass	**1**	**Yes**
High density polyethylene (HDPE)	10	No
Low density polyethylene (LDPE)	10	No
Melamine	10	No
Molded fiber (generic)	10	No

Oriented polyamide (OPA)	10	No
Oriented polypropylene (OPP)	10	No
Paper and board	10	No
Paper and board, alternative fibers (e.g. grass)	10	No
Paper and board, recycled	**10**	**Yes**
PE with 40% lime (Ecoclean Calymer)	10	No
PET	10	No
PET, recycled	10	No
Polyacrylate (acrylic)	10	No
Polyamide/nylon	10	No
Polyethelene napthalene (PEN)	10	No
Polylactic acid (PLA)	10	No
Polypropylene (PP)	10	No
Polystyrene (PS)	10	No
Soft polyvinyl chloride (PVC) (e.g. films and gaskets)	10	No
Stainless steel	**1**	**Yes**

Table 10.2. Assigned inertness score for each generic foodware and packaging product for the Chemicals of Concern (CoC) metric present in the scorecard on a scale from 10 (least inert) to 1 (most inert). Materials that reached an expert consensus are bolded. Products assigned a precautionary worst-case score given a lack of expert consensus and available data are labeled in this table and also clearly flagged for the user on the scorecard's results page

Scorecard Generic Food Contact Article	Representative Primary FCM	Assigned Inertness Score Based on Primary Food Contact Material	Worst-case score assigned due to lack of expert consensus?
acrylic container	Polyacrylate (acrylic)	10	Yes
aluminum can, epoxy lined	Low density polyethylene (LDPE)	10	Yes
aluminum takeout (cold)	Low density polyethylene (LDPE)	10	Yes
aluminum takeout (hot)	Low density polyethylene (LDPE)	10	Yes
bamboo bowl	Bamboo	10	Yes
bamboo plate	Bamboo	10	Yes
bamboo utensil	Bamboo	10	Yes
beverage carton	Low density polyethylene (LDPE)	10	Yes
bioPET (30%) clamshell takeout (cold)	PET	10	Yes
bioPET (30%) cup (cold)	PET	10	Yes
bioPET (30%) lid (cold)	PET	10	Yes
bioPET bottle	PET	10	Yes
bioPET bowl	PET	10	Yes
bioPET film	PET	10	Yes

bioPET ramekin	PET	10	Yes
bioPET tray	PET	10	Yes
cardboard sleeve	Paper and board	10	Yes
ceramic bowl, reusable	**Ceramic**	**1**	**No**
ceramic mug (hot), reusable	**Ceramic**	**1**	**No**
ceramic plate, reusable	**Ceramic**	**1**	**No**
ceramic ramekin, reusable	**Ceramic**	**1**	**No**
CPLA bowl	Crystallized polylactic acid (CPLA)	10	Yes
EPS foam bowl	Expanded polystyrene (EPS)	10	Yes
EPS foam clamshell (hot)	Expanded polystyrene (EPS)	10	Yes
EPS foam clamshell takeout (cold)	Expanded polystyrene (EPS)	10	Yes
EPS foam cup (cold)	Expanded polystyrene (EPS)	10	Yes
EPS foam cup (hot)	Expanded polystyrene (EPS)	10	Yes
EPS foam cushion	Expanded polystyrene (EPS)	10	Yes
EPS foam plate	Expanded polystyrene (EPS)	10	Yes
EPS foam ramekin	Expanded polystyrene (EPS)	10	Yes

EPS foam tray	Expanded polystyrene (EPS)	10	Yes
glass bottle, PP lid	**Glass**	**1**	**No**
glass bowl, reusable	**Glass**	**1**	**No**
glass cup (cold), reusable	**Glass**	**1**	**No**
glass jar, steel lid	**Glass**	**1**	**No**
glass jar, steel lid, reusable	**Glass**	**1**	**No**
glass mug (hot), reusable	**Glass**	**1**	**No**
glass plate, reusable	**Glass**	**1**	**No**
glass ramekin, reusable	**Glass**	**1**	**No**
HDPE bottle	High density polyethylene (HDPE)	10	Yes
HDPE tray, reusable	High density polyethylene (HDPE)	10	Yes
molded fiber bowl, H2O resist	Molded fiber (generic)	10	Yes
molded fiber bowl, PFAS lined	Molded fiber (generic)	10	Yes
molded fiber clamshell, H2O resist (hot)	Molded fiber (generic)	10	Yes
molded fiber clamshell, PFAS coating (hot)	Molded fiber (generic)	10	Yes
molded fiber cup (hot)	Molded fiber (generic)	10	Yes
molded fiber lid (hot)	Molded fiber (generic)	10	Yes

molded fiber plate, PFAS lined	Molded fiber (generic)	10	Yes
molded fiber plate, uncoated	Molded fiber (generic)	10	Yes
molded fiber ramekin (small bowl), PFAS lined	Molded fiber (generic)	10	Yes
molded fiber tray, H2O resist	Molded fiber (generic)	10	Yes
molded fiber tray, PFAS lined	Molded fiber (generic)	10	Yes
molded fiber tray, uncoated	Molded fiber (generic)	10	Yes
nylon cushion	Polyamide/nylon	10	Yes
nylon film	Polyamide/nylon	10	Yes
paper bowl, PE lined	Low density polyethylene (LDPE)	10	Yes
paper bowl, PLA lined	Polylactic acid (PLA)	10	Yes
paper cup, insulated, PLA lined (hot)	Polylactic acid (PLA)	10	Yes
paper cup, PE lined (cold)	Low density polyethylene (LDPE)	10	Yes
paper cup, PE lined (hot)	Low density polyethylene (LDPE)	10	Yes
paper cup, PLA lined (cold)	Polylactic acid (PLA)	10	Yes
paper cup, PLA lined (hot)	Polylactic acid (PLA)	10	Yes
paper cup, unlined (cold)	Paper and board	10	Yes

paper cushion	Paper and board	10	Yes
paper plate, PE lined	Low density polyethylene (LDPE)	10	Yes
paper plate, PLA lined	Polylactic acid (PLA)	10	Yes
paper ramekin, PE lined	Low density polyethylene (LDPE)	10	Yes
paper ramekin, PLA lined	Polylactic acid (PLA)	10	Yes
paper straw	Paper and board	10	Yes
paper takeout, PE coating (cold)	Low density polyethylene (LDPE)	10	Yes
paper takeout, PE coating (hot)	High density polyethylene (HDPE)	10	Yes
paper takeout, PLA coating (cold)	Polylactic acid (PLA)	10	Yes
paper tray, PE lined	Low density polyethylene (LDPE)	10	Yes
paper tray, PLA lined	Polylactic acid (PLA)	10	Yes
paperboard, corrugated	Paper and board	10	Yes
PE bag	Low density polyethylene (LDPE)	10	Yes
PE film	Low density polyethylene (LDPE)	10	Yes
PE foam cushion	Low density polyethylene (LDPE)	10	Yes
PET bottle	PET	10	Yes

PET bowl	PET	10	Yes
PET clamshell takeout (cold)	PET	10	Yes
PET cup (cold)	PET	10	Yes
PET film	PET	10	Yes
PET lid (cold)	PET	10	Yes
PET ramekin	PET	10	Yes
PET tray	PET	10	Yes
PLA bottle	Polylactic acid (PLA)	10	Yes
PLA clamshell takeout (cold)	Polylactic acid (PLA)	10	Yes
PLA cup (cold)	Polylactic acid (PLA)	10	Yes
PLA lid (cold)	Polylactic acid (PLA)	10	Yes
PLA ramekin	Polylactic acid (PLA)	10	Yes
PLA straw	Polylactic acid (PLA)	10	Yes
PLA tray	Polylactic acid (PLA)	10	Yes
PLA utensil	Polylactic acid (PLA)	10	Yes
PP bowl	Polypropylene (PP)	10	Yes
PP clamshell (hot)	Polypropylene (PP)	10	Yes
PP cup (cold)	Polypropylene (PP)	10	Yes
PP film	Polypropylene (PP)	10	Yes
PP lid (cold), reusable	Polypropylene (PP)	10	Yes

PP lid (hot), reusable	Polypropylene (PP)	10	Yes
PP ramekin	Polypropylene (PP)	10	Yes
PP soup container with lid	Polypropylene (PP)	10	Yes
PP straw	Polypropylene (PP)	10	Yes
PP utensil	Polypropylene (PP)	10	Yes
PS bowl	Polystyrene (PS)	10	Yes
PS clamshell takeout (cold)	Polystyrene (PS)	10	Yes
PS cup (cold)	Polystyrene (PS)	10	Yes
PS lid (cold)	Polystyrene (PS)	10	Yes
PS lid (hot)	Polystyrene (PS)	10	Yes
PS plate	Polystyrene (PS)	10	Yes
PS ramekin	Polystyrene (PS)	10	Yes
PS straw	Polystyrene (PS)	10	Yes
PS tray	Polystyrene (PS)	10	Yes
PS utensil	Polystyrene (PS)	10	Yes
PVC film	Soft polyvinyl chloride (PVC)	10	Yes
stainless steel bottle, PP lid, reusable	**Stainless steel**	**1**	**No**
stainless steel bowl, reusable	**Stainless steel**	**1**	**No**
stainless steel pkg, HDPE	**Stainless steel**	**1**	**No**

lid, reusable			
stainless steel ramekin, reusable	**Stainless steel**	**1**	**No**
stainless steel straw, reusable	**Stainless steel**	**1**	**No**
stainless steel takeout (cold), reusable	**Stainless steel**	**1**	**No**
stainless steel takeout (hot), reusable	**Stainless steel**	**1**	**No**
stainless steel tumbler (cold), reusable	**Stainless steel**	**1**	**No**
stainless steel utensil, reusable	**Stainless steel**	**1**	**No**
wood utensil	Wood	10	Yes