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PLASTIC IQ METHODOLOGY DOCUMENT

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1. Introduction

Plastic IQ is a tool that models the impact of plastic packaging and single use items for an individual company. The tool then gives the user the ability to set different strategic goals to reduce impact and compare the company's ambition of the best practices. The approach and data used in Plastic IQ is based on the extensive research in the "Breaking the Plastic Wave" (BPW) report released by SYSTEMIQ in July 2020, plus additional US-specific data. The model for Plastic IQ currently focuses on the U.S. market.

The goal of this Methodology Document is to describe in detail the assumptions that the Plastic IQ tool utilizes. The model estimates the cost and greenhouse gas (GHG) emissions of a company's current baseline plastic and the alternative solutions that a company specifies in the tool as their New Strategy, including reuse, substitution, improving recyclability, or using recycled or bio-based content. Plastic IQ also models the fate of the material ending up as waste (landfilled, incinerated, or polluted) or recycled into new products.

The Methodology Document outlines how the model handles different plastic types as they flow through the system and the sources used to derive the average estimated values for the U.S. Section 1 is devoted to an overview of the model and the system map. Section 2 details how we estimate company's plastic Baseline to 2030. Sections 2-7 follow the order that the user uses the tool from the baseline data entry and projection through each of the levers in Less Packaging and Better Packaging. Section 8 documents the material flow model and assumptions for movement through the system especially at end of life. Section 9 discusses the outside forces that may affect the company's strategy, as presented in the Scenario Analysis Tool accessible from screen 6 "results". Sections 10 and 11 detail methodology for Plastic IQ's circularity scoring and targets recognition, by comparing a firm's New Strategy to best practice.

1.1. Model overview

1.1.1 Scope and units

Scope Item	Notes
Included in scope	The scope of Plastic IQ includes all plastic packaging on sold products that go home with the customer, as well as single use or short-lived plastic products such as shopping bags and disposable tableware, which are sold in the United States.
Excluded from scope	Plastic on sold or purchased items being used and managed at end of life by a brand or retailer such as business-to-business (B2B), transportation, or wholesaling packaging; single-use products in on-site cafes or takeaway dining; and plastic for products with a long-life span such as toothbrush handles, diapers, and other hygiene products.
Geographic scope	United States
Units	Metric tons
Currency	2020 U.S. dollars (excluding inflation)

Greenhouse gas (GHG) emissions	Plastic IQ calculates total life cycle GHG emissions from cradle to grave, i.e., created along the packaging value chain, from production and conversion of packaging to end of life waste management including estimated GHG emissions from reusable packaging, non-plastic materials, and the sourcing, production and conversion of plastic whether virgin, recycled content or made from bio-based content. Our figures do not include GHG emissions associated with the "use phase" of the packaging or the products inside the packaging e.g. transportation emissions and food waste emissions are excluded. Plastic IQ uses average GHG emissions for each activity in the U.S. and assumes average U.S. grid emissions for electricity. See section 6, "Post-consumer Recycled Feedstock " for handling of emissions from recycling and virgin plastic avoidance.
Model units	All materials (plastic and non-plastic/substitutes) are treated in metric tons of *plastic equivalent* (i.e., metric tons of plastic utility switched to this solution lever rather than the actual mass of a non-plastic material – see section 5 for details).

Note: Plastic IQ uses **US-wide averages: all figures are estimates** as rates vary in practice among U.S. states.

1.1.2 Plastic categories

Each of the seven plastic categories for which a user enters data in Plastic IQ is calculated as flowing through the system map individually, then the tool adds all categories' output results together to show overall results. Where different plastic categories behave differently in areas of the system map, these are called out by specifying values for four broad types of materials in table 1.1.2.1 The four types cover the seven plastic categories as follows.

1.1.2.1 Tool and model plastic categories

Tool Plastic Category	Model Category
PET/HDPE bottles	Bottles
PET/PE/PP rigids excluding PET/HDPE bottles	Rigid mono-material
Hard-to-recycle rigids	Hard to recycle
Small formats	Hard to recycle
PE mono-material film	Flexible mono-material
Non-PE film, pouches, other flexibles	Hard to recycle
Multi-material blend	Hard to recycle

In addition, recycling rates and sorting losses change according to how much of your plastic is designed to adhere to APR guidelines – see section 8.2.

1.1.3 Strategies and scenarios

There are two concepts used in the tool and in this document that appear similar but are quite distinct: strategies and scenarios. A strategy refers to variables that are within the company's control. As a company enters its baseline data and then adjusts each lever, it is creating a strategy. These variables include packaging material, post-consumer recycled (PCR) content, and design for recycling.

A scenario refers to variables that are outside of a company's direct control. The final screen of the tool allows a company to test its strategy in different scenarios. Variables that can be adjusted in scenarios include producer responsibility fees, effectiveness of policy, cost of PCR content, and material losses. The business as usual (BAU) scenario includes the base annual assumptions through 2030, generally keeping them similar to current values.

1.2. System map

Plastic IQ's mass flow, GHG emissions and cost estimates are calculated by flowing each type of packaging through a system map adjusted from "Breaking the Plastic Wave" (Pew Charitable Trusts and SYSTEMIQ 2020). There are two parts to the system map – Exhibit 1 shows how flow of plastics through the after-use system is modelled, and Exhibit 2 traces the decisions a company can influence in the production and use phase: plastic reduction, substitution, and use of recycled content.

In each system map, an arrow represents a portion of plastic mass flowing from one box to the next. The boxes represent either an intermediate stage of mass flow or a permanent stage of material accumulation. All boxes with material accumulation are highlighted in bold. All the arrows and boxes have been given an alphanumeric index. The mass flow values associated with those indices in a BAU scenario can be found in Section 8.2. Once the plastic mass flows have been calculated at each step of the system map, relevant boxes and arrows are multiplied by the cost/metric ton and GHG/metric ton figures given in Sections 8.3 and 8.4.

1.1.4 Plastic reduction, reuse, substitution, and feedstock choice system map

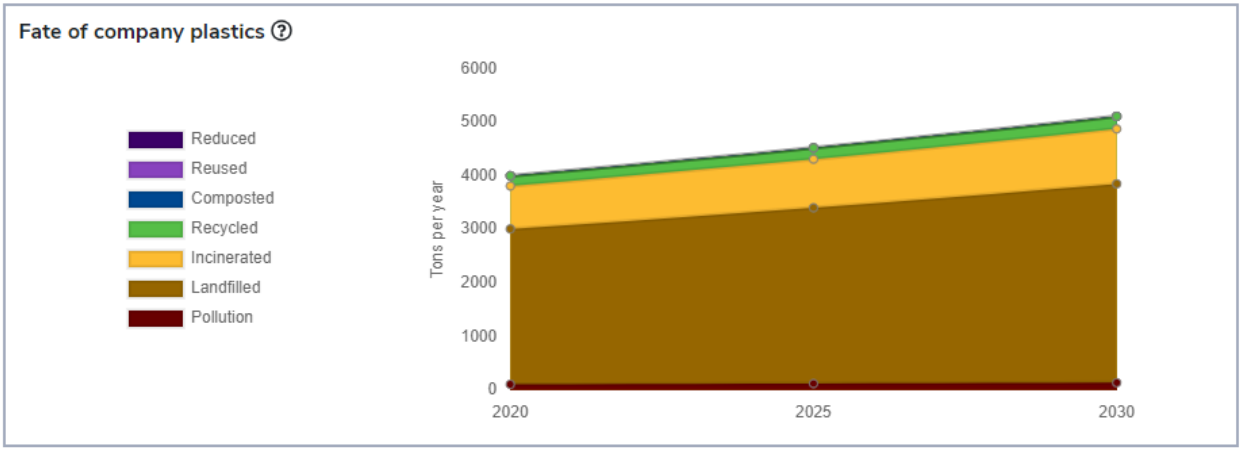
The amount of plastic that enters the after-use system map is decided by a company's packaging strategy to reduce, substitute, or use recycled/bio-based content in its packaging. These are decisions visualized in the "feedstock wedge" results graphs shown on every page of Plastic IQ. The feedstock wedges detail where the user's plastic is coming from based on the strategy information entered into Plastic IQ, detailing how much plastic is coming from fossil-based virgin plastic versus more circular solutions. This packaging strategy leads to a given volume of plastic in box A: total plastic waste after consumer use, which then enters the after-use system map.

1.1.5 After-use system map – end of life

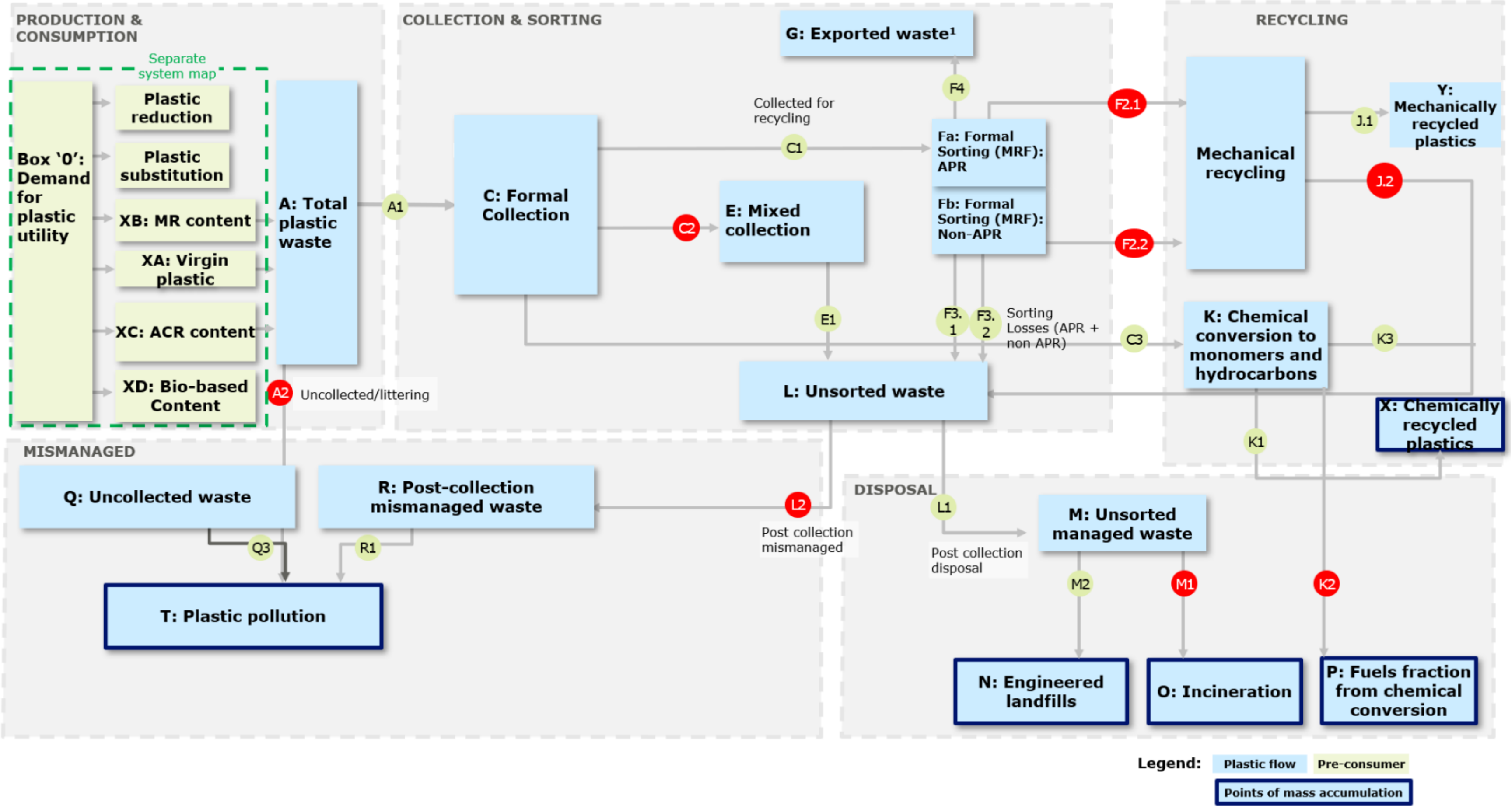
Where plastic ends up in the after-use system map is visualized in the "fate wedges" chart shown on Screen 6. Each wedge refers to the waste end of life treatment which will change based on the strategy designed by the user.

There are four main sections in the system map that refer to the after-use management and end-of-life treatment of plastic waste: Collection and Sorting, Recycling, Mismanaged, and Disposal. All flows in this part of the model are determined by data assumptions. Please refer to the relevant section for each to see the values and source of each. In several instances, plug formulas are used in the mass flow calculations. For example, A2 is a plug formula derived by A2 = 1 – A1. The value of A1 refers to the share of waste that is formally collected. The remaining waste that is not sent to formal collection is left uncollected and can be calculated using A1.

1.1.5.1 Fate of company plastics



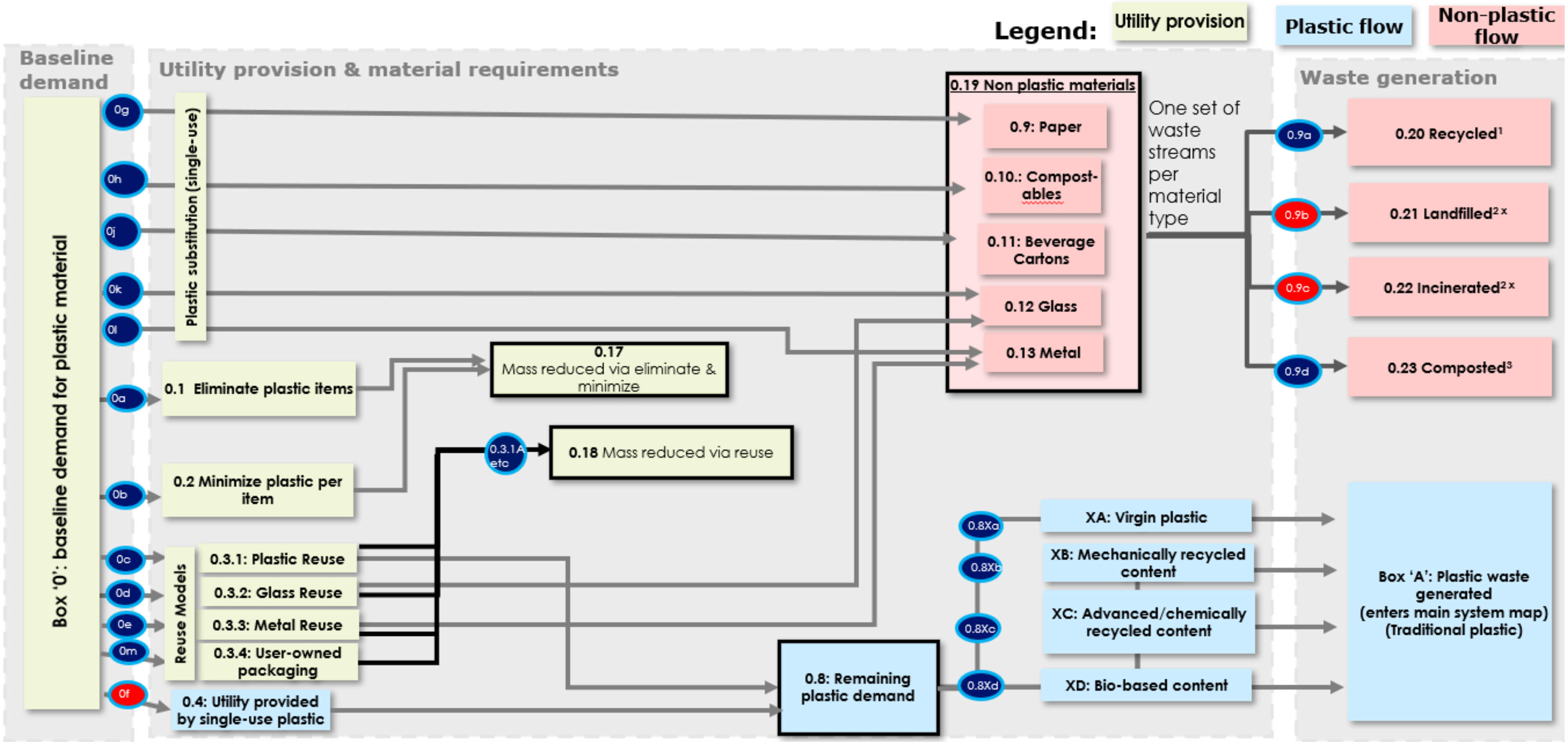
1.1.5.2 Figure 1: After-use plastic system map



Notes:

- Share of arrow C1 going to Formal Sorting (APR) and Formal Sorting (Non-APR) is drawn from user input on APR compliance.
- Arrows from Box 0 to boxes plastic reduction, plastic substitution, XB, XC, and XD is drawn from user input.
- Arrow C1 is impacted by scenario selection in the "Scenario Analysis Tool" accessible on screen 6.
- Red circles on arrows indicate a "plug number,", i.e., the value for that arrow is the remaining share of mass from a specific box. The calculation is 1 – sum of all other Data Assumptions, e.g., A2 = 1 – A1.

1.1.5.3 Figure 2: Plastic reduction, reuse, substitution, and feedstock choice



Note: Arrows controlled by a company's strategy (i.e., user input):

- Arrows 0a, 0b, 0c, 0d, 0e, 0m: % of baseline single-use plastic going to each Reduce or Reuse levers
- Arrows 0g, 0h, 0j, 0k, 0l: % of baseline single-use plastic going to Substitute levers
- Arrow 0.3.1A, 0.3.2A, 0.3.3A are impacted by user selection of "number of reuse cycles" high/medium/low (see section 4.1.1.1)
- Arrows 0.8Xb, 0.8Xc, 0.8Xd to boxes XB, XC, and XD (arrow 0.8Xa virgin plastic is a dummy number and box XA receives any remaining plastic)

Legend for the box colors:

- **Utility provision – yellow –** units for these boxes are "metric tons of baseline plastic mass going to this solution lever", even if there is no actual material mass anymore as the mass has been eliminated.
- **Non-plastic material – red** – units for these boxes, when calculating the "feedstock wedges" and "end-of-life wedges" charts are in metric tons of plastic equivalent (i.e. metric tons of plastic utility switched to this solution lever). For example, if 10 metric tons of glass are required to substitute 1 metric ton of plastic, the charts show 1 metric ton of plastic switching to non-plastic in the "source of packaging" chart , and 1 metric ton of plastic equivalent material entering landfills, recycled or incinerated in the "where packaging ends up at end of life" charts. However, cost and GHG emissions calculations are made using the actual metric tonnage of substitute materials, not plastic equivalent.

Footnotes on the system map:

1 – The Plastic IQ model calculates the cost and GHG emissions of recycling paper substitutes at end-of-life, including an assumption of how much heavier non-plastic materials are than plastic (see table 5.2.1.1 - paper items are assumed 1.5x the mass, etc.). In the "fate" wedges chart, the *portion of a company's plastic* that gets substituted by paper etc. which is then recycled at end of life is shown as part of the "recycled" wedge (in units metric tons of plastic equivalent).

2 – The Plastic IQ model calculates the cost and GHG emissions of landfilling and incinerating each substitute and compostable substitutes at end-of-life, including mass increases (see changes of substitute materials compared to plastic). In the "fate" wedges chart, the *portion of a company's plastic* that gets substituted by paper etc. which is then landfilled or incinerated at end of life are shown in the landfill and incineration wedges respectively.

3 – The Plastic IQ model calculates the cost and GHG emissions of compostables that get composted at end-of-life based on U.S. average household composting rates, including an assumption that compostable items are 1.3x the mass of the plastic items they substitute.

2. Virgin plastic and baseline projection

2.1. Extrapolating baseline company plastic

The basis of the results analysis compares the user-entered strategy against a baseline to 2030. The baseline to 2030 refers to the expected company plastic footprint if the company does not make significant changes to its current packaging strategy. Based on the '2020 Annual Plastic Mass" entered for the plastic types, the user's plastic footprint is projected out to 2030. A continual annual growth rate is applied to account for expected future growth. If the user does not enter a projected growth rate, Plastic IQ uses the following default rates for each plastic category:

- Bottle: 2.1%
- Rigid mono-material: 2.1%
- Flexible mono-material: 2.6%
- Hard to recycle: 2.6%
- Source: Grand View Research (in: Breaking the Plastic Wave, 2020)

For the other user-entered input baseline metrics, "APR Compliance", "Recycled Content" and "Bio-Based Content," the baseline to 2030 assumes the same percentage for all years based on what users input in step 2 of the tool for their 2020 values. This means that the share of fossil-based virgin content will remain constant for all years.

2.1.1. Projecting plastic utility

When a user then creates a new strategy, all user inputs on ambition level to reduce, reuse etc. are calculated as % changes from this baseline. For example, 5% switch to reuse models by 2030 corresponds to a 5% reduction in plastic compared to 2030 baseline projection. This can be thought of as the baseline representing a projection of "plastic utility": i.e., what quantity of valuable services or utility is a company expecting its customers will demand by 2030. Plastic IQ then helps users meet this baseline plastic utility in new ways, such as by reducing, reusing, or substituting plastic.

2.2. Cost of virgin plastic

Unless otherwise specified by the user, Plastic IQ assumes plastic is fossil fuel-based, virgin plastic. The production costs are assumed to be $1,800/metric ton and conversion costs $3,000/metric ton, based on price data from Benchmark Consulting (2020). This is based on an average material cost and average production cost derived from the Benchmark Consulting dataset, for each of the Plastic IQ plastic types. Then, a weighted average of material and production cost based on each plastic type's share of U.S. plastic waste was created. These weighted averages are used as the virgin content material and production prices.

2.3. Treatment of OPEX and CAPEX

The default option in the model assumes no distinction between operational expenditure (OPEX) and capital expenditure (CAPEX). However, if the user knows their own capital base, they may wish to switch the breakdown option on. This breaks costs down into annual OPEX and CAPEX, where annual CAPEX is in effect depreciation. The total cost does not change but the split between OPEX and CAPEX varies between different costs. The split for each type of cost is shown in the table below.

2.3.1.1. OPEX/CAPEX split

	OPEX	CAPEX
Virgin plastic production	75%	25%
Plastic conversion	75%	25%
Formal collection	70%	30%
Informal collection	100%	0%
Formal sorting	75%	25%
Mechanical recycling	78%	22%
Chemical conversion P2P	72%	28%
Chemical conversion P2F	72%	28%
Thermal treatment	70%	30%
Engineered landfills	25%	75%
Reduce - Reuse	84%	16%
Reduce - New Delivery Models	80%	20%
Substitute - Glass	54%	46%
Substitute - Metal	54%	46%
Substitute - Paper	68%	32%
Substitute - Coated paper	68%	32%
Substitute - Compostables	26%	74%

Source: BPW (2020) except for glass and metal, for which an average split of all substitutes was taken.

2.4. Emissions of virgin plastic

As above, unless otherwise specified by the user, Plastic IQ assumes plastic is fossil fuel-based, virgin plastic. The GHG emissions associated with virgin plastic production are 1.85 tCO_2e and conversion generates 0.90 tCO_2e, based on emissions data from Project Gigaton (2020, p. 94).

3. Reduce

For solutions to eliminate plastic items, the cost and emissions vary widely based on whether alternative solutions are needed after elimination, which imposes its own costs and GHG emissions, or whether the elimination requires no alternative solution. In the tables below, the differences between those elimination types can be understood by examining the individual data points of the case studies feeding into the average cost and GHG numbers. In contrast, for minimization solutions no different types of solutions are necessary since plastic mass minimized directly translates into cost and GHG reductions.

3.1. Cost assumptions for elimination and minimization

Cost impacts of elimination can vary widely, ranging from 100% cost savings for plastic elimination not requiring a replacement technology (such as removal of second layer packaging as in individually wrapped cookies within another package) to less significant cost savings in which elimination requires replacement technologies. Case studies in which replacement technologies can range from 59% to 74% less expensive than plastic can be found (see table 3.1.1.1). Replacement technologies include glue dots instead of six-pack wrapping, laser food labeling instead of vegetable wrapping, and reusable instead of disposable water bottles. Still, a lot of the elimination solutions allow for 100% cost savings, as outlined above.

Packaging material minimized leads to reduced packaging costs for businesses through efficiency savings. Plastic IQ estimates a cost saving of 100% for each metric ton of plastic packaging reduced via minimization. The plastic reduced is assumed to be deducted from the packaging's costs while no other additional costs are added. However, packaging redesign and innovation may require initial R&D costs that are not quantified in the Plastic IQ tool but should be evaluated by companies.

3.1.1.1. Elimination and minimization costs

Solution	System map	$/t net plastic reduced for all plastic types	Source
Eliminate plastic items	Box 0.1	$750 (-84%)	**-84% cost reduction compared to single-use plastic** (from Plastic IQ plastic production and conversion costs of $4,800) **as average of six case studies:** *(a) with remaining costs,* ***-69%*** *on average:* Glue Dots**: -59%;** laser food labelling: **-73%;** durable consumer reuse products: **-74%** (all own calculations based on online available price points). *(b) without remaining costs, -100% average:* elimination of individual wrapping: -**100%;** elimination of vegetable packaging: -**100%;** straw removal: -**100%** (all own assumptions).
Minimize plastic per item	Box 0.2	$0 (-100%)	No additional costs (Breaking the Plastic Wave, 2020).

3.2. GHG emissions assumptions for elimination and minimization

Eliminating avoidable packaging has the highest potential emissions savings of any lever: up to 4.3 metric tons of CO2e savings per metric ton of plastic avoided (i.e., 100% savings) through eliminating the package entirely if no replacement technology is needed.

The Plastic IQ tool estimates emission reduction of -86% (3.4 metric tons avoided/ 0.5 metric tons remaining) for every metric ton of single-use plastic eliminated, reflecting that emissions savings shown in available studies vary widely depending on the replacement solution used, if any. There could also be zero or negative impact on overall GHG emissions in practice if unintended consequences are not monitored, so elimination strategies need to be assessed on a case-by-case basis. If packaging is required for food preservation purposes, eliminating this may cause an adverse rise in food waste, causing an increase in GHG emissions.

If done right, minimizing packaging material reduces 100% of the GHG emissions for the weight that was reduced (i.e., reduction of 4.3 metric tons of CO_2e). The GHG of the plastic reduced is assumed to be deducted from the total packaging's GHG while no other additional GHG emerging. Still, it needs to be ensured that packaging minimization does not cause unintended consequences such as increased food waste and breakage, or an increased need for secondary packaging to protect the product, both of which can increase GHG emissions.

3.2.1.1. *Eliminate and minimize GHG emissions*

Solution	System map	tCO2eq/t net plastic reduced for all plastic types	Source
Eliminate plastic items	Box 0.1	0.4 (-86%)	**-86% GHG emissions reduction** (from average single-use plastic GHG in Plastic IQ of 4.3 tCO2eq/t) *a) with remaining GHG, -73% on average:* Lock N´Pop Adhesives: **-71%** (EMF Upstream Innovation, 2020); durable consumer reuse products: **-74%** (one durable water bottle substituting 320 single-use water bottles in one year; one durable plate substituting 52 single-use plates in one year: both own calculation); *(b) without remaining GHG, -100% on average:* elimination of individual wrapping: **-100%;** elimination of vegetable packaging: **-100%;** straw removal: **-100%** (all own calculation).
Minimize plastic per item	Box 0.2	0.0 (-100%)	No additional costs (Breaking the Plastic Save, 2020).

4. Reuse

The cost and emissions of reuse models vary widely based on their set-up (e.g., transport distances, take-back logistics, and washing infrastructure needed/not needed, etc.), and data on at-scale reuse models are lacking. All reuse figures quoted by Plastic IQ are estimates based on modeling and available data (data points and sources outlined in the following data tables). The approach considers all data points from diverse reuse models found to estimate how packaging material reduction, costs, and GHG emissions change with reuse models. This allowed us to create a starting point estimate of the mass, costs, and GHG of reuse models, as follows, by averaging all available data points:

- **Mass reduction:** 72% compared to single-use plastics.
- **Cost reduction:** -7% compared to production and conversion costs of single-use plastics ($4,250 OPES costs and $170 annualized CAPEX costs per metric ton of single-use plastic moving to reuse).
- **GHG reduction:** 51% compared to single-use plastics (1.4 tCO2eq/t single-use plastic moving to reuse).

Details on data points feeding into these assumptions can be found in the tables in the sections below. Note that the above data refer to the mass reduction, costs, and GHG emissions for what Plastic IQ considers "default" reuse models of medium cost with medium reuse cycles. The base for these medium models is in each case the average of all data in case studies, which were identified. The assumption was further made that reuse models with medium reuse cycles show 20 reuse cycles and that plastic is the default material of the reusable container. To help users understand the key dynamics of reuse systems, the available data was used to model some of the key dimensions that impact the performance of these medium, "default" reuse models:

- Different reusable packaging materials;
- If the number of reuse cycles is particularly high, or particularly low;
- If the selected reuse model your company pursues is particularly high-cost or low-cost.

4.1. Assumptions on reusable packaging materials, reuse cycles, and mass reduction

Different reusable packaging materials

Users can choose among reusable packaging made of plastic, glass, or metal. Differing GHG emissions and costs during production and end-of-life of those materials impact the costs and GHG emissions of the reuse models. For weight change, GHG emissions, and cost assumptions made for glass and metal, see section 5. All non-plastic materials (single-use substitutes and reusable non-plastic materials) as well as all plastic materials (single-use plastics and reusable plastics) are treated in combined mass, GHG, and cost flows.

Reuse cycles and mass reduction

The average mass reduction of reuse models is based on an average of nine case studies, as listed in table 4.1.1.1. For this average model, around 20 reuse cycles are assumed to take place. Since reuse cycles can differ widely among different reuse model types and have a major impact on the plastic mass and, hence, the costs and GHG emissions saved, Plastic IQ allows to modify the reuse cycles being modelled. Low reuse cycles are assumed to lead to zero change compared to single-use plastics, which was calculated to be the case for roughly four reuse cycles. High reuse cycles are assumed to be twice as much as for the average, i.e., 40 reuse cycles, which was calculated to lead to a mass reduction of 86% compared to single-use plastic.

In addition to these reuse cycles, consumer-owned packaging presents another option, i.e., packaging not being owned by the company offering the reuse service but instead owned by the consumer. In Plastic IQ, this packaging is assumed to be out of scope for companies. Therefore, consumer-owned packaging allows for 100% mass reduction in Plastic IQ.

The mass reduced via reuse models flows into the *reuse wedges,* both in the *feedstock wedge* and in the *fate wedge*. Hence, the size of these wedges indicate how much material would be saved by moving from single-use plastic to reuse models. The reusable materials flow either in the *non-plastic material feedstock wedge,* or, if reusable plastic is chosen, into the four plastic feedstock wedges (as outlined in

Chapters 2, 6, and 7). In the fate wedges, the reusable materials flow into the *recycled, incinerated, landfilled, and pollution wedges,* as outlined for non-plastic materials in section 5 and for plastic materials in section 8.

4.1.1.1. Reuse cycles and mass reduction

Solution	Reuse cycles	Mass reduction compared to single-use plastic	Source
User selection: Reuse models with medium reuse cycles	~20	72%	**-72% mass based on average of nine case studies:** MIWA: -90%; Everdrop: -85%; Coca-Cola refill bottle: -86% (all EMF Upstream Innovation, 2020); Algramo: -75% (BPW, 2020); Bulk refill: -51% (WRAP, 2007); bulk refill: -84% (ESCP, 2020); Cif ecorefill: -75% (Unilever, 2020); DRS Germany: -59% (PwC, 2007).
User selection: Reuse models with low reuse cycles	~4	0%	Calculation based on ~four reuse cycles with medium (20) reuse cycles as starting point (see "Reuse models with medium reuse cycles")
User selection: Reuse models with high cycles	~40	86%	Calculation based on 40 reuse cycles with medium (20) reuse cycles as starting point (see "Reuse models with medium reuse cycles").
User selection: Reuse models with consumer-owned packaging	na	100%	Consumer-owned packaging out of scope of mass flows.

Note: Reuse models are not shown on the system map.

4.2. Cost assumptions for reuse models

The average OPEX costs of -11% compared to single-use plastic packaging (referring to running costs of offering reuse services, including the production, provision, cleaning, and logistics of reusable packaging, as well as other costs such as for staff) is based on five case studies, as listed in table 4.2.1.1. Since costs among different reuse model types can widely differ, Plastic IQ allows users to modify the OPEX costs being modelled. Low-cost reuse models are assumed to have 35% lower OPEX costs compared to single-use packaging, being based on the two most costly advantageous models identified. High-cost reuse models are assumed to have 25% higher OPEX costs compared to single-use packaging, being based on the highest-cost case study available. For consumer-owned packaging, the OPEX costs assumed to be the same as for medium reuse models are, however, further decreased since the costs of producing packaging (based on 72% mass reduction under medium reuse cycles) can be deducted.

CAPEX costs including investment in reuse infrastructure, installation, and staff retraining costs are assumed to be an additional 4% of single-use plastic packaging costs. These insights are based on two case studies. For low- and high-cost reuse models, these CAPEX costs are assumed to remain unchanged since economies of scale and cross-industry shared reuse models impact CAPEX rather than OPEX costs.

4.2.1.1. *Reuse cycles and mass reduction costs*

Solution	OPEX in $/metric ton of single-use plastic moving to reuse for all plastic types	CAPEX in $/metric ton of single-use plastic moving to reuse for all plastic types	Source
Medium cost reuse models	$4,250 (-11%)	$170	**-11% OPEX** compared to production and conversion of single-use plastic ($4,800 in Plastic IQ) as average of 5 case studies: Algramo: -44% (BPW, 2020); Bulk refill: -33% (WRAP, 2007); Coca Cola Refill bottle: -5% (EMF, 2020); DRS Germany: +25% (DIW Econ, 2016 & PwC, 2011); Refillable shopping bags: 0% (Environment Agency UK, 2011; and own calculation). **CAPEX** estimate based on two case studies: Bulk refill: $83 (WRAP, 2007; RPA, n.d.); Coca Cola refill bottle: $260 (EMF, 2020).
Low-cost reuse models	$3,120 (-35%)	$170	**-35% OPEX** compared to production and conversion of single-use plastic ($4,800 in Plastic IQ) based on 2 case studies showing the lowest costs: Algramo: -44% (BPW, 2020); Bulk refill: -33% (WRAP, 2007). **CAPEX** see above
High-cost reuse models	$5,980 (+25%)	$170	**+25% OPEX** compared to production and conversion of single-use plastic ($4,800 in Plastic IQ) based on the highest-cost case study available: DRS Germany: +25% (DIW Econ, 2016 & PwC, 2011). **CAPEX** see above
Reuse Models with consumer-owned packaging	$2,900 (-40%)	$170	**-40% OPEX** compared to production and conversion of single-use plastic ($4,800 in Plastic IQ) based on average cost reuse models, subtracting the costs for plastic production required for medium reuse cycle models. **CAPEX** see above

Note: Reuse models are not shown on the system map.

4.3. GHG emissions assumptions for reuse models

The average GHG emissions reduction of 51% for reuse models is based on an average of nine case studies, as listed in table 4.3.1.1, translating to 2.1t CO2eq remaining per ton of single-use plastic packaging moving to reuse models. While all reuse cycles are assumed to have the same GHG emissions for the service provision; the material production, conversion, and end-of-life GHG emissions are being influenced by the reuse cycles, based on the mass reduction.

4.3.1.1. *Reuse solution GHG assumptions*

Solution	System Map	tCO2eq/metric ton single-use plastic moving to reuse - all plastic types overall use cycle	Source
Reuse Models	na	1.4 (-51%)	**-51% GHG reduction compared to single-use plastic** (from average single-use plastic GHG in Plastic IQ of 4.3 tCO2eq/t) as average of five case studies: Loop: -34%; MIWA: -46%; SodaStream: -87%; Coca-Cola refill bottle: -47% (all EMF, 2020); Reusable shopping bag: -42% (Environment Agency UK, 2011 and own calculation)

5. Substitute Materials

5.1. Overall approach to material substitutions

In Plastic IQ, single-use and reusable plastics, as well as single-use substitute materials and reusable non-plastic materials, are treated in a combined manner. In this section, data on substitute materials are outlined, being applicable both to single-use and reusable packaging. All substitute materials have their own end-of-life outcomes, end-of-life GHG emissions, and costs taking these end-of-life outcomes into account (e.g., combining % recycled with the GHG of recycling processes) as well as their own production costs and GHG emissions; all taking the weight-factor increases compared to single-use plastic into account.

5.2. Assumed weight-factor increases per substitute

All substitute materials except beverage cartons were found to show a weight-factor increase compared to single-use plastic. This means, for instance, that a paper packaging substituting a certain plastic packaging is on average 50% (weight factor of x1.5) heavier than the plastic packaging counterpart. Solely for beverage cartons, no weight change compared to plastics is assumed since the weight of beverage cartons can either be increased or decreased depending on the plastic packaging being compared. Smaller packaging formats show a weight decrease when switching to beverage cartons (e.g., -25% for 0.3l beverages or -10% for 0.5l beverages), while larger packaging formats show a weight increase (e.g., +5% for 1l beverages or +40% for half-gallon beverages). For the other substitute materials, the average weigh increase is either based on insights of single studies or of average weight changes calculated by comparing different packaging types. For glass, the weight increase is always significant, but certain glass packaging can lead to weight increases up to nearly 2500%. For metal packaging, the weight increase will differ between aluminum and steel packaging. Steel is generally heavier than aluminum packaging. For compostable materials, based on two studies (see table 5.2.1.1) a weight increase of 30% is assumed, comparing either PLA food boxes and clamshell containers to those made of PS; or comparing PLA and PLA/PBAT packaging films to those made of LDPE. Weight changes for compostables, however, differ widely between type of materials. For example, non-plastic compostables such as bagasse may be heavier and switching from rigid un-foamed plastic to PLA could be the same weight.

All substitute materials are treated as *plastic equivalents* in Plastic IQ. This means you will see the mass of the substitute materials as metric tons of original plastic content being replaced by the substitute material. This way, result graphs such as the wedges charts are comparable, and distortion caused by increased mass of substitute materials is avoided. GHG emissions and costs data in Plastic IQ do, nonetheless, take this mass increase into account.

5.2.1.1. Weight factor changes of substitute materials compared to plastic

Solution	System Map	Weight increase compared to single-use plastic	Source
Paper	0.9	x1.5	x1.5: Material Economics, 2018.
Compostables	0.10	x1.3	x1.348: Choi et al., 2018. x1.249: UNEP & Life Cycle Initiative, 2020.
Beverage cartons	0.11	x1 *(same weight)*	Since the weight of beverage cartons can either be increased or decreased – depending on the plastic packaging being compared – the weight is assumed to be the same as for single-use plastics.

Glass	0.12	x10	Average of six glass vs plastic packaging: 723%; 789%; 1059% (all: PwC, 2011); 750% (Ecochain, n.d); 2444%; 1818% (incpen, 2011; Stefanini et al., 2020).
Metal	0.13	x1.2	Weighted average of the packaging generation – 60% steel and 40% aluminum (EPA, 2018): • **Steel: 152%** weight of single-use plastics (tin sheet beer can: 1.28 (PwC, 2011)); coffee steel can: 1.6 (Franklin, 2008); steel can: 1.7 (Recycle USA, n.d.; incpen, 2011). • **Aluminum: 67%** of weight of single-use plastics (aluminum beer can: 0.7 (PwC, 2011) Aluminum can: 0.6 (Ball (2020)); aluminum can: 0.7 (Amienyo (2013))

5.3. End-of-life outcomes of substitute materials

The end-of-life outcomes of the substitute materials are treated separately to those of plastics in the model by calculating their own material flows throughout their lifecycle. In the *feedstock wedge,* all substitute materials are grouped. However, in the *fate wedges* results graphs of the tool, the end-of-life outcomes of *all* materials – plastic and non-plastic – are grouped in the corresponding *wedges*: recycled, composted, incinerated, and landfilled. The unit used in this graph is *plastic equivalent,* hence ignoring the weight change factor for the masses displayed in the graphs (though considered for costs and GHG emissions), but referring to the metric tons of original plastic content that was replaced by the substitute material. This way the *wedges* remain comparable across years and materials.

For all substitute materials except compostables, the end-of-life outcomes already account for losses during collection and recycling. These were deducted from the recycling rate and added equally between landfill and incineration rate.

5.3.1.1. End-of-life assumptions

Solution	System map	Recycling rate	Composting rate	Landfill rate	Incineration rate	Source

Paper	0.9	29%	na	56%	15%	EPA (2018); TRP (2020). State of Curbside Recycling report. Including 8% loss rate during recycling. (Ball 2020)
Compostables	0.10	na	2% *(under BAU, for scenario assumptions see section 9)*	79%	19%	TRP (2020). Capture rate studies for 3-7 plastics applied to current curbside compostable access
Beverage cartons	0.11	12%	na	69%	19%	Carton Council website; same share for landfill and incineration as for paper; including 36% recycling losses (92% recycling efficiency for paper fraction - (Ball, 2020))
Glass	0.12	31%	na	55%	14%	(EPA, 2018) same share for landfill and incineration as for paper
Metal	0.13	55%	na	45%	0%	(EPA, 2018) including 2% loss rate during recycling (Ball, 2020).

5.4. Production and end-of-life costs for substitutes

The production costs of substitute materials include the extraction, production, and conversion of the materials into packaging and represents the costs that companies would pay for packaging, excluding filling costs. The sources in the table refer to percent increases in cost per equivalent package, incorporating the weight change. These cost-increase factors (e.g., compostables production being twice as expensive as plastics) are based on the average cost increase of substitute packaging compared to their plastic counterparts. In comparison, the production cost per ton of substitute refers to a metric ton of the substitute material and not an equivalent package. Similar to other portions of the tool, metal is a combination of aluminum and steel packaging.

5.4.1.1. Substitutes production costs

Solution	System map	Production and conversion costs per metric ton of substitute	Sources
Paper	0.9	$5,350	67% higher costs than equivalent plastic items, based on average cost increase of nine items (see also BPW (2020))
Compostables	0.10	$7,390	100% higher costs than equivalent plastic items, based on average cost increase of 4 items (see also BPW (2020))
Beverage cartons	0.11	$3,840	-20% lower costs than equivalent plastic items, based on SYSTEMIQ estimate of beverage cartons price compared to HDPE bottles
Glass	0.12	$850	78% higher costs than equivalent plastic items, based on average of three data points in two studies. Range of 36% (Shoenwald, 2009) to 231% (CitiGroup, 2018)
Metal	0.13	$4,900	22% higher costs than equivalent plastic items, based on five data points in two studies. Range of 16% (Shoenwald, 2009) to 31% (CitiGroup, 2018)

End-of-life costs of disposing of substitute materials are shown in the final results screen of Plastic IQ, under "public expenditure on managing packaging at end of life." For end-of-life costs, Plastic IQ applies the following assumptions to each metric ton of substitute material after taking into account weight changes.

5.4.1.2. End-of-life treatment costs per metric ton of substitute material

	System map	Collection cost	Sorting cost for recycling	Composting cost	Landfill cost	Incineration cost	Sources
Paper	0.9	$145	$97		$58	$96	(EREF, 2019) - assumed collection, landfilling and incineration cost per metric ton of all materials is the same as plastic; collection cost (TRP, 2020) sorting costs allocated by material in MRFs – (TRP internal analysis, 2021)
Compostables	0.10	$145		$58	$58	$96	Landfilling, incineration, collection costs: see paper. Composting costs: Centralized Composting. (ReFED, 2016)
Beverage cartons	0.11	$145	$1,054		$58	$96	Sorting costs allocated by material in MRFs - (TRP internal analysis, 2021)
Glass	0.12	$145	$147		$58	$96	Sorting costs allocated by material in MRFs - (TRP internal analysis, 2021)
Metal	0	$145	($373)		$58	$96	Sorting costs allocated by material in MRFs - (TRP internal analysis, 2021)

5.5. GHG emissions assumptions for substitutes

For the GHG emissions of substitutes , both a "key data point" used in the Plastic IQ model, and a range of GHG data that acknowledges both the high and low emissions outcomes from a large selection of LCA data are referenced in the following. This approach is intended to give readers balanced insight given that boundary conditions can vary dramatically in different studies and no single data point will accurately reflect readers' specific needs and situations. To ensure Plastic IQ is comparing like-for-like, it was drawn extensively on previous analysis and assumption from the Project Gigaton (2020) Accounting Methodology as "key data point" where available; it was based on Eco-Invent data giving average emissions per metric ton of substitute material in the U.S. Where Gigaton data was not available, other comparable peer reviewed sources were sought for.

Paper: For the production and conversion GHG emissions of paper, data from Project Gigaton was used. Since it is assumed that most packaging has a plastic coating, a 5% of the packaging was assumed to be made of LDPE (2.374t CO2e/t, source: Gigaton). The remaining 95% is assumed to be made of corrugated paper (0.841t CO2e/t, source: Project Gigaton (2020)). It is assumed that 100% of paper packaging is virgin based and the credit for recycling is taken at the end of life, based on the recycling rate. For EOL, data from the WARM model from the U.S. EPA (2016) are taken for each potential situation. Recycling emissions include a credit for offsetting virgin paper emissions (-0.51t CO2e/t), but credit for forest carbon sequestration was excluded as it is included in the Gigaton production data. Combustion of paper includes the direct emissions but also the offset for energy from the average U.S. grid (-0.49t CO2e/t). Landfilling paper emits methane and to be conservative, the credit for carbon storage from landfilling paper was excluded (0.84t CO2e/t). As the listed studies show, GHG emissions of paper production can differ widely, depending on production locations, energy mix, type of paper packaging, and other impact factors.

Beverage cartons: For the production and conversion GHG emissions of beverage cartons, data from Project Ecoinvent, database 3.5 were used, with the assumptions and allocation method chosen outlined in table 5.5.1.1. As the additional data points show, GHG can differ widely for the same reasons as paper. In addition, the type of beverage cartons can differ, e.g., the composition and material share of this multi-material blend can differ. For the EOL GHG emissions, the same data as for paper, sourced from WARM, are used.

Compostables: For compostables production GHG emissions, the GHG emissions from corn-based PLA polymers produced in the U.S. are extracted from the study of Posen et al. (2016), using the system expansion allocation method, as suggested by ISO 14040. Since the emissions are only cradle to gate (not including emissions associated with the "use-phase" of the packaging, e.g., transportation emissions), conversion emissions need to be added, whereby plastic conversion emissions are assumed. GHG emissions credits in the bio content are included. For EOL GHG, data from the WARM model (EPA, 2016) for PLA is used as a proxy for all compostables. Composting includes a carbon storage offset but it is reduced due to the decomposition process. This results in a net savings for composting (-0.15t CO2e/t). Combustion and landfilling use similar assumptions to paper, resulting in net savings for combustion and net emissions for landfilling (-0.65t CO2e/t and 0.02t CO2e/t, respectively). As the listed studies show, GHG emissions both of production and conversion and at EOL greatly differ due to a variety of compostable materials (both plastic and non-plastic) differences in their feedstock, production process, and (EOL) performance.

Glass: Glass packaging has lower emissions per metric ton of material, but it has a much higher weight per package. Since it is much heavier, the transportation emissions have a large impact on the total emissions. In the reviewed studies, production and conversion emissions varied from 0.52 MTCO2eq/metric ton to 1.57 MTCO2eq/metric ton, with the average of 1.00 MTCO2eq/metric ton. Gigaton had a similar result using 35% PCR. Therefore, this value of 1.16 MTCO2eq/metric ton serves as basis for the model.

For end-of-life emissions for glass, the WARM model from the U.S. EPA (2016) was used. Any credits for recycling (i.e., offsetting virgin material) were excluded since PCR was included instead. This way, double counting can be avoided. In general, the EOL emissions are only for transportation to a landfill, incinerator, or recycling facility.

Aluminum: As can be seen in table 5.5.1.1, the GHG emissions for aluminum can vary significantly depending on a couple of factors. The first is a GHG accounting question in which, depending on the methodology used, the GHG emissions can vary by a factor of 1 (Metabolic, 2020). This is due to the higher value of recycled content included in the can than the recycling rate of aluminum cans (i.e. recycled content approach vs. avoided burden approach). In this case, the average is likely a good approximation of the benefits/burdens of the system. The second variable that affects the emissions for aluminum is very real and that is the percentage of recycled content used in the package. The emissions for the same package vary by a factor of 3 when going from 30% recycled content to 100% recycled content (Zampori et al., 2014). The majority of the studies evaluated used the U.S. recycled content average of 73% (with 23% post-industrial material) and the current recycling rate of 49.8%. The Gigaton data shows the same trend in which a PCR content of 35% has over double the emissions than PCR content of 73%. The final number used in the model, 73%, is pulled from Project Gigaton (2020).

Steel: Steel packaging also has a range of emissions based on the researched studies (2.33 MTCO2eq/metric ton to 4.61 MTCO2eq/metric ton). Additionally, the Gigaton dataset was lower than any of the studies found (1.41 MTCO2eq/metric ton with 35% PCR – Franklin (2008)). Since it was outside of the range of the studies, as best course of action, it was chosen to use the average of the studies: 3.25 MTCO2eq/metric ton.

In combining aluminum and steel packaging into one category, it was recognized that these two materials have both GHG emission and weight differences. The aluminum can is generally lighter and has higher GHG emissions (on a per metric ton basis). When averaging the emissions in combination with the average weight change, the net difference in comparison to a plastic package was only 25% higher for steel than for aluminum. The aluminum packages were on average 33% lighter than a corresponding plastic package and had on average 5.80 MTCO2eq/metric ton of material or emissions of 3.88 MTCO2eq/metric ton of plastic equivalent (41% higher). The steel packages were on average 52% heavier than a corresponding plastic package and had on average 3.25 MTCO2eq/metric ton of material or emissions of 4.94 MTCO2eq/metric ton of plastic equivalent (80% higher). To combine the two metrics, a weighted average of the packaging generation from EPA's Facts and Figures (2018) was used – 60% steel and 40% aluminum. On average, it was estimated that metal has 79% higher emissions than an equivalent plastic bottle.

For end-of-life emissions for metal, the WARM model from the U.S. EPA (2016) was used. Any credits for recycling (i.e. offsetting virgin material) were excluded since PCR was included instead. This way, double counting can be avoided. In general, the EOL emissions are only for transportation to a landfill, incinerator, or recycling facility.

5.5.1.1. Substitute GHG emissions

Solution	System map	Production GHG in t CO2eq/ t of substitute	Production and conversion GHG change per ton of single-use plastic to substitute	End of life GHG in t CO2eq/ t of substitute
Paper (key data point)	0.9	**0.9 production and conversion** (Project Gigaton (2020): 95% * corrugated GHG + 5% LDPE GHG), 100% virgin paper	- 51% compared to plastic (incl. weight increase)	Recycling (-0.51); Combustion (-0.49); Landfill (0.84) (EPA, 2016)
Paper (additional data points)		**0.28** (Nabinger et al., 2019: U.S. paper packaging production); **0.55** (SYSTEMIQ compilation of different sources, 2019); **1.85** (EcoInvent database 2.2 polycoated paper box, cited by Frischknecht et al. (2005))		0.3 total end-of-life (SYSTEMIQ compilation of different sources, 2019); Recycling (0.21); Incineration (0.8); Landfill (0.08); (EcoInvent database 2.2 polycoated paper box, cited by Frischknecht et al. (2005))
Compostables (key data point)	0.10	**1.82 production** (corn-based PLA in Posen et al. (2016)) *(+ 0.9 conversion to be added, as plastic)*	+28% compared to plastic production (incl. weight increase)	Composting **(-0.15);** landfill Without the storage offset **(0.02);** combustion with utility credit **(-0.65)** (EPA, 2016)
Compostables (additional data point)		**1.0** (PLA and PHA average in Hottle et al., (2013)); **1.21** (Biocomposites with bagasse fiber in Ita-Nagy et al. (2020)); **0.98** (cassava starch packaging in Casarejos et al. (2018))		Incineration (1.3); Composting (1.7); Landfill (0.04); Posen et al. (2016): average of PLA and PHB. Landfill (2.7); Composting (3.3.) (Benavides et al. (2020): PLA. Total EOL (3.15): Hottle et al. (2013): PHA and PLA average. Total EOL (1.05): Casarejos et al. (2018): compostable of cassava starch.
Beverage cartons (key data point)	0.11	**1.99 for production and conversion** (Ecoinvent 3.7.1 (2020): market for liquid packaging board container, allocation at the point of substitution, IPPC 2013: GWP 100a)	-28% compared to plastic	See paper
Beverage cartons (additional data points)		**6.77, 6.44** (Markwardt et al, (2016) – two EU packages), 2.85 (Franklin, (2008)) - Milk), 4.22, 5.64 (Ball, 2020 – two U.S. packages), 2.52, 2.83 (Ball (2020) – two EU packages)		
Glass (key	0.12	**1.16 Production and conversion** – Project	+322%	Recycling (0.02); Combustion (0.03); Landfill (0.02) (EPA, 2016) – excluding

datapoint)		Gigaton (Walmart (2020)) with 35% PCR (Ball (2020))		recycling credit, as credit is taken with PCR
Glass (other studies)		**1.00 Production & conversion** 0.52 (Amienyo et al. (2013)), 0.67 (Amienyo et al. (2014)), 0.58 (Amienyo et al. (2016)), 0.93 (Humbert et al. (2009)), 1.17 (Markwardt et al. (2016)), 1.14 (Metabolic (2020)), 1.57, 1.37 (Ball (2020)) – U.S. Packages), 1.03, 0.97 (Ball (2020)) – EU Packages).		Recycling (0.02); Combustion (0.03); Landfill (0.02) (EPA, 2016) – excluding recycling credit, as credit is taken with PCR
Metal Overall		Production and conversion from aluminum 39% of U.S. generation; steel 61% of U.S. generation (EPA (2018))	**+64% (4.52** per ton of single-use plastic to metal)	Recycling (0.02); Combustion (0.04); Landfill (0.02) (EPA, 2016) – excluding recycling credit, as credit is taken with PCR
Metal (key datapoint)		**5.80 Production & conversion AL** – Project Gigaton (Walmart, 2020) with 73% PCR (Ball 2020) **3.25 Production & conversion Steel** – 2.34 (Amienyo et al., 2016), 3.95 (Franklin, 2008 - Tune), 2.33 (Franklin, 2008 - Coffee), 4.61 (Markwardt et al., 2016) – average of studies was used as Gigaton data wasn't in the range of study results	**+41% AL (3.89** per t of single-use plastic to AL) **+80% steel (4.94** per t of single-use plastic to steel)	Recycling (0.02); Combustion (0.04); Landfill (0.02) ((EPA, 2016) excluding recycling credit, as credit is taken with PCR
Metal (other studies)	0.13	**Production & conversion AL:** 6.28 (Amienyo et al., 2013), 6.78 (Amienyo et al., 2016), 9.28 (Zampori et al., 2014 – 30% recycled content), 2.93 (Zampori et al., 2014 – 100% recycled content), 4.85 (Metabolic 2020 – 73% recycled content), 8.13 (Metabolic 2020 – 50% recycling rate), 6.51, 6.67, 6.37 (Ball 2020 – U.S. packages), 7.07, 7.78, 6.93 (Ball 2020 – EU packages). **Production & conversion Steel** 2.34 (Amienyo et al., 2016), 3.95 (Franklin, 2008 - Tuna), 2.33 (Franklin, 2008 - Coffee), 4.61 (Markwardt et al., 2016), 1.41 (Gigaton (Walmart, 2020) with 35% PCR)		Recycling (0.02); Combustion (0.04); Landfill (0.02) ((EPA, 2016) excluding recycling credit, as credit is taken with PCR

6. Post-consumer Recycled Feedstock

6.1. Cost assumptions

[This section may be updated as research continues in this area.]

Plastic IQ uses an assumption that a metric ton of mechanically recycled (MR) content costs 15% more than virgin content, based on a study done by Closed Loop Partners (n.d.) for PET. The study estimated that the production cost of PCR content was between 7% and 16% higher than the production cost of virgin. Another data point is from More Recycling (2021), which compared the cost for virgin HDPE to both colored and natural PCR. They found colored PCR to be cheaper than virgin, but natural color was double the cost. A price at the high end of this range was chosen on the assumption that a significant share will be used for food-grade high-quality content, but in practice lower-cost.

CR cost assumptions are an estimate based on expert views of likely cost evolution. The CR sector is still highly immature, and cost data are difficult to source. Although CR content presently is much more than 50% above virgin-content prices, one can believe this premium will come down over time as the technology matures and supplies increase.

6.2. GHG assumptions

Methodology

Both the production of recycled content and its use in producing new packaging are essential steps in a circular economy, as one without the other does not yield any emissions savings. Recognizing this, the GHG emissions associated with the recycling process and the credit for emissions avoided by not producing virgin plastic are split evenly between the producer and the consumer of recycled content. This methodology is referred to as the "Shared Burden" or "50/50" approach in life-cycle analysis academia (Nicholson et al., 2009). Each party's emissions were calculated under a scenario in which 100% of the savings are attributed to the producer and a scenario in which 100% of the savings are attributed to the consumer, then taking an average for each party's respective emissions under each scenario. The savings were then subtracted from gross emissions to reach net emissions. This is performed for both MR and CR.

Emissions from producing recycled content

The process of recycling waste plastic accrues losses during the physical and/or chemical treatment of the waste feedstock[1]. For mechanical recycling, the recycling processing loss rate varies among plastic types but since PET/HDPE bottles account for the majority of MR feedstock, this plastic type's rate of 5% for MR losses was applied. Similarly flexible materials have a loss rate of 27% and account for the majority of CR waste feedstock; hence 27% for all CR losses was applied.

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[1] Note that this refers to the process inside the facility: sorting losses at the MRF are handled elsewhere.

Applying these loss rates implies that producing 1 metric ton of mechanically recycled content requires 1.05 metric tons of waste plastic feedstock and 1.37 metric tons when using CR. The process of recycling 1 metric ton of plastic waste through MR emits 0.5 tCO2e and 3.0 tCO2e via CR[2]. Thus, the emissions associated with producing 1 metric ton of recycled content via MR are 0.5*1.05 = 0.53tCO2e and 3.0*1.37 = 4.11tCO2e.

Emissions avoided from substituting recycled content for virgin

The production of 1 metric ton of virgin plastic is assumed to emit 1.85 tCO2e (Project Gigaton, 2020). Substituting recycled content (MR or CR) for virgin content avoids 1.85 tCO2e. Since half the savings are attributed to the recycled content consumer, the emission credit associated with using 1 metric ton of recycled content in packaging instead of virgin content is 1.85 ÷ 2 = 0.92 tCO2e. So both the producer and consumer are allocated carbon credit of 0.92tCO2e per metric ton recycled content produced/consumed. For the consumer, this deduction comes against the baseline of 1.85tCO2e emitted, so the savings reduces their emissions for the new plastic from 1.85 to 0.53tCO2e.

Note that the value differs between MR and CR for 1 metric ton of plastic waste recycled, owing to loss rates. One metric ton of mechanically recycled waste only delivers 0.95 metric ton recycled content, hence it only offsets 0.88 tCO2e instead of 0.92 tCO2e. Similarly recycling a metric ton of plastic waste through CR only produces 0.73 metric ton recycled content and thus only offsets 0.68 tCO2e.

Net emissions from mechanically and chemically recycled plastic content

The net GHG emissions for recycled content are the result of emissions released during recycling minus emissions saved from avoiding virgin plastic.

- The MR producer emits 0.25tCO2e per metric ton recycled but saves 0.88tCO2e so in total reduces emissions by 0.63tCO2e.
- The CR producer emits 1.50tCO2e but saves 0.68tCO2e so in total emits 0.82tCO2e.
- The MR consumer emits 0.26tCO2e per metric ton recycled content produced but saves 0.92tCO2e (against a baseline of 1.85tCO2e), therefore net emissions = 1.19tCO2e *2.7 (baseline) + 2.05 (50% recycling emissions) – 1.35 (50% emission savings) = +3.40 (net effects)*
- The CR consumer emits 2.05tCO2e per metric ton purchased but saves 0.92 tCO2e against a baseline of 1.85tCO2e, therefore net emissions are 2.98tCO2e.

6.2.1.1. Recycled content emissions

		tCO2e/metric ton plastic waste recycled
Recycling	MR	-0.63
	CR	0.82
		tCO2e/metric ton recycled content purchased

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[2] For the sake of transparent accounting and parsimony of methodology, the GHG calculation assumes that 100% of MR is closed loop and CR quality. The plastic to Fuel (P2F) conversion process is assumed to emit 0.3 tCO2e per ton, based on Benavides et al (2017).

Purchasing	MR	1.19
	CR	2.98

7. Bio-based Plastic Content

7.1.1. Cost assumptions for bio-based plastic content

Plastic IQ uses an assumption that a metric ton of bio-based drop-in plastic content costs 23% more than virgin fossil fuel-based content (leading to a bio-based production costs (i.e., excluding conversion) of $2,200/t material). This cost increase assumes that bio-PE is the most common bio-based plastic used for packaging today with the highest current and necessary production capacity (Brizga et al. (2020)). The cost increase of 23% is based on averaging two studies: a 10%-20% cost increase reported by van den Oever et al. (2017) and a 30% cost increase reported by Sirascusa & Blanco (2020). In comparison, bio-PP was found to be 80% -100% more expensive (van den Oever et al. (2017) Sirascussa & Blanco (2020)).

7.1.2. GHG emission assumptions for bio-based plastic content

GHG emissions of bio-based plastic drop-in feedstock differ depending on the plastic type, feedstock, geographical region, and energy sources in refineries. Table 7.1.2.1 summarizes the findings from Posen et al. (2016) and Chen & Patel (2012), analyzing plastics from biological sources, for instance showing that GHG emissions from bio-PET are higher than for bio-PP or Bio-PE. In these studies, as well as in the Plastic IQ tool, the carbon stored in the biomass (i.e., carbon from regenerative biogenic sources) is included as negative emissions in the "cradle-to-gate" phase since they count as positive emissions at the end of life. Plastic IQ assumes that bio-PE is the most common bio-based plastic used for packaging with the highest current and necessary production capacity (Brizga et al., 2020). As feedstock, corn the primary feedstock used for PLA in North America was chosen (rather than cassava or sugarcane which are more common in other geographic areas) (GreenBlue, n.d.).

To ensure consistent boundary conditions and assumptions, GHG per metric ton for both bio-based plastic and compostable plastic is based on Posen et al. (2016). As suggested by ISO 14040, system expansion allocation data was chosen and a mean confidence interval. This source is considered conservative, as other sources cite lower emissions are possible depending on data, assumptions, and boundary conditions (see table 7.1.2.1). Building on this, Plastic IQ assumes 0.97 CO2eq per ton of bio-based produced, from cradle to gate, i.e., including production but excluding plastic conversion, end-of-life, and "use-phase" emissions of the packaging (e.g., transportation emissions), equaling a ~50% GHG emission reduction compared to virgin, fossil fuel-based plastic production. From Posen et al. (2016), the system expansion allocation method was chosen, as suggested by ISO 14040.

7.1.2.1. Bio-based plastic GHG assumptions

Plastic type	Feedstock	Cradle-to-gate: t CO2eq/t plastic

Bio-HDPE, LDPE average (data point used in Plastic IQ)	Corn	*0.97 (Posen et al. (2016))*
Bio-PE	Corn	-0.34 (*Chen & Patel (2012)*)
Bio-PE	Sugarcane	-2.05 (*Chen & Patel, 2012)*
Bio-PP	Corn	-0.25 (*Chen & Patel, 2012)*
Bio-PET	Corn	1.4 (*Chen & Patel, 2012)*
Bio-PET	Corn	2.24 (*Posen et al., 2016)*
Bio-PET	Sugarcane	1 (*Chen & Patel, 2012)*

Comparison of cradle-to-gate GHG emissions of different bio-based plastics as cited in Chen & Patel (2012) and Posen et al. (2016)

Aside from GHG emissions, burden shifting to different environmental impacts than for fossil fuel-based plastics can be a risk of bio-based plastics, in particular regarding the additional amounts of land and water needed, increasing competition for different land uses, and negative effects on biodiversity. Other environmental impacts can also be caused by the agrochemicals used in the agricultural production (Brizga et al. (2020)).

8. End of Life

8.1. Overview of approach

The Plastic IQ model maps the end-of-life mass flows for plastic after use in the U.S. There are four main sections of the model representing the key stages in the system (see the post-production system map).

8.1.1. Collection and sorting

a. Is the U.S, the majority (98%) of waste is formally collected. From here, the waste moves into "Recycling", "Mismanaged", and "Disposal."
b. Higher levels of recyclability denoted by APR compliance rates increase the amount of waste that moves to recycling, and lower loss rates.

8.1.1.1. Exports

i. Plastic exports are assumed to end up in recycling, landfill, incineration, or pollution to the environment at rates observed in the lower-income geographies to which the U.S. exports (see table below). These end-of-life percentages are applied to Box G.

Assumptions of End-of-Life Fate of Exports							
Mechanically recycled		%	13%	13%	13%	not relevant	BPW (2020), global south
Incinerated		%	4%	4%	4%	not relevant	BPW (2020), global south

Landfilled		%	12%	12%	12%	not relevant	BPW (2020), global south
Pollution		%	71%	71%	71%	not relevant	BPW (2020), global south

8.1.2. Recycling

c. The recyclability of the plastic categories included in the user's plastic footprint is determined by the percentage of plastic that adheres to APR preferred guidelines. The user enters the % adhering to APR guidelines in the baseline footprint section as well as entering a 2030 target value for one of the 'Better Plastic' levers, "Enhance Recyclability." These user-entered percentages determine the APR compliance %. The amount of plastic waste losses from formal sorting to recycling and from mechanical recycling to entering back into the system is determined by the **APR** compliance %.

8.1.3. Disposal

d. A proportion of plastic waste sent for "Collection and Sorting" remains unsorted. A proportion of this waste is managed before being discarded in an engineered landfill or sent for incineration. None of this waste is recycled.
e. A proportion of the chemical conversion recycling is disposed as fuel.

8.1.4. Mismanaged

a. The plastic waste that remains outside of the formal collection system ends up discarded into the natural environment, i.e. as plastic pollution.
b. In addition, a small amount of plastic that is formally collected remains unsorted and ends up being mismanaged, meeting the same end-of-life fate as plastic that is not formally collected.
c. All mismanaged waste is shown in the "pollution to the environment" wedge of the fate wedges chart.

8.2. Mass flow assumptions for each post-production step: BAU scenario

BAU scenario							
Mass flows							
			Bottles	**Rigid mono material**	**Flexible mono material**	**Hard to recycle**	**Sources**
Model assumptions and sources							
U.S.-wide plastic generation data							

BAU scenario							
Mass flows							
			Bottles	**Rigid mono material**	**Flexible mono material**	**Hard to recycle**	**Sources**
Generation actual metric tons		Metric tons/year	4793	2,254	1095	1649	Calculation from: (TRP (2020)), (APR/ACC (2018)), (EPA (2018))
Generation % of total		%	49%	23%	11%	17%	Calculation from: (TRP, 2020), (APR/ACC, 2018) (EPA, 2018)
Collection assumptions							
Average archetype collection rates	Arrow A1	%	98%	98%	98%	98%	BPW (2020)
Share of formal collected for recycling (separated at source)	Arrow C1	%	29%	15%	1%	0%	EPA (2018)
Sorting Assumptions							
Share of mixed waste to chemical conversion (as % of Box C)	Arrow E1	%	0%	0%	1.4%	1.4%	BPW (2020)
Share of mixed waste to dirty MRF	Arrow E3	%	0%	0%	0%	0%	
Share sorted waste to losses – APR preferred compliant	Arrow F3.1	%	10%	20%	20%	0%	Calculation from: (TRP (2020)), (APR/ACC (2018)), (EPA (2018)) A: Assumed same as Rigids
Share of sorted wasted to losses - non-APR preferred compliant	Arrow F3.2	%	30%	40%	40%	0%	Calculation from: (TRP (2020)), (APR/ACC (2018)), (EPA (2018)) B:
Total exported waste	Arrow F4	%	3%	5%	16%	0%	ACC (2017)

BAU scenario							
Mass flows							
			Bottles	**Rigid mono material**	**Flexible mono material**	**Hard to recycle**	**Sources**
Recycle assumptions							
Share of recycling to losses – APR preferred compliant	Arrow I1.1	%	5%	20%	27%	not relevant	TRP Estimate (n.d.); (BPW (2020))
Share of recycling to losses non-APR preferred compliant	Arrow I1.2	%	30%	40%	54%	not relevant	TRP Estimate (n.d.); (BPW (2020))
Share of chemical to plastic	Arrow K1	%	0%	0%	0%	0%	Team assumption based on expert interviews giving the following rationale: Unless current conditions change, plastic-to-plastic advanced chemical recycling is unlikely to reach meaningful scale U.S.-wide by 2030
Share of chemical to losses	Arrow K3	%	27%	27%	27%	27%	BPW (2020)
Dispose assumption							
% Managed waste from post-collection waste	Arrow L1	%	99.4%	99.4%	99.4%	99.4%	Law et al. (2020): Midpoint between 0.3 and 0.9.
Share of managed to Incineration	Arrow M1	%	21%	21%	21%	21%	EPA (2018)
Share of managed to Engineered landfills	Arrow M2	%	79%	79%	79%	79%	EPA (2018)
Mismanaged assumptions							

BAU scenario							
Mass flows							
			Bottles	**Rigid mono material**	**Flexible mono material**	**Hard to recycle**	**Sources**
Share uncollected to open burn	Arrow Q1	%	22%	22%	22%	22%	BPW (2020)

8.3. Cost assumptions for post-production

End-of-life costs of disposing of substitute materials are shown in the final results screen of Plastic IQ, under "public expenditure on managing packaging at end of life." For end-of-life costs, the following assumptions were applied to each metric ton going through the system map. Each variable is applied to the relevant box in the system map.

BAU scenario				
Costs and Prices				
			Values	**Sources**
OPEX				**Source/logic**
Formal collection	Box C	$/metric tons to be collected	$ 380	U.S. estimate for all materials; Formal collection – Assumes $6/HH/month for collection, $5/HH/year for education and 450 lbs/HH for recovery (TRP, 2020)
Formal sorting	Box Fa and Box Fb	$/metric tons to be sorted	$ 40	Based on TRP MRF capital and operating model ($30 million total capital, 83,000 metric tons/year) with capital for optical sorters allocated specifically to plastic. Overall gross operating cost (including amortized capital) of $119/metric ton. Net cost to sort plastics - $280/metric ton and revenue per metric ton of plastics of $240 based on past two years of data from recyclingmarkets.net
Mechanical recycling	Box Ia and Box Ib	$/metric tons to be recycled	$ -	The U.S. does not subsidise; 0 cost are assumed for recycling to public funds, as recycling is a privately run activity
Chemical conversion P2P	Box X	$/metric tons to be	$ -	

BAU scenario				
Costs and Prices				
		chemically converted		
Chemical conversion P2F	Box P	$/metric tons to be chemically converted	$ -	
Incineration	Box O	$/metric tons to be thermally treated	$ 50	The World Bank (2018)
Incineration energy sale (per metric ton of plastic)	Box O	$/metric tons input	$ 44	BPW (2020)
Engineered landfills	Box N	$/metric tons to be landfilled	$ 15	Estimated operating cost of landfill tipping fee, capital cost is itemized separately. Total tipping fee of 57/metric ton (EPA, 2018) increase of 0,56 USD/metric tons p.a. increase from 2004- 2017, alternative: 52.52 USD/US short ton (2018) with 2.74 increase to 2019 (EREF, 2019)
Annual CAPEX (depreciation)				
Formal collection	Box C	$/metric tons to be sorted	$ -	CAPEX set to zero, as amortized capital costs for trucks, carts and other equipment are included in the OPEX cost
Formal sorting	Box F	$/metric tons to be sorted	$ -	CAPEX set to zero, as amortized capital costs for building, sorting equipment and rolling stock are included in the OPEX cost
Mechanical recycling	Box I	$/metric tons to be recycled	$ -	We have assumed 0 cost for recycling to public funds, as recycling is a privately run activity
Incineration	Box O	$/metric tons to be treated	$ 36	The World Bank (2018)

BAU scenario				
Costs and Prices				
Engineered landfills	Box N	$/metric tons to be landfilled	$ 42	Landfill tipping fee, EPA (2018), increase of 0,56 USD/metric tons p.a. increase from 2004- 2017, alternative: 52.52 USD/US short ton (2018) with 2.74 increase to 2019 (EREF, 2019)

8.4. GHG emissions assumptions for post-production

We include all end-of-life emissions in Plastic IQ's calculation of life-cycle emissions of packaging, as well as production and conversion emissions. End-of-life assumptions apply to each metric ton going through the system map, as follows. Each variable is applied to the relevant box in the system map.

All scenario				
GHG emissions				
			Values	**Sources**
Formal collection	Box C	tCO2e/metric ton	0.02	BPW (2020): Extensive explanation provided in report (page 32)
Sorting	Box F	tCO2e/metric ton	0.05	BPW (2020): Assumed combination of sorting and transport to recyclers, extensive explanation provided in report (page 32)
Mechanical recycling	Box I	tCO2e/metric ton	-1.03	BPW (2020): Based on APR report, average value of PP, PET, and HDPE, it includes flake to pellet energy, bale-to-flake energy, transport-to-reclaimer, and collect and sort. Collect and sort has been subtracted (page 34). MR emits 0.25t per metric ton recycled but saves 1.28t; therefore, net emissions = -1.03t Please refer to section "6.2.1 Recycled content emissions" for more information.
Chemical conversion P2P	Arrow K1	tCO2e/metric ton	0.51	BPW (2020): Based on reverse engineering done by Mats Linder of figures given by Benavides paper for the process of converting plastic waste into fuel. To this the emissions of producing virgin plastic has been added. CR emits 1.5t per metric ton recycled but saves 0.99t, therefore net emissions = 0.51t Please refer to section "6.2.1 Recycled content emissions" for more information.
Chemical conversion P2F	Arrow K2	tCO2e/metric ton	0.30	BPW (2020): Based on reverse engineering done by Mats Linder of figures given by Benavides paper for the process of converting plastic waste into fuel.

All scenario				
GHG emissions				
Incineration	Box O	tCO2e/metric ton	1.4	BPW (2020): value given for incinerating mixed plastics, offset of displacing normal U.S. energy mix assumed
Engineered landfills	Box N	tCO2e/metric ton	0.01	BPW (2020): as given in report, based on multiple provided pieces of research
Open burning		tCO2e/metric ton	2.89	BPW (2020): as given in the appendix of the BPW report. The proportion of uncollected waste that goes to open burning is applied to this emissions factor.

9. Scenarios

All results of the tool are given for a BAU scenario, apart from the Scenario Analysis tool results section accessible from Screen 6, where users can choose between different scenarios. Table 9.1.1.1 lists the EPR rates for different plastic types by scenario. Table 9.2.1.1 lists the collection rates, losses, costs, and composting rates by scenario (no distinction is made for plastic types here).

9.1. EPR fees

Extended Producer Responsibility (EPR) fees are a cost levied on producers representing the environmental externalities associated with a product throughout its life cycle. EPR fees vary by plastic type and are applied at varying rates under different scenarios. The maximum rates are applied in the "System change" and are 100% of current Canadian EPR fees, as published in "Canadian Stewardship Services Alliance, National Provincial and Material Fee Rates (2021 Update)." EPR fees under "High recycling" and "Low plastic" are 50% of "System change" rates (equivalent to 50% of the U.S. rolling out Canadian level EPR fees) and BAU are 0%. The fees are levied on a dollar per metric ton basis. Thus, each rate is multiplied against the user's relevant plastic type annual volume thereby determining overall company costs.

9.1.1.1. *EPR Fees (US$/metric ton)*

	BAU	High recycling	Low plastic	System change
Bottles	0	354	177	354
Rigids	0	473	237	473
Flexibles	0	255	255	255
Hard to recycle	0	564	282	564

9.2. Custom scenario dynamic variables

The custom scenario section allows the user to alter assumptions concerning EPR coverage, EPR policy effectiveness, composting rates, and the uptake of re-use models across the US. Altering these variables gives rise to variations in plastic collection rates, composting rates, reuse model costs and overall system transition costs. The central methodology underpinning the system cost calculations is to take an estimated capital cost attributed to the maximum achievable level possible and derive a sliding scale by assuming a linear relationship. These maximum levels and their cost assumptions are set out in the table below:

9.2.1.1. *System transition costs*

	Maximum Target	System Transition Cost (US$bn)

Composting rate	31%	13.4
Weighted average collection rate	63%	7.8
Advanced MRF flexibles capability coverage[3]	100%	4.1

Separately, the user can also vary the cost of recycled content and plastic substitutes. The resulting changes to the user's cost outlook in the custom scenario are a function of the user's new strategy footprint and the new cost input alone – no additional assumptions go into this calculation.

The estimates for increasing the recycling rate and expanding access to flexibles capability include more than just capital cost. They also include aggressive education and resident engagement over five years to ensure high performing programs. More detail will be released with The Recycling Partnership's National Capital Needs Assessment report (June 2021).

9.2.2. EPR coverage, policy effectiveness and collection for recycling

In the custom scenario section, the user can alter assumptions concerning EPR coverage and the effectiveness of EPR policies. These two inputs are used to calculate the collection for recycling rates for each of the plastic types, which in turn affect the user's end-of-life (EOL) performance in their custom scenario and indicates their weighted average collection rate (this does not affect the company's circularity score or performance under other scenarios).

The calculation is based on the assumed rates of collection for different plastic types and EPR coverage in 2030 under" BAU" and "System change". The data points used in the model are set out below:

9.2.2.1. EPR and collection rates

Scenario	**EPR Coverage**	**Collection for recycling rate by plastic types**			
		PT1	PT2	PT5	PT3,4,6,7
		Bottles	Rigid mono-materials	PE Mono film	Hard to recycle
BAU	0%	29%	15%	1%	0%
System Change	100%	70%	52%	10%	0%

Sources: TRP State of Curbside Recycling Report, 2020 and American Chemistry Council National Post-Consumer Plastic Bottle Recycling Report, 2018

The "System change" scenario has high policy effectiveness. A linear relationship between collection rates and EPR coverage is assumed, meaning the effective collection rate for any plastic at any given level of EPR coverage can be calculated, based on a regression between the known data points. For example, since an EPR coverage rate of 0% under BAU yields 29% PT1 collection, the collection rate under BAU

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[3] This metric reflects the extent to which MRF capacity across the U.S. reaches sufficient sophistication to be able to process flexible materials. 100% implies all MRFs can handle flexibles.

for any given EPR rate (0-100%) can be determined, thus deriving the low policy effectiveness line for PT1.

Having derived the low and high points on the respective “BAU” and “System change” policy effectiveness curves for each plastic type, a medium policy was assumed to fall at the mid-point between the two extremes. The gap between each policy effectiveness curve represents assumed difference in effectiveness of EPR policy. For illustrative purposes, a delta of 10% was applied. This implies the same EPR coverage rate under medium EPR effectiveness yields +/- 10% collection rates on the high/low policy effectiveness lines.

Having determined the collection rates for each of the plastic types, the plastic waste footprint was applied for the user’s new strategy in 2030. This gives us the weighted average collection rate.

9.3. Transition system costs

Total U.S. transition system costs in the custom scenario are given by the sum of composting, collection and flexible MRF infrastructure costs.

9.3.1. Reuse system costs

In the custom scenario section users can test the effect of either medium or high uptake of reuse models (compared to the BAU uptake of reuse models). The effect of these different scale-ups varies per reuse cost model (earlier, users can choose if their reuse models should be average, high-or low-cost models as outlined in section 4). Only the OPEX (service provision/running) costs are assumed to decrease while CAPEX costs are assumed to stay the same across the uptake scales.

If there is rapid, high scale-up of reuse systems across the USA, such as through great improvements in consumer adoption and (shared) logistics and infrastructure across industry, costs are assumed to significantly decrease as a result of streamlined logistics, transport, and using refill infrastructure to full capacity. For high scale-up, the following assumptions are made per cost reuse model:

- **Low-cost reuse models:** OPEX costs stay the same since costs are unlikely to further decrease.
- **Average cost reuse models**: OPEX costs reach the cost level of low-cost models
- **High-cost reuse models:** OPEX costs reach the cost level of average cost models.

If there is moderate scale-up of reuse systems across the U.S., costs are similarly assumed to go down, but less than for high scale-up models. For medium scale-up, the following assumptions are made per cost reuse model:

- **Low-cost reuse models:** OPEX costs stay the same since costs are unlikely to further decrease.
- **Average cost reuse models:** OPEX costs halfway between BAU and high scale-up average cost reuse models.
- **High-cost reuse models:** OPEX costs halfway between BAU and high scale-up high-cost reuse models.

9.3.2. Composting rates

The Custom Scenario allows the user to choose a composting rate from 2% - 31%, with 2% representing the current composting rate in the U.S. (see section 5) and 31% presenting the targeted composting rate as stated by ReFED (n.d.). This determines the capital investment into U.S. composting infrastructure. The relationship is based on ReFED's Solution Database (in turn informed by an analysis from RRS Consulting) which estimates that $1.34 billion over 10 years can isolate 31% of target organic waste material. This data point allows the estimation of a relationship and thus a sliding scale in the model.

9.3.3. Collection infrastructure costs

The Custom Scenario calculates a weighted average collection rate of from 24% - 63%, based on the EPR coverage and policy effectiveness choices entered (see above). This in turn determines the capital investment into U.S. recycling infrastructure. The relationship is based upon TRP's estimate that the maximum likely weighted average collection rate by 2030 in the U.S. is 63% and that this will require ~$7.7 billion capital investment. This data point allows the estimation of a relationship and thus a sliding scale in the model.

9.3.4. Flexible content capacity costs

The EPR coverage and policy effectiveness choices entered determine the capital investment into U.S. flexible MRF capacity. The relationship is based upon an estimate from The Recycling Partnership's forthcoming National Capital Needs Assessment Report, which states that $4.1 billion will be necessary to ensure capacity to recycle flexible mono-materials. The cost breakdown is shown in table 9.3.4.1. This table summarizes the other key assumptions under the three different predetermined scenarios that users can choose.

9.3.4.1. Collection rates, EPR fees, and policy effectiveness by scenario

		Bottles	**Rigids**	**Flexible mono-materials**	**Hard to recycle**
BAU	EPR Fees ($/t)	0	0	0	0
	EPR policy effectiveness	Low	Low	Low	Low
	Recycling rate	29%	15%	1%	0%
High recycling scenario	EPR fees ($/metric ton)	354	473	510	564
	EPR policy effectiveness	High	High	High	High
	Recycling rate	70%	52%	10%	0%
	EPR fees ($/t)	177	237	255	282

Low plastic scenario	EPR policy effectiveness	Medium	Medium	Medium	Medium
	Recycling rate	44%	29%	4%	0%
System change scenario	EPR fees ($/t)	354	473	510	564
	EPR policy effectiveness	High	High	High	High
	Recycling rate	70%	52%	10%	0%

Source: see chapter 9 for calculation of EPR fees and recycling rates

9.3.4.2. Cost of plastic substitutes and composting rates by scenario

	BAU	High recycling Scenario	Low plastic scenario	System change scenario	Source
Cost of recycled MR content ($/t)	2,106	2,106	2,106	2,106	Closed Loop Partners (n.d.)
Cost of CR content ($/t)	2,700	2,700	2,700	2,700	Based on internal estimate
Cost of plastic substitutes - paper ($/t)	8,030	8,030	7,620	7,210	BAU: see section 5; System change scenario: cost parity per t of paper to t of plastic; Low plastic scenario: 50% to cost parity per t of paper to t of plastic
Cost of plastic substitutes - compostables ($/t)	9,600	9,600	7,920	6,240	BAU: see section 5; System change scenario: cost parity per t of compostables to t of plastic; Low plastic scenario: 50% to cost parity per t of compostables to t of plastic
Composting rate	2%	2%	31%	31%	ReFED (n.d.)

10. Circularity score

The "overall circularity" score takes the average of the three better circularity sub-scores.

10.1. Less packaging score

The Less Packaging score is one of three key metrics that are averaged to determine the overall Circularity Score in Step 6: "Results." The Less Packaging score calculates how close a company is to the best practice target of using the same amount or less packaging with the New Strategy in 2030 compared to today. To achieve this, any growth in plastic packaging must be offset by reducing or reusing packaging.

- The Less packaging score takes the actual packaging mass in 2030 a company would have according to the baseline plastic demand and the targeted packaging mass goals to be achieved by reduction and reuse; and compares it to the current packaging mass in 2020.
- Companies are scored in reference to benchmarks in industry best practice, which in this case is using the same amount or less (<=0%) packaging in 2030 compared to today. While companies have only committed to overall ambitious plastic (rather than packaging) reduction targets, from these, the packaging reduction target was roughly extrapolated as conservative best practice.
- As an illustrated example of the scoring calculation, assume a company has 100 metric tons of plastic in 2020 and expects to have 120 metric tons in 2030 due to company growth. If the company enters to reduce the baseline 2030 packaging mass by 10% through reduce and reuse solutions, it will reduce 12 metric tons (10% x 120 metric tons) compared to the 2030 baseline, leaving it with 108 metric tons of plastic remaining in 2030. it would have increased its packaging mass by 8 metric tons from 2020 to 2030, but it would have decreased the packaging volume compared to the 2030 baseline. This would be a "Less packaging" score of 60% (calculated by dividing the packaging reduction compared to baseline by the expected packaging increase with the 2030 baseline: 12t/20t = 60%).

10.2. Better packaging score

The Better Packaging score is one of three key metrics that are averaged to determine the overall Circularity Score in Step 6: Results.

The Better Packaging score is a composite score made up of three calculations:

- Part 1 calculates how close a company is to the best practice of using at least 30% less virgin plastic compared to today.
- Part 2 calculates how close a company is to the best practice of using at least 50% recycled or bio-based plastic content.
- Part 3 calculates how close a company is to having 100% of its plastic packaging being compliant to the "APR preferred" recyclability guidelines.

Part 1: virgin plastic reduction

- Part 1 of the Better Packaging score compares a company's virgin and bio-based plastic in 2020 to the virgin and bio-based plastic content in 2030 a company would have according to its baseline plastic and the targeted virgin and bio-based plastic content it could achieve by reducing plastic or switching to recycled content or non-plastic substitutes.

- Companies are scored in reference to benchmarks in industry best practice, which in this case is using at least 30% less virgin plastic compared to today (e.g., Unilever and Henkel 50%, PepsiCo 35%, Nestlé 33%, and Mars 25% virgin reduction targets).
- As an example of the scoring calculation, assume a company has 100 metric tons of virgin and bio-based plastic in 2020 and expects to have 120 metric tons in 2030 due to company growth. If the company enters to reduce its virgin plastic mass by 34% compared to its 2030 baseline, it will have 80 metric tons of virgin and bio-based plastic left with its New Strategy in 2030. This would be a Part 1 Better Packaging score of 80% ((120t-80t)t/ 120 – (70%*80t)).

Part 2: recycled and bio-based content

- Part 2 of the Better Packaging score compares the recycled and bio-based plastic content a company would have in 2030 compared to the overall plastic mass.
- A company is scored in reference to benchmarks in industry best practice, which in this case is at least 50% of the overall plastic being based on recycled or bio-based content in 2030 (e.g., Coca-Cola and California rPET goals of 50%).
- As an example of the scoring calculation, assume a company enters to have 30 metric tons of recycled and bio-based plastic out of a total of 120 metric tons of plastic volume with the New Strategy in 2020, then it would have a recycled and bio-based content share of 25%. This would be a Part 2 Better Packaging score of 50% (25%/50%).

Part 3: design to enhance recyclability

- Part 3 of the Better packaging score compares the plastics a company plans to design to be fully recyclable in 2030 to its overall plastic mass.
- A company is scored in reference to benchmarks in industry best practice, which in this case is 100% of the overall plastic being designed to be fully recyclable by adhering to "APR preferred" guidelines.
- As an example of the scoring calculation, assume a company enters to have 90 metric tons of plastic being designed to be fully recyclable out of a total 120 metric tons of plastic volume with the New Strategy in 2020, it would have a share of 75% designed to be fully recyclable. This would be a Part 3 Better Packaging score of 75%.

10.3. Better System score

The Better System score is one of three key metrics that are averaged to determine the overall Circularity Score in Step 6: "Results."

- The Better System score compares the investment in system initiatives for reuse, design and innovation, collection and recycling, policy and advocacy, and recycled plastics and feedstock development a company would contribute with its New Strategy in 2030 to a best practice target of collaborative investment.

- Companies are scored in reference to best practice, which is defined as covering 50% of EPR costs in Canada per plastic type, equaling $177 to $282 per metric ton of plastic – depending on the plastic type. In addition, they receive one additional percentage point per initiative they are investing in or participating in, with a maximum additional contribution of 5%.
- As an example of the scoring calculation, assume a company has a plastic footprint of 1,000 metric tons with its New Strategy in 2030, of which 500 metric tons are PET bottles and 500 metric tons are PE mono-material film. In Canada, it would need to pay $432,000 in EPR fees for those plastics. If the company enters $100,000 in investment in system initiatives on this page that total equals 23% of EPR fees and hence a score of 46% compared to the best practice of 50%. In addition, the company would invest and participate in four initiatives, bringing an additional 4%. This would be a Better System score of 50% ((23%/50%) + 4%)).

11. Target-Setting and Medals Methodology

For all four target categories, users can choose their target year (2021-2030), while the default target is 2030. Thresholds for each category are defined to be reached by 2030, but users can meet the thresholds earlier than that year, if desired. In the following, 2030 is used as the target year for illustrative purposes.

Companies can receive medals for each target category: GOLD or SILVER (with certain thresholds to be met) or ADOPTER (to receive "adopter" recognition companies need to formally submit their action plan but there is no minimum threshold). In addition, an overall medal award is calculated, based on the four target categories as follows:

- GOLD: If a company's new strategy meets any three of the four gold thresholds for the four target categories
- SILVER: If two of the thresholds from target categories 1, 2, or 3 reach the silver threshold or above.
- ADOPTER: no minimum threshold required.

11.1. Target category 1: Virgin plastic reduction

Using a real, historical baseline such as 2020 mass to measure and report plastic reduction against, rather than a 2030 projected plastic usage, is considered best practice such as in the Ellen MacArthur Foundation's Global Commitment guidance. The "virgin plastic reduction" target category therefore calculates how much virgin plastic mass a company reduces in their New Strategy by 2030 compared to 2020, as a % of 2020 virgin plastic mass, whereby:

- Virgin plastic mass includes traditional polymers (such as PE, PP, PET) as well as certified compostable plastics (such as PLA, PHA, PHB, as entered into the tool in screen 4), whether bio-based or from fossil fuels. Compostable non-plastic materials are excluded.
- The tool considers that virgin plastic reduction can come from elimination, minimization, reuse, non-plastic materials (switching to compostable plastic does not contribute to virgin plastic reduction), or using mechanically or chemically

recycled content. It is broadly considered more beneficial to leverage elimination, minimization, and reuse (i.e., solutions that reduce overall packaging requirements of all materials) than using other means to achieve virgin plastic reduction (see Solutions Database for more information). The suitability of switching from plastic to non-plastic materials needs to be evaluated on a case-by-case basis. Packagers should understand a number of key factors in their decision-making process when choosing between plastic and non-plastic materials – see the Solutions Database for some of these key factors.

For GOLD, there is an additional requirement that relates to "absolute plastic reduction", whereby:

- absolute plastic reduction refers to decreasing total plastic mass used in New Strategy 2030 compared to 2020 total plastic mass;
- total plastic mass includes virgin plastic mass plus recycled content;
- the tool considers that absolute plastic reduction can come from elimination, minimization, reuse, or non-plastic materials (switching to compostable plastic does not contribute to virgin plastic reduction), but it is generally considered more beneficial to focus on elimination, minimization and reuse according to the waste hierarchy (i.e. solutions that reduce overall packaging requirements of all materials)..

The medal thresholds are as follows:

- For GOLD, the firm needs to meet both 1 and 2 below. The GOLD threshold is based on best practice laid out in EU Plastics Pact aiming to "reduce virgin plastic products and packaging by at least 20% (by weight) by 2025, with half of this reduction coming from an absolute reduction in plastics".

  1) reduce virgin plastic usage with the New Strategy by 2030 to a level 20% lower than 2020 virgin plastic baseline (virgin plastic reduction >=20% vs 2020)
  2) absolute plastic reduction >=10% vs 2020

- For SILVER, the firm needs to have the same or less virgin plastic usage with the New Strategy by 2030 compared to 2020 virgin plastic baseline (virgin plastic reduction >=0% vs 2020). The SILVER threshold is based on New Plastics Economy Global Commitment guidance to set targets that reduce absolute usage of virgin plastic by 2025 compared to a historical baseline.
- If these targets are not met, but firms submit any target, they achieve ADOPTER status.

11.2. Target category 2: Recycled and bio-based content

The "recycled and bio-based content" target calculates how many metric tons of recycled and bio-based content a company has with its New Strategy in 2030, as a percentage of total remaining plastic mass in its New Strategy in 2030, where:

- recycled content is defined as being from post-consumer mechanically or chemically recycled content;

- bio-based content includes bio-based certified compostable plastics and bio-based “drop-in” plastics (such as bio-PE, bio-PP, bio-PET);
- total remaining plastic mass includes traditional polymers (such as PE, PP, PET) as well as compostable plastics (such as PLA, PHA, PHB, as entered into the tool in screen 4), whether bio-based or from fossil fuels.

Medal thresholds are as follows:

- For GOLD at least 30% of the total remaining plastic mass needs to be from recycled or bio-based sources. This threshold is based on the stated goal of the U.S. Plastics Pact to have at least 30% recycled or bio-based content in plastic.
- For SILVER, at least 15% of the overall remaining plastic volume with the New Strategy needs to come from recycled or bio-based sources. This threshold is based on the midpoint to GOLD.
- If these targets are not met, but firms formally submit any target, they achieve ADOPTER status.

11.3. Target category 3: Design to enhance recyclability

The “design to enhance recyclability” target category calculates whether a company’s New Strategy in 2030 aims to meet the best practice target of ensuring 100% of plastic packaging is designed to enhance recyclability. Plastic IQ provides recognition of a gold medal for this target category to firms who meet **either of the following**:

- 100% of plastic in the New Strategy by 2030 (or sooner) adhering to “APR preferred” guidelines, as entered in the tool step 4 (“better packaging”).(Note: achieving 100% APR preferred packaging does not mean your packages meet the Ellen MacArthur Foundation’s Global Commitment definition of “recyclable”).

Or:

- Commit to the Ellen MacArthur Foundation’s New Plastic Economy Global Commitment target to have 100% reusable, recyclable or compostable plastics by 2025, as entered by ticking a box in the target submission screen. This commitment defines recyclable as being in practice and at scale; see the Global Commitment guidance for further information.

If this threshold is not met, but firms formally submit their New Strategy, they achieve ADOPTER status.

11.4. Target category 4: Collaborative action

The “collaborative action” target category provides a GOLD medal if companies meet the specified threshold for financial contributions into system initiatives for reuse, design and innovation, collection and recycling, policy and advocacy, and recycled plastics and feedstock development, as entered in step 5 (“better system”) of the Tool.

- There are no SILVER or ADOPTER awards for this target category.
- For GOLD, companies need to invest annual financial contributions between now and 2030 worth 25% of your estimated EPR fees if EPR fees were adopted

US-wide. This equates to a contribution of $86 to $141 per metric ton of plastic depending on a company's plastic types.

Any future EPR fees your company pays in the U.S. could be counted towards your annual financial contributions.

The contribution threshold is linked to Plastic IQ's estimated system costs of recovering and recycling your packaging: i.e. estimated EPR fees of $354-564/metric ton if EPR fees mirroring Canada's fees were rolled out U.S.-wide. See section 9 of the Methodology Document for details and source of the EPR fee assumptions.

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