THE PLASTIC WASTE MAKERS INDEX

Basis of Preparation

MINDEROO FOUNDATION

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CONTENTS

STEERING COMMITTEE, ANALYTICAL PARTNERS AND DATA PROVIDERS

Collection of blue plastic bottles pressed ready for recycling. Photo credit: Kemter via Getty Images

Steering Committee

A steering committee of seven experts, reflecting knowledge and experience of the plastics industry, trade economics, supply chain analytics and with broad geographic scope, was assembled to jointly develop a conceptual model of the global value chain for single-use plastic **(Figure 1)**. From September to December 2020, the Steering Committee participated in four virtual workshops.

The primary objective of the Steering Committee was to challenge the analysis and assumptions made in the modelling and endorse the resulting estimates. To achieve these objectives, the Steering Committee was given mandate to review and, where necessary, recommend changes to the methodology.

The Steering Committee also offered guidance on the relevant insights of the analysis and suggestions to improve its impact. It did not, however, formally endorse any opinions and implications derived from the work.

An analytical and data framework for each relevant sub-section of the single-use plastic value chain was developed. Where data were scarce or where insufficient scientific evidence was identified, the authors arrived at preliminary estimates that were then presented to the Steering Committee in pre-workshop reading materials and validated by discussion in the virtual workshops.

Figure 1

Composition of the Steering Committee, affiliation, and title.

Name	Affiliation	Title
Prof. Sam Fankhauser (Chair)	University of Oxford and Grantham Research Institute on Climate Change, London School of Economics	Professor of Climate Economics and Policy
Prof. Ambuj Sagar	Indian Institute of Technology, Delhi	Head of School of Public Policy
Mark Barnaba	Fortescue Metals Group	Deputy Chairman and Lead Independent Director
Robin Millington	Planet Tracker	CEO
Toby Gardner	Stockholm Environment Institute	Senior Research Fellow and Director, Trase
Steve Jenkins	Wood Mackenzie	VP, Consulting
Mark Spicer (Observer)	KPMG	Head of Sustainability Services

Analytical partners

Neural Alpha is a sustainable fintech start-up solving the biggest challenges in sustainability and finance using innovative, connected data technologies. It supported the analysis of customs data to track single-use plastic material flows (Section 3.5).

Planet Tracker is a non-profit financial think tank aligning capital markets with planetary boundaries. It supported the analysis of equity ownership of polymer producers. (Section 4.3).

Profundo is an independent not-for-profit company which aims to make a practical contribution to a sustainable world and social justice with profound and fact-based research and advice. It supported the analysis of financing of polymer producers (Section 4.4).

Wood Mackenzie is an energy research consultancy that empowers strategic decision-making in global natural resources with quality data, analysis and advice. It supported the analyses of single-use plastic material flows (Section 3).

Contributors

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Acknowledgments

We would like to thank Martin Stuchtey and the team at SYSTEMIQ Ltd. for their collaboration and analytical support across our transparency initiative.

Close to 85 per cent of all single-use plastics is produced from just five polymers - PP, PET, LLDPE, HDPE and LDPE. Shown here is the manufacture of plastic bags which are commonly made from LDPE. Photo credit: firemanYU via Getty Images.

Data providers and sources

Bloomberg delivers business and financial information, news and insight. Its data was used to inform the financing and ownership analysis (Section 4).

ExportGenius is a market research company providing global export import data and trade intelligence reports. Its data was used to inform the material flow analysis (Section 3.5).

FactSet is a data, analytics, service and technology company, with an entity-centric data model that exposes parent and ultimate parent hierarchical relationships. Its data was used to inform the material flow analysis (Section 3.5).

IJGlobal provides market intelligence for the energy and infrastructure finance industry. Its data was used to inform the financing analysis (Section 4.4)

Nexant provides software, consulting and energy services, including capacity, supply, demand and trade-flow projections, profitability and price forecasts, value chain, and end use analysis. Its data was used to inform the financing and ownership analysis (Section 4).

Orbis, a Bureau van Dijk product, is a resource for entity data with information on close to 400 million companies. Its data was used to inform the financing and ownership analysis (Section 4).

Refinitiv provides financial software and risk solutions – delivering news, information and analytics. Its data was used to inform the financing and ownership analysis (Section 4).

UN Comtrade is a repository of official international trade statistics and relevant analytical tables. Its data was used to inform the material flow analysis (Sections 3.5, 3.7, 3.8).

Wood Mackenzie is an energy research consultancy that empowers strategic decision-making in global natural resources with quality data, analysis and advice. Its data was used to inform the material flow analysis (Sections 3.4, 3.6).

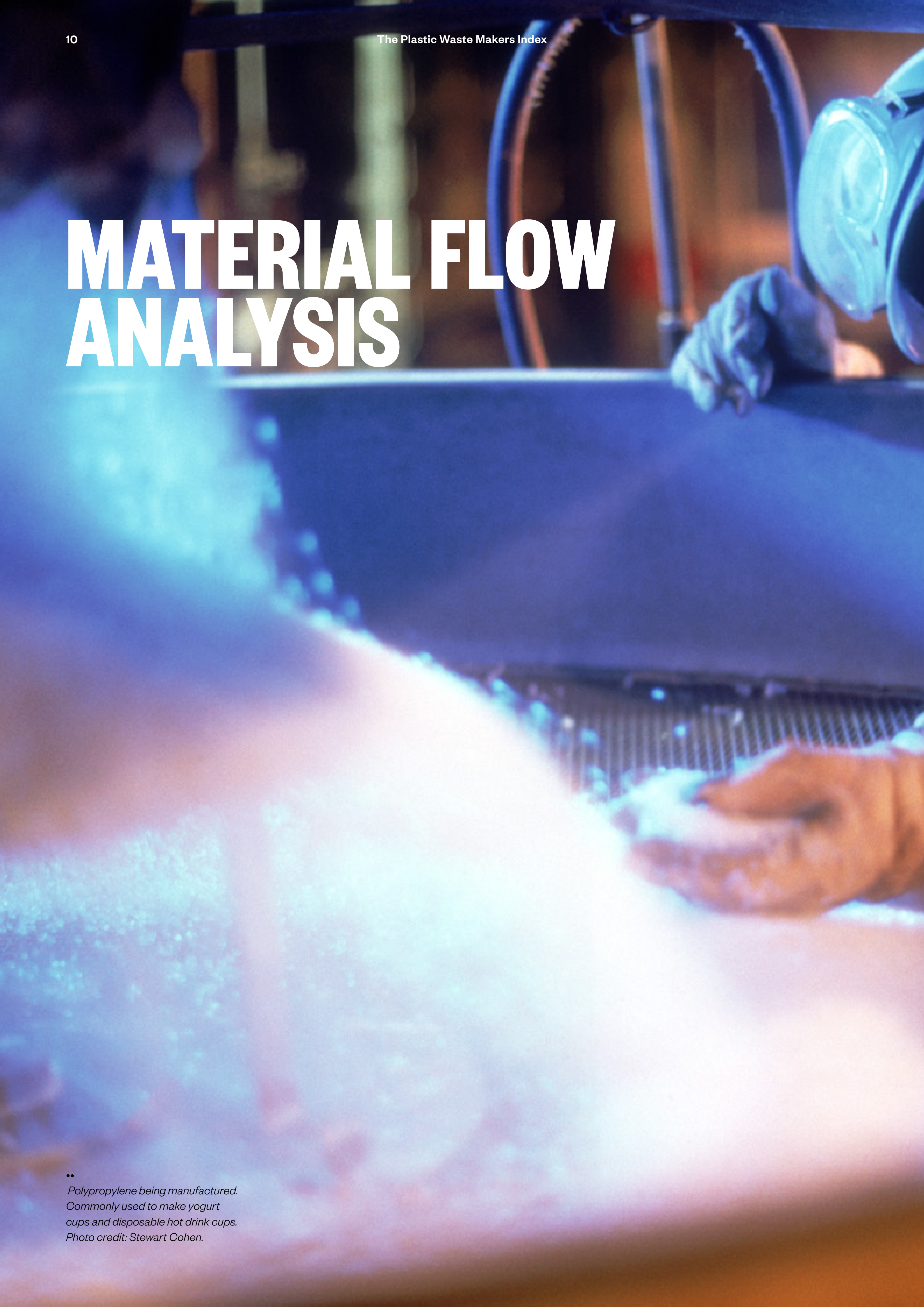
World Integrated Trade Solution is software developed by the World Bank in collaboration with the United Nations Conference on Trade and Development (UNCTAD), which allows users to access and retrieve information on trade and tariffs. Its data was used to inform the material flow analysis (Section 3.8).

ANALYTICAL COMPONENTS

The Plastic Waste Makers Index report comprises of three components, namely a Steering Committee of seven experts reflecting knowledge and experience of:

1. Material flow analysis
2. Financing and ownership analysis
3. Circularity assessment

This document outlines the steps taken to complete each analysis. It can be read independently of the Method in Detail section in the Plastic Waste Makers Index Report.



MATERIAL FLOW ANALYSIS

Polypropylene being manufactured. Commonly used to make yogurt cups and disposable hot drink cups. Photo credit: Stewart Cohen.

Introduction

The purpose of this analysis is to develop a comprehensive and representative model of the global flows of single-use plastic, from the production of polymers in primary form through to generation of single-use plastic waste.

Material flows approach

Several earlier studies model the total volume of plastic in global municipal solid waste streams (MSW-P). In these cases, the volume of MSW-P is estimated looking only at one point in the plastics life-cycle – the "end", or point of disposal.[1,2,3,4] Estimates are made by combining country-level data on total waste generation per capita with data on the plastic proportion of the waste.

Estimates of per capita waste generation are generally reported nationally, although methodologies and consistency differ country to country.[5] Estimates of the share of plastic in MSW are more problematic:

derived from sampling, they are limited in number, frequency, and require aggregating a patchwork of primary sources to report at a global level.[6] As a result, several studies present MSW-P estimates at the regional or archetype level to avoid false precision of extrapolating to individual country estimates.[7,8]

By contrast, in our model we take a whole life-cycle - or material flow – approach to estimating single-use plastic content in MSW (which we estimate make up around two-thirds of total MSW-P, the balance being primarily durable household goods and textiles).[9] We track the flow of single-use plastic materials through their lifecycle - from polymer form to finished goods to waste – and estimate where they are produced, converted, consumed and disposed. The results provide estimated volumes of single-use plastic in MSW with country-level granularity.

A similar methodology was conceived by the US EPA in the 1970s (and in use ever since) – and recent research has produced regional estimates for the EU[10] -- but, to our knowledge, this approach has never been applied on a global scale, nor tracked material flows starting from individual production assets.[11]

To estimate the contribution to single-use plastic waste from all polymer producers operating globally, the integrated model follows a supply-chain approach. There are six modules in the integrated model, aligning with the key supply chain steps. The structure and objective of the integrated model is to maintain visibility over in-scope materials as they flow from source to waste, considering the following six steps:

1. Production as Polymers – Section 3.4;
2. International trade of polymers in primary form – Section 3.5;
3. Conversion of polymers into rigid and flexible single-use plastic – Section 3.6;
4. International trade of single-use plastic in bulk – Section 3.7;
5. International trade in single-use plastic in finished goods – Section 3.8;
6. Resulting volume of single-use plastic in Municipal Solid Waste (MSW) – Section 3.9.

The methodology applied in modules one-six is described in detail in the following sections. A high-level description of the key questions answered by each module, scope, limitations, volumes and key data sources is provided below in **Figure 2** below.

Figure 2

Overview of the model, key questions, scope and limitations

VALUE CHAIN	Polymer production	Polymer trade	Conversation	Single-use plastics trade in bulk	Trade of single-use plastics in finished goods	Single Use Plastics in MSW
KEY QUESTIONS	Who produces what resin where?	What are the trade relations between producer and converter countries?	How is polymer converted to single-use products?	How are packaging and products traded internationally?	What derived of single- use plastic is traded and what are the trade patterns?	How much single-use plastic is in every country and what is its composition?
SCOPE	Estimated 2019 Production volumes for all relevant assets world wide	Estimated trade volumes of individual producers using bills of lading and UN Comtrade	Focus on top five polymers contributing 85%+ to single-use plastic in MSW	Map 90%+ of trade in global plastic packaging from UN Comtrade date	Use Consumer products to map 95%+ of trade of products on single-use plastics.	Country-level and format specific estimations of single-use plastic in MSW
LIMITATIONS	Asset capacity known, utilisation estimated at country level	Limited access to customs data, requiring a mass-balance approach to resin trade	Excluding 10+ polymers that account for ~15% of single use plastics in MSW Excluding conversation and processing losses	Assumptions made around polymer of converted packaging and finished goods		Excluding textiles, durable consumee products, and other non-fast moving plastics
ESTIMATED MASS, MMT	~200	~90	~110	~40	~25	~110

Scope of the analysis - virgin single-use plastic

We focus on 'single-use plastics' as the key unit of analysis. We define "single-use plastic" as those usage categories with the shortest lifespan – typically three to six months comprising mostly of Plastic Packaging, plus single-use Consumer and Institutional Products.[12]

Material composition of single-use plastic

The fate of single-use plastic waste as it passes through any waste management system – whether it is collected, recycled, landfilled, burned or leaks into the environment – differs depending on its material composition: principally, whether the packaging or product is rigid, flexible or multi-layer/multi-material plastic[13]. We have consolidated flexibles and multi-layer/multi-material plastics into a single category, which all have the property of flexibles.

To estimate the share of rigids versus. flexibles in single use plastic waste, we analyse how packaging and products are produced: i.e., we infer composition based on the polymer type and the conversion process used, and track both format and polymer composition throughout the value chain.

Production sources

By tracking the transformation of single-use plastic from polymers, via conversion processes, into packaging and products, we are also able to estimate the source of waste volumes. We link in additional analysis of where polymers are produced, by whom, and in what quantities, to provide estimates, not just of the source country of plastic polymer production, but also the source producer – i.e., specific assets of polymer producers.

Lifespan

Given the estimated short lifecycle of single-use plastic,[14] we make the simplifying assumption that the total volume of polymer produced in a single calendar year are – within the same calendar year – also: traded; converted into packaging and products; traded as packaging and consumer products; traded as a constituent of finished goods; and disposed. This is, in effect, a material flows model (and not a stocks model) and we make no adjustments for existing stocks or build-up of inventory.

This analysis was completed between June and November 2020. For consistency and based on data availability, in all cases, we use data for calendar year 2019.

In-scope polymers

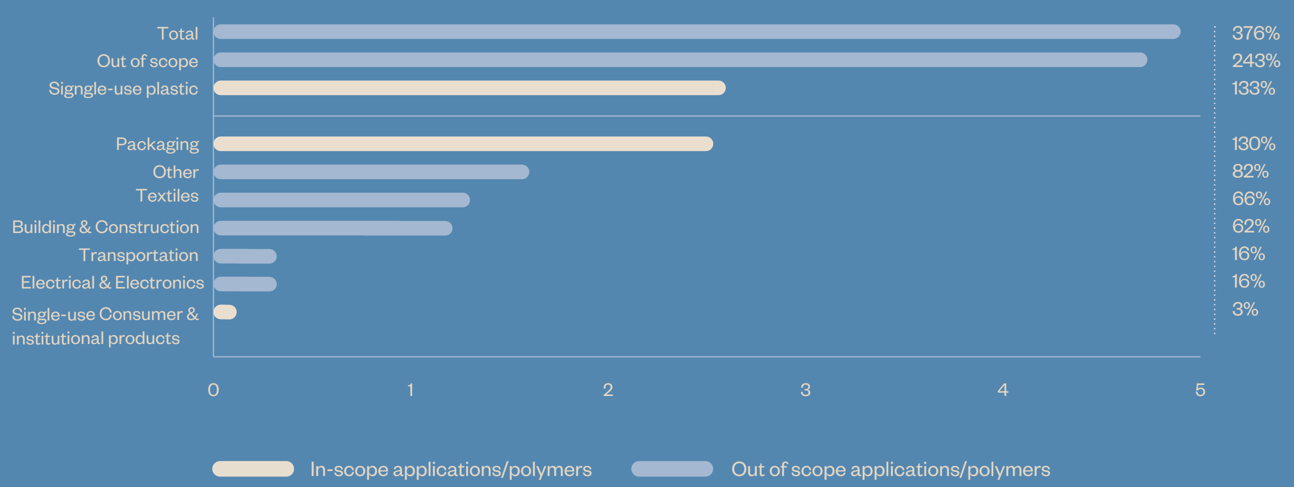
Overview

In 2019, an estimated 376 million metric tons of polymer– across 14 discrete polymer types – were converted into a similar volume of plastic products. This global total can be disaggregated into estimated volumes of per industrial sector use, for each polymer and for over 100 individual countries.

Across all polymers, we estimated the total volume of single-use plastic to be approximately 133 million metric tons (MMT), comprising 130 MMT of Packaging and 3 MMT of single-use Consumer and Institutional Products (**Figure 2**). The remaining 243 MMT are used by other industrial sectors, which are considered to be non-single use, such as Textiles (66 MMT), Building and Construction (62 MMT), Transportation (16 MMT), Electrical/Electronics (16 MMT) or Other (82 MMT; including durable consumer and institutional products; **Figure 3**).

Figure 3

Consumption of plastic polymers by industrial use sector (MMT, 2019)



Source: Minderoo/SYSTEMIQ analysis

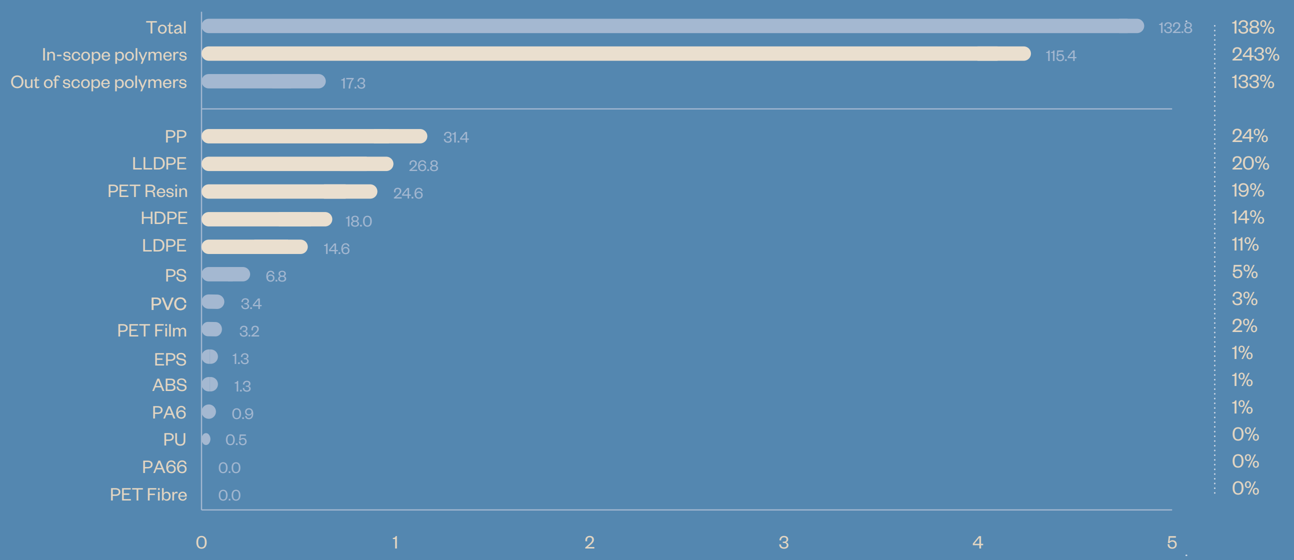
The subsequent analysis focuses on Packaging and Consumer and Institutional Products (P and CI) only, with the remaining 'non-single use' categories excluded from further analysis.

To prioritize which polymers would be in-scope for detailed analysis - i.e., tracking volumes from source asset of production, through polymer trade, into converted products - we analysed the polymer composition of P and CI and estimated which polymers contribute materially to P and CI and thus to single-use plastic waste. Prioritization was done based on materiality: i.e., polymers that represent at least 10 per cent of total single-use plastic volumes were included for detailed provenance analysis.

Based on the analysis of the polymer composition of single-use plastic, five polymers (PP, HDPE, LDPE, LLDPE, PET) were included as in-scope for the end-to-end analysis of material flows, composition and sources, as summarized in **Figure 4**. These polymers represent 87 per cent, or 115 MMT, of total single-use plastic volumes in 2019. The out-of-scope polymers (e.g., PS, PVC, PA/66/EPS) make up the remaining 17 MMT of single-use plastic volumes.

Figure 4

Polymer composition of single-use plastic category (MMT, 2019)



Source: Minderoo/SYSTEMIQ analysis

Blue polymer granules.
Photo credit: Luka Svetic / EyeEm via Getty Images.

Polymer production

We have estimated 2019 output volumes for all production facilities (hereafter, described as "assets") producing in-scope polymers.[15] The database includes 1,205 individual Single-use Plastic Polymer assets globally, with asset names and the location (country and region). Each asset was designated as producing one of the in-scope polymers at a given annual capacity (in thousand tonnes). Where an asset can produce multiple in-scope polymers, these assets are described as having "swing" capacity. In absence of data detailing the exact output of these "swing capacity "asset for each polymer, the total in-scope capacity was divided equally between the in-scope polymers.

The operator and owner of each asset is captured. Where an asset is jointly owned by two or more companies, the asset is listed multiple times (once for each owner), with the per cent age ownership share recorded against each asset record. Production capacity of each asset/owner combination was calculated as the product of total (nameplate) capacity of each asset and ownership per cent age. Production capacity of each asset owner was multiplied by an estimated region and polymer specific asset utilization rate to calculate actual production attributable to any specific asset and owner.

A single operating utilization rate was estimated for all assets producing a given polymer in each region. There are eight regions (Africa, Asia, Europe, Latin America and the Caribbean, Middle East, North America, Oceania, Russia and the Caspian); and five in-scope polymers (HDPE, LDPE, LLDPE, PP, PET); resulting in 40 operating utilization rate assumptions.

Figure 5

An illustrative sample of the production model

id	Asset Name	Polymer	Region	Country	Operator	Owner	Owner (per cent)	Capacity	Op Rate (per cent)	Production (kt)
2	Asset A	LDPE	North America	Canada	Local Company A	Parent Company A	100	35	84	29
4	Asset B	LLDPE	North America	Canada	Local Company B	Parent Company B	100	180	86	155
5	Asset C	LLDPE	North America	Canada	Local Company C	Parent Company C	100	250	86	215
6	Asset D	LLDPE	North America	Canada	Local Company D	Parent Company D	100	455	86	391
7	Asset E	HDPE	North America	Canada	Local Company E	Parent Company E	100	455	93	421

The output of this module is a detailed view of the volumes of in-scope polymers produced by different operators and owners in every country, or aggregated regions (**Figure 5**). The outputs of this module are used as inputs in the Polymer Trade module.

Polymer trade

After production, polymers are either converted domestically or traded internationally. To model the trade of polymers and track the flow of polymers from source to destination countries, we combined the outputs from the Polymer Production module with customs data – taken from individual bills of lading that detail individual shipments of polymer – as well as bilateral trade data at the country-level from Wood Mackenzie and UN Comtrade.[16]

To simulate how primary polymers flow from production either to domestic consumption or export trade, we evaluated three different possible modelling variants:

1. **Domestic first:** Under this paradigm, exports are primarily served by domestic production. Domestic production that is not exported, and imports serve domestic consumption. Domestic consumption in this paradigm is calculated as the sum of residual domestic volumes, production minus exports, and imports.
2. **Import first:** In this approach, exports are primarily served by imports, whereas domestic production primarily serves domestic consumption. If imports surpass exports, the residual amounts are consumed domestically. Equally, if imports fall short to satisfy export demand, the gap is served by domestic consumption. Domestic consumption in this paradigm is calculated as the sum of residual imported volumes (imports minus exports) and the sum of domestic volumes (domestic production minus exports if total exports surpass imports).
3. **Pooled:** Imports and domestic consumption are pooled and serve exports and domestic consumption according to their relative weight. Domestic consumption in this paradigm is calculated as the sum of domestic production and imports, minus the exported volumes.

The analysis pursued the 'domestic first logic' to model the trade of polymers, for the following rationale: as plastics are a high volume, low margin commodity, business logistic costs matter – discounting the viability of 'imports first' and 'pooled approach'. Furthermore, an 'imports first' paradigm results in an illogical scenario where most imported plastic is re-exported immediately – creating a never-ending flow of material.

Following the 'domestic first logic', we modelled the trade of polymers based on the volume produced in each country, by asset and polymer, as well as by polymer-specific trade matrices provided by Wood Mackenzie, and based on UN Comtrade data. These matrices detail, for each in-scope polymer, the volumes traded by any country to any other country. Our model did not consider re-exports, as the data quality was insufficient to draw robust conclusions on whose polymers are re-exported.

Finally, while in most cases the calculated net polymer position of each country aligned with the Wood Mackenzie country-level conversion demand, in a few cases there was some meaningful deviation (>+10 per cent). Differences can be explained by some combination of inaccuracies in the trade data, re-exports, stocks and inventory. To account for these differences, we proceeded with the lower value and are therefore more conservative in our estimation of net polymer position in certain countries. The impact on global in-scope polymer volumes is less than 10 per cent (106 MMT versus 115 MMT).

Where we did not have access to customs-level data, detailing company-specific shipments of polymers, we followed a mass-balance approach to model the trade of polymers – assets export per their market share - acknowledging that this introduces the assumption that all assets (within a country and per polymer) share the same export rate. Secondly, the mass-balance approach also implies that assets follow the same trade patterns of countries.[17]

Based on the production data and the trade matrices we determined

1. ***The export share of each country:*** The polymer-specific export share for each country was calculated by dividing the total polymer exports of country x by the total polymer production volumes of country x.

$$\text{Export share (per cent)} = \frac{\text{Exports (Country x, Polymer y)}}{\text{Production (Country x, Polymer y)}}$$

2. ***The country production market share of each asset:*** The markets share of each asset in each country was calculated by dividing the total output of polymer by a specific asset by the total production that polymer in the country.

$$\text{Market share (Asset x,Country y;Polymer z)} = \frac{\text{Production (Asset x, Country y, Polymer z)}}{\text{Total Production (Asset x, Country y, Polymer z)}}$$

3. ***The absolute volume, and relative share, exported to each country, for each asset and by polymer:*** Based on the polymer trade grids, the countries' export orientation and the asset's market share we calculated the exports of all assets:

   Total Exports (Country x, Polymer y): 1,000 tonnes – 100 per cent

   Exports to country a: 100 tonnes – 10 per cent

   Exports to country b: 400 tonnes – 40 per cent

4. ***For each asset, the exported volumes and the volumes that are converted domestically:*** Based on the countries' export share (eq.1), the assets' market share in country, and the trade grids, we calculated i) how much of an asset's production is exported, ii) where it is exported to, and iii) the residual amounts serving domestic consumption:

   Exported volumes (Asset x,Country y,Polymer z) = Production * Market Share * Export Share

   Domestic volumes (Asset x,Country y,Polymer z) = Production - Export Volumes

5. ***The contribution of a polymer producer in Country A for polymers exported to country B:*** We calculated the contribution (in tons) of each asset in different countries by multiplying the total volume of polymers exported by that asset with the per cent share going to the respective country:

   Responsibility (Asset x,Polymer y,Country n) = Exported Volume * per cent of Exports to Country (n)

6. ***A net polymer position in each country, by polymer, for each asset:***

   Net resin (Country x,Polymer y) = Production - Exports + Imports

The outputs of this module are an estimated contribution of each asset to the polymer-specific net polymer position of each country – or: taking polymer trade into account, who is the original polymer producer of the different polymers in any given country. The outputs of this module are used in the Conversion module to estimate how much of each assets' contribution to the net polymer volumes in each country is converted into single-use plastic.

Customs data approach

We were able to acquire customs bills of lading for 11 countries for calendar year 2019, from ExportGenius, detailing the trade of polymer and plastic products, including exporter name, source country, volumes, and values, as well as the local importers. The relevant customs declarations for in-scope polymers were based on the Harmonized Commodity Description and Coding System (HS Codes) developed by the World Customs Organizaton (**Figure 6**).

The goal of using the customs data analysis is to provide a proof-point that company-level attribution of international polymer trade is possible, that shipments and traded volumes can be linked to individual polymer producers, creating transparency on trade flows and contribution to plastic volumes in importing countries. In this first iteration, only import flows were analysed and included in the polymer trade modelling, however future iterations of the report aim to include additional countries, import and export flows, as well as processed plastics such as packaging.

The overall dataset contains more than 500,000 relevant bills of lading for export of in-scope polymers, representing more than 10 MMT of exports.

Figure 6

Countries and HS codes in scope for custom data analysis:

Country	HS codes in scope for imports				
India	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Brazil	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Russia	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Vietnam	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Indonesia	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Philippines	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Pakistan	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Nigeria	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Bangladesh	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Mexico	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769
Colombia	PP: 390210 and 390230	HDPE: 390120	LLDPE: 390140	LDPE: 390130	PET: 390760 and 390761 and 390769

To link shipments to individual polymer producers, the customs data was cleaned and aggregated in several steps in partnership with Neural Alpha:

1. All volumes were converted to tons, values converted to US$, country names segregated and standardized using SO 3166-1 alpha-two codes. HS codes that did not pertain to the trade of in-scope polymers in primary form, were filtered out.
    a. Bills of lading that included units that could not be converted in tons, such as pieces or sets, were excluded from the analysis.
    b. Bills of lading that did not include exporter names and country, units or values were excluded from the analysis.
2. Assigned import volumes to legal entities. We resolved entities in the customs declaration table by:
    a. Exporter names were cleansed and aggregated by Neural Alpha, leveraging fuzzy string matching on exporter names.
    b. Exporters were matched against a recognised company ID, the primary source for this project was FactSet, which can be used to retrieve further information about the company from financial and corporate databases. All bills of lading where the exporter that could not be linked to a FactSet ID were excluded from further analysis.
    c. All unique exporters with a recognised FactSet ID were matched to parent organisations, polymer producers, and ultimate owners. All bills of lading with an existing exporter FactSet ID but a missing link to a recognised polymer producer or parent organisation were excluded from further analysis.
    d. Created a join between the customs declaration data, the exporters and the polymer producers using the string matches and FactSet ID's, enabling the linking of volumes to the parent organisation.
3. In the final data cleaning and aggregation step, the data was screened for shipments that may be misclassified in the data set:
    a. All shipments smaller than 10 tonnes and larger than 10,000 tonnes were excluded from the analysis. Very small shipment sizes, especially combined in high unit process indicate misclassifications, where processed plastics are labelled with primary plastics HS Codes. Very large shipments, typically characterized by extremely low unit prices, were also excluded from further analysis.
    b. All bills of lading concerning shipments with an average price per ton smaller than US$800 and larger than US$2,000 were excluded from the analysis.

This process resulted in a final dataset containing 150,000+ bills of lading and 2,500 unique exporters. From this dataset, approximately 4.8 TBC of traded primary plastics were directly linked to specific polymer producers.

In the trade flow modelling described above, any export volumes that were linked to specific production assets through the customs data analysis were allocated first. All residual export volumes that could not be linked to a specific polymer producer, were allocated following the mass-balance approach as outlined in the previous section.

The customs data analysis followed a rigorous process, based on precautionary principles: At every step, if there was a possibility of uncertainty or ambiguity, bills of lading were excluded from the subsequent analysis. This process can be refined in the future to increase coverage.

The purpose of the analysis was to develop a methodology and provide a proof point that company-level trade mapping is possible. This approach and depth of data analysis can be refined in future iterations, increasing the matching of exporters to polymer producers, including additional countries, and expanding the product scope.

Conversion into rigid and flexible single-use plastic

The output of the Polymer Trade module is an estimated net polymer volume for each in-scope polymer, in each country for every asset. This Conversion module estimates the share of polymer volumes converted into single-use plastic – and those that are transformed into other out-of-scope product categories, as well as the proportions of rigid versus flexible formats.

Detailed methodology to estimate single-use plastic

The methodology to estimate single-use plastic, and polymer composition, was informed by three types of datasets:

1. Typology of industrial uses of plastics: describing what products are used by which industrial sectors and their format
2. Plastic application data: describing the volumes of products produced by different processes and thereby enabling the matching of polymers to conversion processes and industrial sectors, described by data from the American Chemistry Council (ACC), Wood Mackenzie (WM), and Plastics Europe (PE).
3. Country-level conversion demand by polymer and process: estimation of the volume of polymers converted by different processes in 191 countries, based on Wood Mackenzie's 2019 country-level polymer analysis

Together, these three datasets allow us to calculate:

1. The total conversion output of 191 countries
2. How much plastics, in which format, are used by the different industrial sectors across all 191 countries
3. The polymer split of all conversion outputs, and thereby the polymer split of products in the different industrial sectors and by format.
4. Calculate relative share of contribution to single-use plastic on a company level.

Plastic usage by different industrial sectors

For each polymer, we estimate what share is converted into each of eight Plastic Product Categories by Industrial Sector, represented in **Figure 7** below:

Rubbish pile in trash dump or landfill. Photo credit: Truong Phuong Tram via Getty Images.

Figure 7

Plastic product categories by industrial sector

Category	Example Products
Packaging	• Plastic bottles for beverages, water, carbonated soft drinks or other liquid food products, including caps and closures • Plastic bottles for non-food liquids, including household detergents, personal care products • Plastic containers in the shape of pots, tubs, and trays, including rigid food and grocery containers • Industrial containers such as crates and totes and non-categorized rigid packaging • Laminated paper and aluminium packaging materials • Plastic bags for carrying small items • Thin plastic packaging films • Sachets and multilayer flexible plastic packaging commonly used for food and consumer product retail sales
Single-use Consumer and Institutional Products	• Rigid health and hygiene (e.g., applicators) • Flexible health and hygiene (e.g., diapers)
Transportation	• Motor vehicles and their parts (including autos, trucks, buses, motorcycles and bicycles), railroad equipment, travel trailers, campers, golf carts, snowmobiles, aircraft, military vehicles, ships, boats and recreational vehicles.
Building and Construction	• Pipe, conduit and fittings (including drainage, irrigation, plumbing fixtures and septic tanks), siding, flooring, carpeting, insulation materials, panels, doors, windows, skylights, bathroom units, furniture, gratings and railings, coatings, adhesives, sealants
Electrical/ Electronic	• Home and industrial appliances (including electrical and industrial equipment), wire and cable coverings, communications equipment, resistors, magnetic tape and batteries.
Industrial Machinery	• Engine and turbine parts, farm and garden machinery, construction and related equipment, fishing and marine supplies, machine tools, ordnance and firearms, fishing and marine supplies, and chemical process equipment.
Textiles	• Woven fabric for apparel, footwear
Other	• Major categories represented include agriculture, large industrial containers, bedding • Durable Consumer & Institutional Products (e.g., homewares, furniture)

Plastic segmentation data

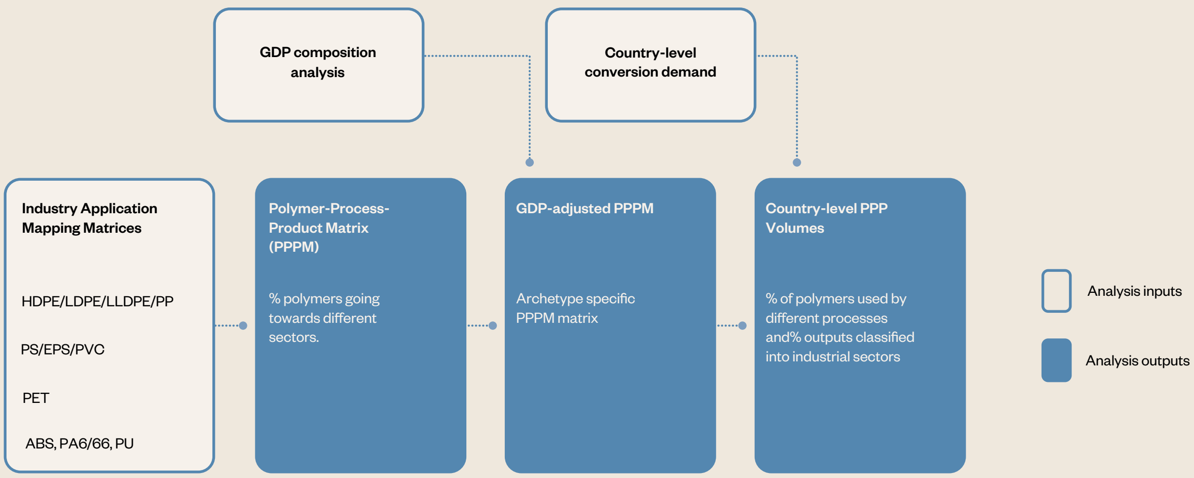
The methodology for mapping polymer volumes to Product Categories by Industrial Sector was informed by published plastic application segmentation data from three sources:

1. American Chemistry Council ("ACC") – application segmentation for HDPE, LLDPE, LDPE, PP, PS, EPS, and PVC[18]
2. Plastic Europe – application segmentation for ABS, PA6/66, PU[19]
3. Wood Mackenzie – application segmentation for PET

The application segmentation data from the above three sources was used to construct a series of mapping matrices to link each polymer's country-level volume to the defined Product Categories by Industrial Sector. In some cases, the outputs of conversion processes can be used by different sectors and the importance of these sectors varies between economies. To account for these differences, we have included the GDP composition as a factor influencing classification of outputs volumes produced into industrial sectors. The re-categorized country-level volume data was then aggregated into a regional and global view of plastic volumes. The high-level overview of the methodology is illustrated in **Figure 8**.

Figure 8

Overview of the methodology to determine in-scope polymers



To construct the matrices and estimate country-level production of single-use plastic a series of mapping and transformation processes were undertaken, as illustrated in **Figure 3** above and described in detail below:

1.1 Industry Application Mapping Matrices – HDPE/LLDPE/LDPE/PP

Wood Mackenzie segments HDPE, LLDPE, LDPE, and PP country-level demand volumes by the conversion processes. These segmentations are mapped into product categories by industrial sector segments by referencing the American Chemistry Council Plastics Industry Producers' Statistics (ACC PIPS) for HDPE, LLDPE, LDPE, and PP. The ACC PIPS statistical reports provide application breakdowns of plastic polymer sales (by weight) for each Conversion Process employed.

For each plastic, the percentage of each application falling under a particular Conversion Process was calculated, and each application was allocated to a Product Category by Industrial Use based on the application description. For example, the percentage of HDPE Film consumed for Food Packaging is given by the formula

$$\text{per cent HDPE Film Consumed for Food Packaging} = \frac{\text{HDPE Food Packaging Film}}{\text{Total HDPE Film}} = 15.95 \text{ per cent}$$

For the Conversion Processes for which ACC PIPS statistical report application breakdowns are not available, the allocation to Product Category by Industrial Use was done:

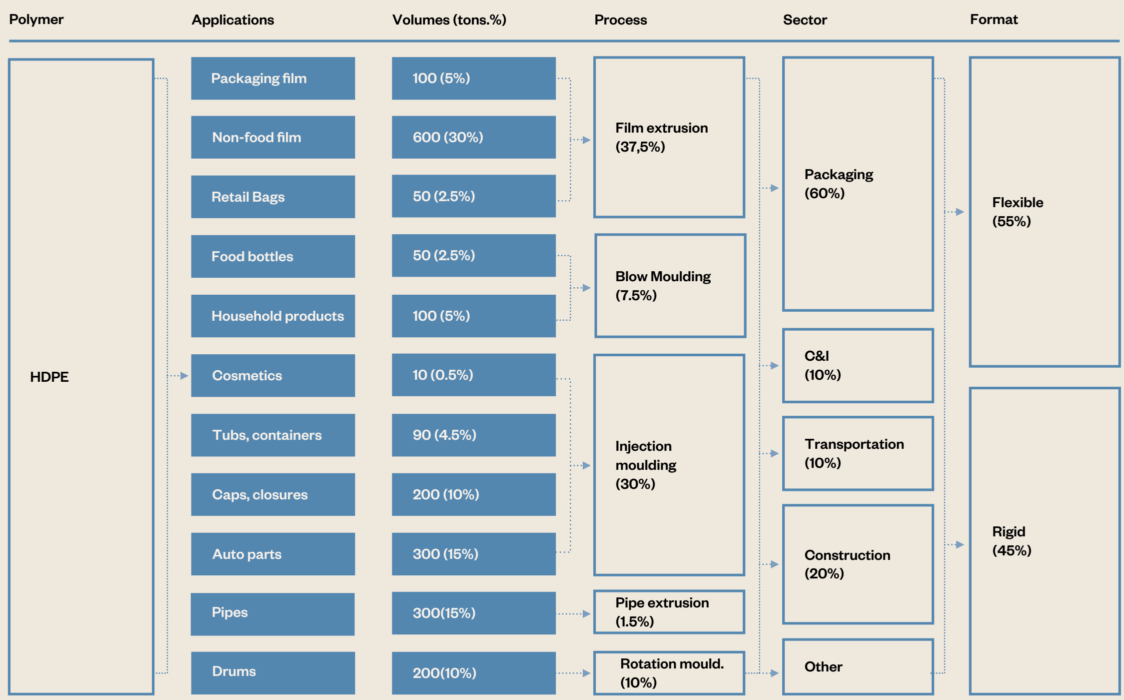
1. directly if the implied application is considered obvious (i.e. Fibre extrusion, Cable/wire extrusion), or
2. informed by the US GDP composition by industry if the Conversion Process was known to be utilized in multiple application categories (i.e. HDPE, LDPE, LLDPE sheet extrusion).

The rationale and assumptions made for each allocation from ACC PIPS are documented in Industry Application Mapping Matrices – HDPE/LLDPE/LDPE/PP in the endnotes.[20]

An example of the mapping matrices for HDPE is shown in **Figure 9**.

<u>**Figure 9**</u>

Example of mapping matrices for HDPE



1.2 Industry Application Mapping Matrices – PS/EPS/PVC

Wood Mackenzie reports PS, EPS and PVC country-level demand as aggregated volumes, and further segmentation into application categories are informed by ACC PIPS statistical reports for PS, EPS, and PVC. These reports provide application breakdowns of plastic polymer sales (by weight) for each plastic, and these applications are allocated Product Categories by Industrial Use based on their description. The rationale and assumptions made for each allocation from ACC are documented in Industry Application Mapping Matrices – PS/EPS/PVC in the endnotes[21].

1.3 Industry Application Mapping Matrices – PET

Wood Mackenzie reports PET Resin country-level demand by application categories, i.e. country level-conversion of PET into end applications such as water bottles, toiletries, or cosmetics. Hence, these volumes are directly allocated to Product Categories by Industrial Use based on their description. The application breakdown for PET Fibre and

PET Film are informed from Wood Mackenzie industry analysis and are also directly allocated to Product Categories by Industrial Use based on their description, e.g. country level demand for automotive PET filament. The rationale and assumptions made for each allocation are documented in the Industry Application Mapping Matrices – PET in the Endnotes.

1.4 Industry Application Mapping Matrices – ABS, PA6/66, PU

Wood Mackenzie reports ABS, PA6/66 and PU country-level demand as aggregated volumes, and further segmentation into application categories are informed by Plastics Europe application segmentations for these three polymers. The Plastic Europe application segmentations are then allocated to Product Categories by Industrial Use based on their description. The rationale and assumptions made for each allocation are documented in Industry Application Mapping Matrices – ABS, PA6/66, PU in the Endnotes.

Step 1. Synthesis in a matrix

After the categorization of polymer-to-product conversion volumes using the matrices described above, the percentage breakdown for each polymer – by conversion process, application or both – are used to synthesize a Polymer-Process-Product Matrix (PPPM) as illustrated in **Figure 10.**

<u>**Figure 10**</u>

Archetype Matrix of Polymer-to-Product conversion

		Packaging		**CI**		**Transportation**		**...**	
Polymer	Process	Rigid	Flex	Rigid	Flex	Rigid	Flex	Rigid	Flex
HDPE	Film extrusion	0%	75%	0%	20%	0%	0%	0%	5%
	Sheet extrusion	60%	0%	10%	0%	20%	0%	10%	0%
	Injection	70%	0%	10%	0%	20%	0%	0%	0%
	Pipe extr.	0%	0%	0%	0%	0%	0%	100%	0%
	...	20%	10%	5%	20%	10%	15%	10%	0%
LDPE	Film extrusion	0%	40%	0%	20%	0%	30%	0%	10%
	Sheet extrusion	3.50%	0%	0%	0%	10%	0%	5.50%	0%
	Injection	0%	0%	0%	50%	0%	0%	0%	50%
	Pipe extr.	0%	0%	0%	0%	20%	0%	80%	0%
	...	0%	0%	10%	0%	0%	10%	0%	80%
...	...	0%	3.50%	7%	13%	5%	20%	8%	2%

Step 2. GDP sensitivity analysis

The outputs of some conversion processes are used by different industrial sectors, e.g., film extruded products can be used either for packaging or for agricultural applications, and the relevance of these industrial sectors differs between economies. To account for these differences, we formulated six economy archetypes – US, China, High-income countries, upper-middle income countries, lower-middle income countries and low-income countries, following the World Bank classification – analysed the relative economic importance of the sectors using plastics, and constructed GDP-adjusted Polymer-Product-Product Matrices (PPP Matrices).

Step 3. Application of mapping, matrices, country, level, demand

The GDP-adjusted PPP-Matrix was then applied to Wood Mackenzie's 2019 country-level polymer demand data to convert all demand data into Product Categories. An example of this mapping for one country is shown in **Figure 11.** The country-level mapped plastic demand was then further aggregated to provide a regional and global view of plastic demand for Product Categories by Industrial Use.

Figure 11

Illustrative example of archetype matrix applied to wood mackenzie country-level polymer conversion volumes data

			Packaging		CI		Transportation		...		
Country	**Polymer**	**Process**	**Demand (kt)**	**Rigid**	**Flex**	**Rigid**	**Flex**	**Rigid**	**Flex**	**Rigid**	**Flex**
China	**HDPE**	Film extrusion	200	0	150	0	40	0	0	0	10
		Sheet extrusion	500	300	0	50	0	100	0	50	0
		Injection	400	280	0	40	0	80	0	0	0
		Pipe extr.	100	0	0	0	0	0	0	100	0
		...	200	40	20	10	40	20	30	20	0
		Film extrusion	100	0	40	0	20	0	30	0	10
	LDPE	Sheet extrusion	700	250	0	0	0	70	0	380	0
		Injection	200	0	0	0	200	0	0	0	100
		Pipe extr.	10	0	0	0	0	4	0	16	0
		...	100	0	0	10	0	0	10	0	80
	...	...	100	35		7	13	5	20	8	2

The mapping of polymers to processes and products, in combination with the country-level demand per process and polymers, enables the estimation of the polymer composition of the converted products, as well as of the industrial sectors that use these products.

In other words, based on this analysis, for each country we know the share of each polymer converted to single-use vs non-single use plastics.

For each individual line of the PPP Matrices described above, the output of the polymer-to-product categorization is also designated as a Rigid or Flexible.[22]

Additionally, by applying a mass balance approach, the source assets of these single-use plastic volumes are estimated. The calculation used is:

Post conversion responsibility=

Net resin (asset x,polymer y,country z)

*per cent polymer converted to Fast-Moving Plastics

*per cent (rigids/flexibles)

An illustrative sample of the outputs is shown in **Figure 12**. For example, Asset #5 exports 210kt of LLDPE, of which 180kt is exported to the United States. The United States has a conversion rate of 78.3 per cent for single-use plastic, meaning it converts 141kt (= 78.3 per cent * 180kt) of Asset #5's LLDPE into single-use plastic. Similarly, 5kt of Asset #5's LLDPE is converted in-country in Canada, which has a conversion rate of 79 per cent for single-use plastic, equating to 4kt of in-scope polymer. Using this methodology across the globe, we calculate that Asset #5 has 169kt of LLDPE volumes converted into in-scope polymers, of which the majority (168.48kt) is in Flexible formats.

Figure 12

An illustrative sample of the outputs

Asset ID	Polymer	Owner Name	Country	Production	Export	Domestic	In-scope	Rigids	Flexibles
4	LLDPE	Company A	Canada	155	151	3.6	121.6	0.3	121.3
5	LLDPE	Company B	Canada	215	210	5.1	169	0.5	168.5
6	LLDPE	Company C	Canada	391	382	9.2	307.5	0.9	306.6

The degree of uncertainty or error introduced by applying this approach is driven by the relative share of each polymer converted into single-use plastic versus other Product Categories by Industrial Sector. For example, 100 per cent of PET Resin is estimated to be converted into single-use plastic; suggesting a perfect correlation between source inputs and outputs. On the other hand, approximately 40 per cent of HDPE is converted into single-use plastic; meaning three-fifths of the global HDPE is bound for out-of-scope plastics. Thus, in the absence of more detailed data that provides insight over the destination of specific source polymer, we assumed that all polymer producers share proportionate accountability for the resulting volumes of single-use plastic.

The output of this Conversion module is an estimated contribution of each asset to the volumes of single-use plastic converted in every country.

Bulk packaging trade

Despite many polymer producers having sustainability statements and goals, 54 out of 100 companies in this study received an "E" grade for circularity – the lowest grade possible. Photo credit: Bloomberg Creative via Getty Images.

Post conversion, packaging material is either transformed domestically into finished products or traded internationally. Out of the 106 MMT of in-scope polymers converted into single-use packaging, our analysis of the packaging trade reveals that an estimated 37 MMT of in-scope packaging are traded globally, impacting the contribution of each polymer producer, and 78 MMT tons are transformed domestically into finished goods.

In the absence of transparency on a conversion level – whose polymers are converted into which products and which ones are traded – we again employ a mass-balance approach to model the trade of plastics in the form of packaging.

The modelling of the packaging trade is based on the following steps:

1. **Identification of product categories that encompass in-scope plastic packaging material. Cheap fossil fuel feedstocks:**

- We evaluated a list of 37 UN Comtrade HS six-digit codes and their product descriptors and characterized the products by:
  - Whether the product is likely to be transformed into single-use plastic
  - Whether it is likely composed of in-scope polymers
- This analysis resulted in 16 product categories that fulfil both criteria and that were classified as in-scope for further analysis, as detailed in **Figure 13** below. The results of this analysis were tested and refined with industry

2. In-scope products were further mapped against their polymer composition and format and the associated conversion processes (**Figure 13**). While many categories do not explicitly define the format or the polymer composition, the chosen categories cover over 95 per cent + of the total traded packaging and thus are assumed to be representative of all packaging trade.
3. For each of these product categories, a country-to-country trade grid was built based on public-access UN Comtrade data, covering 90 per cent + of the traded volumes. For each of the 16 identified product categories, these trade grids detail the total volume exported and imported for 200+ countries, the source country of imports as well as the destination of exports.

Figure 13

In-scope products mapping against polymer composition, format the associated process type

Packaging Categories		Conversion Process Mapping						
Six Digit HS Code	Product	Film Extrusion	Sheet Extrusion	Extrusion Coating	Blow Moulding	Injection Moulding	Raffia	PET Conversion
391910	Plastics; plates, sheets, film, foil, tape strip, other flat shapes thereof, self adhesive, in rolls of a width not exceeding 20cm	X	X					
391990	Plastics; plates, sheets, film, foil, tape strip, other flat shapes thereof, self adhesive, other than rolls of a width not exceeding 20cm	X	X					
392010	Plastics; plates, sheets, film, foil and strip, of polymers of ethylene, non-cellular and not reinforced, laminated supported or similarly combined with other materials.	X	X					
392020	Plastics; of polymers of propylene, plates, sheets, film, foil, tape strip, non-cellular and not reinforced, laminated, supported or similarly combined with other materials	X	X					
392062	Plastics; plates, sheets, film, foil and strip, of polyethylene terephthalate, non-cellular and not reinforced, laminated, supported or similarly combined with other materials							X
392119	Plates, sheets, film, foil and strip, of cellular plastic, unworked or merely surface-worked or merely cut into squares or rectangles (excluding....)	X	X					
392190	Plates, sheets, film, foil and strip, of plastics, reinforced, laminated, supported or similarly combined with other materials, unworked or merely surface-worked or merely cut into squares or rectangles (excluding of....)	X	X					
392310	Plastics; boxes, cases, crates, and similar articles for the conveyance or packing of goods			X	X	X		
392321	Ethylene polymers; sacks and similar articles for the conveyance or packing of goods	X						
392329	Plastics; sacks and bags (including cones), for the conveyance or packing of goods	X						
392330	Plastics; carboys, bottles, flasks and similar articles. for the conveyance or packaging of goods				X	X		
392340	Plastics; spools, cops, bobbins and similar supports, for the conveyance or packaging of goods				X	X		
392350	Plastics; stoppers, lids, caps and other closures, for the conveyance or packing of goods				X	X		
392390	Plastics; articles for the conveyance or packing of goods n.e.s. in heading no. 3923	X	X		X	X		
392410	Plastics; tableware and kitchenware				X	X		
392490	Plastics; household and toilet articles				X	X		

1. Based on the conversion process mapping of the in-scope packaging categories, as well as the known polymer split of these conversion processes, we estimated the polymer and format composition of traded packaging, for all countries and in-scope products.

   By doing so, we can translate and express *packaging trade grids* into *polymer* and *format specific trade grids*. This process entails several steps:

- As categories include outputs of several processes, e.g. Product 391910 could be either sheet of film extruded outputs, for each country/product, we estimated the relative share of these processes:

$$\text{Product A (Process 1, Country x)} = \frac{\text{Output Process 1 (Country x)}}{\text{Output Process 1 (Country x)} + \text{Output Process n (County x)}}$$

Product A (Country x) = 100 per cent - Process 1 = 50 per cent - Process 2 = 20 per cent - Process n = i

- We calculated the absolute contribution of each process to the traded volumes, multiplying the traded volumes by their relative process split

Process contribution (ktons,Process x,Country y, Product z) = Traded volumes traded* Process Share

- Once the relative and absolute contribution of each process to the traded products was established, we use the country specific polymer composition of each process, calculated from the conversion model, to derive the polymer composition of the traded products:

Polymer 1 (Product x,Country y)=

per cent Polymer 1 (Process z)*

per cent Process z (Product x)*

Volume (Product x)

- As conversion processes are typically associated with specific packaging formats- e.g. all extruded film is flexible whereas all blow moulded products are rigids - we were able to determine the share of each polymer going towards rigid versus flexible formats within that product category. Thus, we disaggregated the products into two format categories – rigid versus flexible - which were further subdivided by the five-in-scope polymers, resulting in 10 format/polymer vectors for each product, e.g. "*Product 391910 – RigidPP*" or "*Product 391910 – FlexibleLLDPE*".

2. The resulting format-polymer vectors were combined with the country-to-country trade matrices for all 16 in-scope products, modelling the trade of packaging expressed as format-polymer vectors. The trade matrix of one product is now expressed in 10 format-product matrices.
3. In the sub-final step, the format-polymer-matrices for all 16 product categories were combined into single format-polymer trade matrices (one for each format-polymer combination, e.g., *FlexiblePP*)

$$\sum \text{(Format (x), Polymer (y))} = \sum_{\text{Product (n)}}^{\text{Product (i)}} \text{Format (x), Polymer (y)}$$

The format-polymer trade matrices were then combined with the output of the conversion model, the contribution of rigid and flexible single-use plastic of each polymer producer in every country. For example, if a producer is responsible for 10 per cent of rigid PP in a country A, which exports rigid PP to country B, company A's net contribution in country A would decrease by 10 per cent and increase by the exported amount in country B.

Whereas the overall contribution of single-use packaging stayed the same for each polymer producer, it shifted between countries, according to the trade flows of in-scope packaging material between these countries. For example, China and Germany are large net exporters of packaging material, therefore a polymer producer's contribution to single-use plastic waste in these countries would decrease because of the trade and increase in the importing countries.

Finished goods trade

Once single-use plastic are formed into final products – e.g., filled, used as wrapping, or as a single-use products in their own right – these finished goods can be either consumer domestically or traded internationally. As with the trade of bulk packaging, a polymer producer's final contribution to single-use plastic waste is impacted by the trade of finished goods - decreasing in exporting countries and increasing in countries that import goods containing plastics attributable to the polymer producer. Given that asset-level attribution is only possible up until the point of conversion, we applied again a mass-balance approach to model the trade of finished goods and its impact on polymer producer contribution to single-use plastic waste.

Identification of value chain archetypes for single-use plastic products

To model the trade of finished goods and the single-use plastic used within them, we evaluated archetypical single-use plastic product value chains, their trade patterns and intensities, and the impact on country-level estimates of single-use plastic waste generation.

From a comprehensive study of 23 global value chains by the McKinsey Global Institute , four value chains were selected as the most relevant and representative archetypes for single-use plastic products **(Figure 14)**. The same study analysed each value chain from World Input-Output Tables to compute a Trade intensity – gross exports / gross output (per cent) – in other words, the proportion of finished goods that are exported.

Single-use plastic are found in the majority of finished goods in these four value chains. We acknowledge that the share of plastic in finished goods, by both weight and value, will vary between the value chains – e.g., a higher share of weight and value in a single-use plastic bottle (in the Food and Beverage value chain) versus the film wrapping for a smartphone (in the Computer and Electronics value chain). However, given a lack of available data detailing the share of plastic across or within these value chains – and an analysis beyond the scope of this project to compile – we made the simplifying assumption that the plastic share, by weight and value, in each value chain is constant. Therefore, we calculated the weighted average trade intensity, across the globally traded volumes of these four value chains, as a proxy for the trade intensity of the volume of single-use plastic in finished goods **(Figure 14)**.

Figure 14

Single-use plastic Product Value Chains, trade intensities and globally traded volumes

Product Category	Trade intensity (per cent)	Globally traded volumes (US$BN) [24]
Food and Beverages	13%	880
Plastics and Rubber	23%	192
Furniture and Other manufacturing	25%	244
Computer and Electronics	48%	596
Combined	26% weighted average	

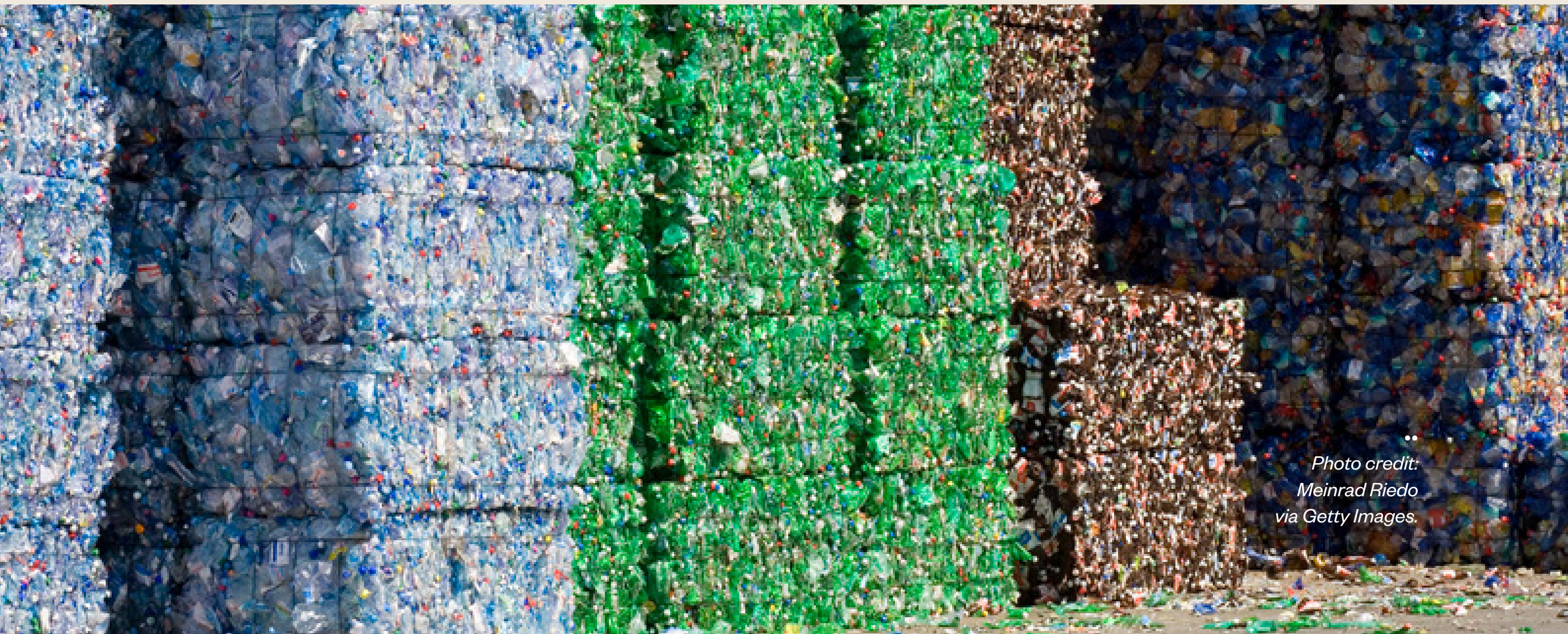


Photo credit: Meinrad Riedo via Getty Images.

We then modelled the dynamics of the trade in finished goods using one super-archetype product grouping: Consumer Goods, as defined by UN Comtrade Product Group "SoP3" (and accessed via the World Bank Integrated Trade Tool), which combines more than 1,523 individual product categories – including all the product categories in the four value chains selected previously.

Calculation of country-level trade intensities and traded volumes

The overall trade intensity describes how much of the total output is traded on average. However, some countries participate more in trade than others, impacting both volumes traded as single-use plastic and the country-level trade intensity. To calculate the volumes traded by each country, we estimated:

1. The total amount of single-use plastic traded as finished goods:
   - The total volume of single-use plastic post conversion is 106 MMT.
   - A trade intensity of 26 per cent implies that ~25 MMT of single-use plastic are traded internationally in the form of finished goods.
2. A country-level traded volumes and trade intensity, calculated by:
   - The individual countries' trade participation, i.e., the countries' share of the global traded volumes in Consumer Goods (as defined by UN Comtrade). For example, China contributes approximately 16 per cent to the global exports of consumer goods, and imports 6.3 per cent of all traded consumer goods.
   - The ratio between single-use plastic in-country post packaging trade and single-use plastic traded as finished goods. Given the paucity of data on re-exports, the country-level trade intensity was capped at 100 per cent, meaning no country can export more plastic in finished goods than there is single-use plastics in country post packaging trade.

Compilation of trade matrices

To analyse the trade flows of finished goods between countries, identify net exporter and importers, as well as the destinations, respectively the source of trade, again a country-to-country trade matrix was built based on World Bank's Integrated Trade Tool database .

The trade matrices include detailed accounts of the top 25 importers and exporters, and their trade partners, covering 95 per cent + of the global traded value of Consumer Products. As plastic contents in the trade of Consumer Products cannot be differentiated by format or polymer, the same trade intensity (trade over outputs) was used for all single use plastics in traded consumer goods.

To test the robustness of the analysis, we conducted a sensitivity analysis to estimate the impact of using different trade intensities on national MSW volumes and triangulated the results with prior studies and secondary literature.

Estimation of the impact of finished goods trade on polymer producer contributions to single-use plastic waste

The country-level trade intensities (describing how much leaves the country) in combination with the trade grids (describing where single-use plastic as finished goods is traded to) were used to compute the impact of the trade of finished goods on polymer producer contributions to single-use plastic waste:

1. We modelled all trade relationships between countries that collectively represent 95 per cent of the traded volumes. In this model, 71 countries collectively represented 95 per cent + of the traded volumes and therefore we included the top 5,041 top trade relationships (71*71) in the analysis. Trade to and from countries that are not within the top 71 was not included in the model.
2. In combination with the country-level trade intensities, these detailed trade matrices describe the absolute flow of single-use plastic between these countries.
3. Based on the relative market share of each asset (n=1,205) in each country, we computed the impact on polymer producer contribution to single-use plastic waste. For example:
   - Contribution in country X post packaging trade: 100
   - Country level trade intensity: 30 per cent
   - Relative importance of partner countries
     - Country A – 80 per cent
     - Country B – 20 per cent
   - Impact of trade on contribution:
     - Country X: – 100 * (1-30 per cent) = 70
     - Country A: 100 * 30 per cent * 80 per cent = 24
     - Country B: 100 * 30 per cent * 20 per cent= 6
4. By computing both trade from countries as well as trade to countries, the model estimates the impact of the finished goods trade on polymer producer contribution to single-use plastic waste in each of the countries and a new estimation of net contribution post finished goods trade.

Estimates of single-use plastic waste

As described above, estimates of single-use plastic waste volumes at the country level – in addition to company-level contributions – are one of the outputs of this analysis. We triangulated the results of our analysis with previous country level estimations to ensure the robustness of our results and classify our study within a wider stream of research on plastics. , They can be used as the baseline to inform granular waste management and plastic pollution models.

Single-use plastic waste estimates by country are calculated by taking the post-conversion volume (Chapter 3.6), adding net Packaging Trade (Chapter 3.7) and adding net Finished Goods Trade (Chapter 3.8). Calculations were done separately for Rigids and Flexible, which then provide a combined total volume.

The same calculation is performed at the asset level to track single-use plastic waste volumes back to production sources. Source single-use plastic waste volumes for each asset in each country were summed to express a global single-use plastic waste volume for every production asset. Hence, for each polymer producer, we can reconcile total contribution to single-use plastic waste across every country, and compare these volumes to the total volumes of plastic produced, plastics converted and total single-use plastic waste. The calculation for "rolling up" from individual production assets (n=1,205) to a global total for each polymer producer/ company is described in Section 6: Producer Definition.

An illustrative sample of the outputs is provided in **Figure 15** below.

Figure 15

An illustrative sample of the outputs of total single-use plastic waste

ID	Polymer	Asset	Country	Flex MSWsingle use plastic waste (kt)	Rigid single use plastic waste (kt)	Total single use plastic waste (kt)
4	LLDPE	Asset A	Canada	123.9	0.3	124.2
27	HDPE	Asset B	United States	35.7	90.3	126.0
151	HDPE	Asset C	Argentina	25.6	44.1	69.7
470	LDPE	Asset D	Belgium	112.5	22.4	134.9

Confidence levels and uncertainties

Country-level estimates of single-use plastic across production, polymer trade, conversion and packaging trade have a high confidence levels: by which we mean that data sources are credible, triangulated and calculation methodologies are proven. We expect the vast majority of results to be within a narrow margin of error **(Figure 16)**.

The assumption on finished goods trade intensity introduces some uncertainty about the final country-level single-use plastic waste estimates. We take the trade intensity of four value chains as a proxy for all single-use plastic. These value chains have trade intensities ranging from 13 per cent to 48 per cent, and each will have different proportions of plastic as a share of total product value and weight. Estimating the total volume of single-use plastic in each of these global value chains, and calculating the weighted average trade intensity, would be a refinement to our simplifying assumption. However, such an analysis was beyond the scope of this report.

Producer-level estimates of single-use plastic production have high confidence levels. Confidence levels around polymer trade vary according to whether the producer has an export-led business model or is domestic sales-led. Confidence in the producer conversion estimates are high for producers of PET Resin, where the proportions of polymers going into in-scope applications is 100 per cent. This proportion is lower for other in-scope polymers (71per cent of LLDPE; 66 per cent of LDPE; 42 per cent of PP; 39 per cent of HDPE), and it is theoretically possible that any single producer of these polymers in any country may be actively engaged in long-term supply to out-of-scope applications accounting for all their output.

In the absence of producer-specific data on polymer trade or sales by plastic application, we apply a mass balance calculation: a "fair" representation of on-the-ground reality, all other things being equal. Some degree of disclosures on these matters are made by individual companies ; we actively encourage greater disclosure by producers in the spirit of transparency and intend to update our analysis in response.

Figure 16

Summary of data confidence and uncertainty

Module	**Confidence** (Credible or triangulated data sources and robust/ proven methodology)	Uncertainty (Variance within data, signle source, or new methodology)	Relative impact on results
Resin Production	High confidence in accuracy asset level production capacities	Some uncertainties around assets specific operating production rates	high
Resin Trade	High confidence in the identified trade patterns at the country level and by polymer	**High uncertainitie for assets in diverse, export oriented markets**	
	Hi confidence for assets in markets with low trade volums or high marketbshares	Domestic first 'vs' mass balance logic' for re-exports has low uncertainty	
Conversion	High confidence in conversion demand of country and process level (+5%)	Some uncertainty in the classification of in /out of scope application fro some specific polymers (HDPE/PP) excl, USA	
	Hi confidence in the classification of in/out of scope applications for most polymers (< five%)	Some uncertainty in sensitivity to GDP sector differences	
Packaging Trade	Hi confidence in representative packaging product categories and trade gids (+10)	low uncertainty around composition of product groups e.g. films, sheets or foil of polythylene	
Finished Goods Trade		**High uncertainty on 'weighted' trade intensity of plastic in packaging and CI**	low

••

Accumulation of plastic garbage in a canal leading to the Buriganga River in Dhaka, Bangladesh. The Buriganga river is known as one of the most polluted rivers in the country due to rampant dumping of industrial and human waste. Photo credit: Rehman Asad via Getty Images.

FINANCING AND OWNERSHIP

Major global investors and banks are enabling single-use plastics production and pollution. Plastic pollution has worsened during the Covid-19 crisis. Photo credit: d3sign via Getty Images

The Financing and Ownership (F and O) analysis complements to the Material Flow Analysis (MFA) with the objective of understanding the financial flows into the largest producers of single-use plastic polymers identified. Where the MFA model estimates the single-use plastic waste generated (SUP-W) by each producer, the F and O model analyses who is enabling those producers, through the value of shareholders' equity ownership, and the value of financing through loans and underwriting provisions.

There are two parts to the modelling. The first part focuses on Ownership: the shareholders (institutional asset managers, state/sovereign owners, private individuals/institutions) that own the equity in producers of single-use plastic waste. This analysis was performed by Planet Tracker.

The second part focuses on the Financing, that is, the banks that have provided loans and underwriting services to the producers of single-use plastic waste. This analysis was performed by Profundo.

Ownership analysis: shareholders' equity

The responsible investment trend has led to environment, social, and governance (ESG) principles being increasingly integrated into capital allocation decisions. Impact investors are discovering the importance of natural capital – clean water, biodiversity, stable climate, etc – in the "E" (environment) of ESG. There is pressure on financial institutions to move capital away from public companies that perform negatively against ESG criteria and into ones that perform positively. This analysis seeks to identify which classes of shareholders (institutional asset managers, state/sovereign owners, private individuals/institutions) hold what value of equity in the companies producing single-use plastic, and their estimated contribution to plastic waste. The Ownership analysis covers the financial institutions backing the top 200 producers in terms of SUP polymer production, which represents over 95 per cent of total production volume.

Financing analysis: loans and underwriting

When a financial institution provides credit, it can be through a loan, through a revolving credit facility, or many other debt structures. Investment banks can also earn fee income for advising and arranging things such as mergers, bond issues, securitization, etc. One important activity they carry out is the underwriting of bond or share issues. By capturing both the loans and underwriting services provided by banks, we are identifying a better picture of the key facilitators of debt instruments to companies producing single-use plastic, and their estimated contribution to plastic waste. Given time and data limitations, the Financing analysis covers the financial institutions backing the top 50 producers in terms of SUP polymer production (around two-thirds of total production volume).

Bond ownership was initially in scope, but given data limitations – where only ~20 per cent of total bond holdings could be linked to specific owners – this was left out of scope.

An overview of the key sources, dates, share of financing captured, assumptions, and confidence levels is provided below in **Figure 17**. A detailed description of the methodology applied in the F and O model is described in the following Sections:

• Adjusting value of Ownership and Financing for single-use plastic polymer production;

• Ownership: shareholders' equity;

• Financing: loans and underwriting.

Figure 17

key sources, dates, share of financing captured, assumptions, and confidence levels

		OUT OF SCOPE	
	Equity	**Bonds**	**Loans/underwriting**
Source:	Bloombreg, Orbis, FactSet	Bloomberg, Orbis	Bloomberg, Refinitiv, IJGlobal
Date:	As at 8 Jan 2021	As at 8 Jan 2021	Jan 2011 - Dec 2020
Share:	**70%** of total issuance - USD 1.2trn out of USD 1.7trn	**20%** of total issuance- USD 105bn of USD 540bn	**80%** of total issuance - USD 1.4trn out of USD 1.75trn
Assumption:	% held by institutions only	% held by institutions only	Distributed based on book runner/ manager participation and fees
Confidence level:	High	Low	High

Adjusting value of ownership and financing for single-use plastic polymer production

Most producers of single-use plastic polymer are part of diversified oil and gas and/or (petro)chemical companies with multiple business units and streams of revenue – of which single-use plastic is only one. In general, their parent companies do not split out and report results for business units that map to our definition (i.e., the production of the five in-scope polymers defined in the MFA); and even where there is consistency at the reported level, there is no public market valuation of the relevant business unit.

For this analysis, we want to understand not just the total value of ownership or financing provided to the parent companies of polymer producers – which would skew the results towards the owners or financers of largest, most diversified companies – but, specifically, the value that is enabling the production of single-use plastic polymers.

As a proxy for this, we make the assumption that the share

of value attributable to single-use plastic polymer production is directly proportionate to the share of revenue this business generates for its parent company. By extension, we assume that the total value of equity held or total value of financing given to a parent company can be adjusted by the same revenue weighting – producing an estimate of the value of equity or of financing specific to single-use plastic polymer production.

Estimating polymer producers' revenues from single-use plastic

The end point of the MFA analysis is the starting point here. We took the contribution to SUP waste from each in-scope production asset, in tonnes, and then estimated the revenue of the SUP at the individual asset level following three steps:

1. Each of the 1,205 assets were mapped to country, sub-region and regions;
2. Average 2019 Polymer prices in USD for each country, sub-region, and region (where available) were sourced from Nexant;
3. Production volume from each asset was multiplied by relevant average polymer price for the relevant country (or sub-region, or region, where not available).

The output of this analysis is therefore an estimated revenue figure for each asset.

An illustrative example can be seen in the figure below.

Figure 18

Example of asset-level estimated revenue generated from SUP

Asset ID	Polymer	Operator	Producer	Country	Sub-Region	Region	2019 SUP (kt)	2019 Revenue (US$m)
2	LDPE	Local company A	Company A	Canada	North America	Americas	24.8	37
4	LLDPE	Local company B	Company B	Canada	North America	Americas	124.2	160
5	LLDPE	Local company C	Company C	Canada	North America	Americas	172.5	222
6	LLDPE	Local company D	Company D	Canada	North America	Americas	314.0	405

The revenue figures at the asset level were then aggregated to estimate the SUP revenue figures at the producer level. 1,205 in-scope polymer production assets are operated by 425 unique local companies, which are in turn owned by 295 unique global producers. See illustrative example in **Figure 19**; a full definition of a Producer is outlined in Section 5 ('Producer definition').

Figure 19

Example of assets with operators, producers, and SUP volumes

Asset ID	Polymer	Operator	Producer	Country	Ownership per cent
1	LDPE	Local company A	Producer A	Canada	100
2	LLDPE	Local company B	Producer B	Canada	50
2	LLDPE	Local company B	Producer C	Canada	50
3	LLDPE	Local company C	Producer D	Canada	100

Ownership: shareholders' equity

Direct equity ownership

We classified the top 200 producers based on whether their parent company is publicly listed (90 out of the top 200 producers) or privately held. On this basis, we sourced market capitalisation and revenues for 2019 for publicly listed companies via Bloomberg (on 8th January 2021) and reported revenues for 2019 for privately held companies via Orbis. Shareholding information was not available from either Bloomberg or Orbis for 15 producers out of the top 200.

Publicly listed companies

Shareholder data (owner, value) for each company was aggregated up to the level of global ultimate owner. The value of equity holdings across all companies for each global ultimate owner were then summed and ranked. The top 250 equity owners represented close to 95 per cent of the total value of holdings in the publicly listed companies.

Figure 20

Illustrative example of the value of direct equity ownership at the group level in publicly listed producers, in USDm

Investor	Investor type	US$ value of shares in...	US$ value of shares in...	US$ value of shares in...	US$ value of shares in...	US$ value of shares in...
		Parent company of Producer A	Parent company of Producer B	Parent company of Producer C	Parent company of Producer D	Parent company of Producer E
Global Ultimate Owner A	Sovereign	0	0	3	33	8
Global Ultimate Owner B	Sovereign	0	0	0	0	0
Global Ultimate Owner C	Private	0	0	0	0	0
Global Ultimate Owner D	Public	1,913	38	1,550	11,657	2,883

Once the direct equity owners at the group level were identified, we adjusted the ownership holding attributed to SUP by taking the direct equity ownership holding in the relevant company and multiplying it by the calculated share of total revenue from SUP (as per the previous section). The formula can be seen below.

$$\textit{Revenue adjusted holding in USD} = \textit{Total holding in USD} * \frac{\textit{(Revenue from Fast Moving Plastics Production in USD)}}{\textit{Total Revenue in USD}}$$

Figure 21

Illustrative example of the value of direct equity ownership attributable to SUP in five publicly listed producers, in USDm

Investor	Investor type	US$ value of shares adj. for SUP in...	Producer	Country	Sub-Region	Region
		Parent company of Producer A	Parent company of Producer B	Parent company of Producer C	Parent company of Producer D	Parent company of Producer E
Global Ultimate Owner A	Sovereign	0	0	3	33	8
Global Ultimate Owner B	Sovereign	0	0	0	0	0
Global Ultimate Owner C	Private	0	0	0	0	0
Global Ultimate Owner D	Public	4	12	190	11,657	519

As an example, Chevron Corporation is a diversified oil and gas company that has a market cap of USD166bn. Chevron's revenue generated from the SUP is estimated to be USD2.3bn, on a total reported group revenue on USD140bn, i.e., 1.6 per cent of total revenue. Vanguard Group holds seven per cent of Chevron's equity, i.e., a holding with a value of USD11.7bn. Therefore, to estimate what proportion of Vanguard Group's shareholding in Chevron can be directly attributed to SUP, we adjust to 1.6 per cent of the total value, estimating it at ~USD190m. (All numbers as downloaded from Bloomberg on 8 January 2021).

Privately owned companies

Given market capitalisation data is not available for private companies, we estimated the value of their single-use plastic businesses by applying a revenue to market cap multiple. An average revenue to market cap was computed using the data for the 90 publicly listed companies, as described above. This multiple was applied to each private company's estimated SUP revenues to calculate an approximate value of the SUP business.

We then used Orbis as the data source for equity ownership of private producers (110 out of the top 200 producers). As above, shareholder data was aggregated up to the level of global ultimate owner. Combining this with the valuation estimates, we were then able to calculate the value of shareholder's equity attributable to single-use plastic waste generation.

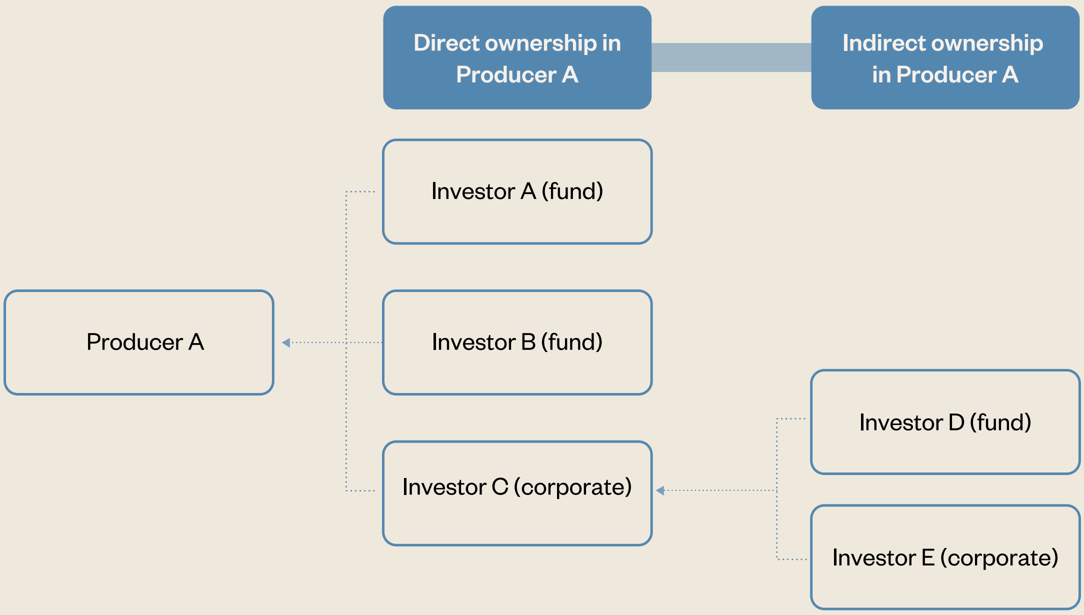
We then summed and ranked value the of shareholder's equity by global ultimate owner across all top 200 producers – both publicly listed and privately owned.

Indirect equity ownership

Shareholder data from Bloomberg and Orbis in public and privately owned producers included some corporate holdings

Figure 22

Illustration of indirect equity ownership.



We rolled-up the value of these indirect holdings and attributed them to the shareholders of the intermediary corporations. To do this, we estimated the value of the corporate's stake in the producer and divided it by the total market cap of the corporate. In other words, we assumed the value of the corporate's equity stake in a producer (as per our estimate) is perfectly reflected in the corporate's own valuation. The formula below outlines this calculation:

$$\text{Value of Corporate's ownership (per cent)} = \frac{\text{Value of Corporate's stake in producer (USDm)}}{\text{Market cap of Corporate (USDm)}}$$

We then applied this ownership per cent age to the ultimate equity holders of the corporate to estimate the value of their indirect ownership. The formula below outlines this calculation:

Indirect ownership of Investor x (USDm)

= Value of Corporate's ownership (per cent)

* Investor x' s holding in Corporate (USDm)

This ownership roll-up exercise was carried out for both Public and Private Entities. The outputs was a list of financial institutions and individuals that directly and indirectly own equity (shares) across the top 200 producers, outlining the extent to which these institutions or individuals are, by proxy, funding single-use plastic waste.

Loans and underwriting

This section focuses on the banks that have provided loans and underwriting facilities to SUP polymer producers for the period January 2011 – December 2020. Given capacity and time constraints, the analysis focused on loans and underwriting provided to the top 50 producers by contribution to waste (approximately two-thirds of total SUP waste generation).

Given polymer production plants are operational for at least 10 years (and often far longer), a 10-year historical data on financing provided by banks was taken as a proxy for the financing of production in 2019 (including project finance, working capital and refinance). This research utilized financial databases (Bloomberg, Refinitiv, and project finance data from IJGlobal). This analysis was performed by Profundo.

Individual bank contributions to syndicated loans and underwriting (bond and share issuance underwriting) were recorded to the largest extent possible where these details were included in the financial database, or company or media publications. In many cases, the total value of a loan or issuance is known, as are the banks that participate in this loan or issuance.

However, often the amount that each individual bank commits to the loan or issuance must be estimated. In the first instance, an attempt was made to calculate each individual bank's commitment based on the fee they received as a proportion of the total fees received by all financial institutions. This proportion (e.g. Bank A received 10 per cent of all fees) was then applied to the known total deal value (e.g. 10 per cent x US$ 10 million = US$ 1 million for Bank A).

Where deal fee data was missing or incomplete, Profundo used the bookratio. The bookratio (see formula below) is used to determine the spread over bookrunners and other managers.

$$\text{Bookratio} = \frac{\text{No. of participants - No. of bookrunners}}{\text{No. of bookrunners}}$$

Figure 23 below shows the commitment assigned to bookrunner groups with Profundo's estimation method. When the number of total participants in relation to the number of bookrunners increases, the share that is attributed to bookrunners decreases. This prevents very large differences in amounts attributed to bookrunners and other participants.

Figure 23

Commitment assigned to bookrunner groups using Profundo's estimation method.

Bookratio	Loans	Issuances
> 1/3	75%	75%
> 2/3	60%	75%
> 1.5	40%	75%
> 3.0	< 40%*	< 75%*

*** In case of deals with a bookratio of more than 3.0, Profundo used a formula which gradually lowers the commitment assigned to the bookrunners as the bookratio increases. The formula used for this:**

$$\frac{\frac{1}{\sqrt{\text{Bookratio}}}}{1.443375673}$$

The number in the denominator is used to let the formula start at 40 per cent in case of a bookratio of 3.0. As the bookratio increases the formula will go down from 40 per cent. In case of issuances the number in the denominator is 0.769800358.

Once the data has been calculated as such, we created a matrix to calculate the total financing per bank provided to each producer **(Figure 24).**

Figure 24

Illustrative example of the total loans and underwriting facilities provided by banks across five producers, in USDm

Bank	Producer parent company A	Producer parent company B	Producer parent company C	Producer parent company D	Producer parent company E
Bank A	3675	735	1940	1616	5054
Bank B	3916	770	1625	333	8986
Bank C	2945	69	614	342	7861
Bank D	1486	0	4019	0	7242

Once we have identified the banks that have provided loans and underwriting facilities at the group level, we then adjusted the financing attributed to SUP by taking the financing provided to the relevant company and multiplying it by the calculated share of total revenue from SUP (as per the Ownership section). The formula can be seen below.

$$\text{Revenue adjusted financing in USD} = \text{Total financing in USD} * \frac{\text{Revenue from Fast Moving Plastics Production in USD}}{\text{Total Revenue in USD}}$$

As an example, Chevron's revenue generated from the SUP is calculated to be USD1.4bn, on a total reported group revenue on USD140bn, i.e., one per cent of total revenue. Barclays has provided USD7.2bn of financing to Chevron, therefore, we adjust Barclay's financing to Chevron attributed to SUP to one per cent of the total value, estimating it at ~USD74m.

From conducting this Financing analysis, we were able to identify financial institutions that have an important role to play in reducing single-use plastic waste and increasing circular business practices. Where the Material Flow Analysis estimated the single-use plastic waste "footprint" of the producers, the Circularity Assessment in the next section outlines how these producers are responding to the problem through publicly available corporate targets and commitments.

••
Sites like this petrochemical plant, capable of producing 150,000 metric tons of plastic polymer per year, are found all over the world. Photo credit: Bim via Getty Images.

CIRCULARITY ASSESSMENT

Trash island in the Caribbean.
Photo credit: Caroline Power

Introduction

One output from the Material Flow Analysis is the estimated contribution to single-use plastic waste by each polymer producer. Complementary to this, we believe it is important to acknowledge whether and how these producers are responding to this problem. We have therefore conducted a Circularity Assessment (CA) to capture their response to the plastic waste problem through the adoption of circular economy principles and practices.

A circular economy is restorative and regenerative by design. This means materials constantly flow around a 'closed loop' system, rather than a 'linear' system. In the case of plastic, this means simultaneously keeping the value of plastics in the economy, without leakage into the natural environment.

Minderoo's Circularity Assessment aims to capture and rank the efforts of the world's largest producers of single-use plastic to embrace circular economy principles and, thereby, reduce their accountability for plastic pollution. The purpose of this exercise is to equip all stakeholders with an understanding of how producers of plastic polymers are responding to the plastic waste problem and, in turn, encourage greater commitment, engagement and progress.

A description of the methodology applied in the CA exercise is described in the following chapters. The structure of the analysis is carried out in the following steps:

- Scope of the analysis;
- Approach to the Circularity Assessment;
- Conducting the Circularity Assessment;
- Partnering with SYSTEMIQ;
- Scoring and weighting.

Scope of the analysis

Scope

For this assessment, we have focused on the top 100 producers of single-use plastic (based on their 2019 production of the five in-scope polymer, as defined in the MFA), who collectively account for ~85 per cent of global production.

We relied on the Ellen MacArthur Foundation's (EMF) *Circulytics* survey to complete this analysis. EMF developed *Circulytics* as a comprehensive circularity assessment for businesses, in the form of a self-reported survey. It builds on work by multiple organizations and looks at both enablers for change and actual outcomes.[31] A initial pilot phase concluded in July 2020 and involved 30 companies, including one producer of plastic polymers. A more extensive v2.0 of the survey started in October 2020 and reports August 2021.

The exercise we conducted here is complementary to EMF's survey, but designed to be undertaken "outside-in"– i.e., desk-based research based on public reports – and made specific to plastic polymer producers. It is, therefore, by design more limited in scope than *Circulytics* – focusing on a subset of seven key questions from a total of more than 50 in the full survey.

More than 70 of the top 100 producers are publicly listed companies, for whom disclosure of non-financial information (such as ESG topics) through sustainability and integrated reports is widely adopted. As a result, we assumed sufficient information to be available to assess producers' efforts to transition to circular models of productive in response to the single-use plastic waste problem.

In **Figure 25** below, we outline the seven questions. Together, these questions are intended provide an indicative measure of the extent to which polymer producers are committed to and actively addressing the challenge of plastic pollution through transitioning to a more circular business model.

Questions one to five are qualitative, addressing the policies and commitments around circularity – the 'Enablers' that allow a company-wide transformation towards circular business practices. Questions six and seven are quantitative, providing information on current circularity – the Outcomes, i.e., what proportion of the company's inputs and outputs are sourced from recycled, or other sustainable circular feedstocks, versus from linear fossil-fuels.

The remaining questions from EMF's *Circulytics* survey were not used in our assessment, either because they would require information unlikely to be available in public reports, or where it was felt an outside-in approach would be unable to provide a sufficient degree of accuracy in answering.

Plastic waste in the Siak River, Indonesia. Photo credit: Barcroft Media / Contributor via Getty Images

Figure 25

Question, answer and scoring grids used in Circularity Assessment of SUP polymer producers (developed from EMF's *Circulytics* survey).

Questions	Answers	Scoring
1. Is your strategy aligned with becoming more circular?	1. No relevant mentions of circular economy	0%
	2. Relevant concept (e.g. materials circulation, new business models that follow the principles of circular economy, not just resource efficiency) mentioned as part of strategic priorities	50%
	3. Circular economy explicitly mentioned as part of strategic priorities	100%
2. Do you have measurable circular economy targets?	1. No targets	0%
	2. Targets are being developed either for a relevant concept (e.g. materials circulation) or circular economy explicitly	25%
	3. Targets developed on overall organisation level, but are not SMART targets	50%
	4. SMART targets developed on organisation level	75%
	5. SMART targets developed on organisation level and further down on sub-unit (e.g. business unit or region) level	100%
3. To what extent is suitable infrastructure in place to support a circular business model?	1. No plans in place to reconfigure existing or configure new infrastructure to support a circular business model	0%
	2. Existing infrastructure is currently being reviewed to prepare the shift to a circular business model	25%
	3. Existing infrastructure has been reviewed and/or new infrastructure are being designed to prepare the shift to a circular business model	50%
	4. Reconfiguration of existing infrastructure or development of new infrastructure have started in order to support a circular business model	75%
	5. All infrastructure is suitable for circular business models	100%
4. To what extent do you engage with suppliers to increase sourcing based on circular economy principles?	1. No interactions involving circular economy as a topic	0%
	2. Ad-hoc interactions involving circular economy as a topic	20%
	3. Ad-hoc interactions involving circular economy as a topic AND a plan in development for a programme using circular economy principles (e.g. codesigning material inputs for products designed along circular economy principles)	40%
	4. Ongoing programme with one or more suppliers using circular economy principles	60%
	5. Ongoing programme with one or more top five suppliers by mass (or by revenue when referring to services) using circular economy principles	80%
	6. Supplier requirements based on circular economy principles, as specified in contracts, are in place with one or more of the top five suppliers by mass (or by revenue when referring to services)	100%
5. To what extent do you engage with customers on advancing circular economy topics?	1. No interactions involving circular economy as a topic	0%
	2. Ad-hoc interactions involving circular economy as a topic	25%
	3. Ad-hoc interactions involving circular economy as a topic AND a plan in development for an ongoing programme using circular economy principles (e.g. collaboration in communicating the benefits of products and services based on circular economy principles)	50%
	4. Ongoing programme using circular economy principles with any customer	75%
	5. Ongoing programme using circular economy principles with the majority of customers	100%
6. For materials (renewable and non-renewable) suitable for the technical cycle, what % of your materials inflow (physical material that comes into your manufacturing processes) is:	• Non-virgin (including reused and recycled products and materials)	0-100%
7. What % (by mass) of your total outflow of materials (renewable and non-renewable) suitable for the technical cycle is materials processing waste or by-products that go to landfill or incineration (and are therefore not recirculated)?		0-100%

Conducting the circularity assessment

We answered questions one to five through desk-based research and publicly available information. Our research focused on reviewing annual reports, sustainability reports, and press releases. In instances where a company has multiple subsidiaries, we focused our analysis on group-level reporting. We have included a source to each answer in our underlying model, which outlines the report and page number or link to a press release or website page.

It is important to note for these questions that we assessed a company's response to the plastic waste problem specifically, using circular economy principles. There were several instances where companies have disclosed information and outlined commitments to reduce greenhouse gas emissions, energy consumption, water consumption, and waste produced at site, but fell short of mentioning any commitments or targets relating to plastic leakage specifically. While we are encouraged by the level of commitment by many polymer producers to reduce their impact on climate issues, we have scored this exercise solely on a company's performance with respect to circular practices related to plastics.

Question six and seven were answered with reference to the Material Flows Analysis section and other publicly available data sources.

Below outlinines the seven questions and the scoring associated for each answer. For a definitions of terms that was when applying the answer grid, see Section 6 – Definitions: Circularity Assessment.

Question one: Is your strategy aligned with becoming more circular?
This question focused on the group's overall strategy as well as its sustainability strategy.

- Where there was no mention of circular economy principles for plastic waste in either strategy, then the company received a score of 0 per cent.
- Where relevant concepts of circular economy principles for plastic waste were "loosely" mentioned, i.e. where a company seeks to play an important role in the circular economy for plastics, then the company received a score of 50 per cent.
- The company only received a score of 100 per cent where we believed circular economy principles for plastics were specifically mentioned as part of the strategic priorities and/or as part of the group's core strategy pillars.

Question two: Do you have measurable circular economy targets?

This question focused on the group's development and disclosure of SMART circular economy targets for plastics - Specific (clearly defined), Measurable (expressed with a number), Achievable (ambitious but not unrealistic), Relevant (the target talks about circular economy concepts) and Time-bound (there's a deadline to achieve it).

- Where no targets on circular economy principles for plastics were mentioned, then the company received a score of 0 per cent.
- Companies that had targets at an organizational level but were not SMART targets received a score of 50 per cent, e.g. double the company's PET bottle recycling rate, without a specific time frame given.
- Companies that had SMART targets at the organization level and sub-unit level received a score of 100 per cent.

Question three: To what extent is suitable infrastructure in place to support a circular business model?

This question focuses on infrastructure that supports circular economy principles for plastics.

- Companies received a score of 0 per cent where there were no plans to reconfigure or develop infrastructure that supported circular economy principles for plastics.
- Companies that are in the process of developing pilot plant projects or are investing in R and D to minimize plastic waste received a score of 25 per cent or 50 per cent depending on the stage and timeline.
- Companies received a score of 75 per cent if new or existing infrastructure has been configured or designed to support circular economy principles for plastics, e.g. building a plant to produce PET from post-consumer waste.
- Companies received a score of 100 per cent if all infrastructure is already suitable for circular business models for plastics.

Question four: To what extent do you engage with suppliers to increase sourcing based on circular economy principles?

- To score a company based on their engagement with suppliers, which, to increase sourcing based on circular economy principles, we looked at joint venture agreement and partnerships. In our view, this includes engagement with waste management and recycling companies. e.g. recycling initiatives with suppliers for increasing recycled content into the polymer production process. Where there was no evidence of interactions with suppliers on circularity for plastics, then the company received a score of 0 per cent.
- Where we came across evidence of ad-hoc interactions with suppliers plus a plan in development with one supplier then the company received a score between 40-60 per cent.
- Where ongoing programmes with all suppliers, as specified in contracts, was in place then the company received a score of 100 per cent.

We intentionally did not include a question on company membership with circular economy related initiatives as we believe we are not in a position to make a judgement on the effectiveness of these initiatives. That said, where companies are members of circular economy related initiatives (e.g. Alliance to End Plastic Waste), we gave companies the benefit of the doubt and the company received a score of at least 20 per cent for Question four.

Question five: To what extent do you engage with customers on advancing circular economy topics?

To score a company based on their engagement with customers, we took a similar view to Question four.

- Where there was no evidence of interactions with customers on circularity for plastics, then the company received a score of 0 per cent.
- Where we came across evidence of ad-hoc interactions with customers plus a plan in development with one customer then the company received a score of 50 per cent.
- Where ongoing programmes with the majority of customers was in place then the company received a score of 100 per cent.

Question six: For materials (renewable and non-renewable) suitable for the technical cycle, what per cent of your materials inflow (physical material that comes into your manufacturing processes) is non-virgin (including reused and recycled products and materials)

To calculate the percentage of materials inflow that are non-virgin, i.e. materials that have been previously used such as recycled products, we considered the recycling capacity of polymer producers.

Detailed data on recycling capacity at a company level was available for PET/rPET. A simplifying assumption was made that recycling capacity and material input for other in-scope polymers was negligible in 2019.

To calculate the recycled PET (rPET) capacity for producers that did produce PET polymers, we used Wood Mackenzie's rPET capacity database, which mapped out over 300 assets worldwide. The majority of these assets are owned by small, private companies. Only five producers in our list had ownership of some of the rPET assets in Wood Mackenzie's database.

Given that PET fibre is out-of-scope (textiles are not considered as single-use plastic), we only considered rPET capacities for food-grade, injection-moulding, and sheet PET as these were considered single-use plastic applications, similar to those under our scope in the Material Flow Analysis. The below formula was used to calculate the materials inflow per cent age of non-virgin materials for a company:

$$\text{Non-virgin material inputs (per cent)} = \frac{\text{rPET capacity (kt)}}{\text{Total PET produciton (kt)}}$$

Question seven: What per cent (by mass) of your total outflow of materials (renewable and non-renewable) suitable for the technical cycle is materials processing waste or by-products that go to landfill or incineration (and are therefore not recirculated)?

Question six estimates the per cent age of non-virgin plastic feedstock flowing into the production cycle, which is ultimately controlled by the company and hence we use company-level production capacity rates.

Question seven, on the other hand, estimates the per cent age of plastic flowing out of the production cycle that is not recycled in the country where the plastic eventually ends up. We therefore account for country-level recycling rates for Question 7.

To calculate the per cent age material outflows, we used global recycling rates for PP, HDPE, LDPE, and LLDPE at a country level, where possible.

- The European Commission has recycling rates for the 27 countries in the EU for PP, HDPE, and LDPE/LLDPE .
- OECD provided recycling rates for PP, HDPE, and LDPE/LLDPE for the US and Japan .
- Where recycling rates for individual countries was not found, we used the global recycling rates for PP and PE, which are two per cent and four per cent, respectively, as sourced by Wood Mackenzie. This, in our view, is acceptable as recycling rates in countries outside of EU, Japan, and US are not likely to have recycling rates materially higher than the global rates.

Regarding PET, we used Wood Mackenzie's global supply and demand model for PET bottle consumption and rPET flake consumption. Wood Mackenzie developed a supply and demand model for rPET for every country of the world that has PET demand exceeding three thousand tonnes and for countries which have production facilities. Trade flows for the plastic waste trade are also included in the model, however, for the purpose of simplicity, we have not considered trade flows into our analysis as they represent less than two percent of global PET bottle consumption.

1. To calculate the PET recycling rate in-country, we used the following formula:

$$\text{PET recycling rate (per cent)} = \frac{\text{Flake consumption (kt)}}{\text{Bottle consumption (kt)}}$$

As an example, global flake consumption is circa nine million tonnes, with global bottle consumption at circa 23 million tonnes, equating to a global PET recycling rate of circa 40 per cent. We carried out this exercise for each country in the model.

2. These country recycling rates for PP, PE, and PET were then applied to our SUP model at the individual asset level, for both rigids and flexible plastics. The SUP model is generated in the Material Flow Analysis (section 3.9) and estimates what per cent age the single-use plastic waste produced by each asset ends of up where, on a country-by-country basis. This method considers the recycling rates of each country where the per cent age of waste produced by each asset ends up. We use the formula below.

$$\text{SUP of asset x recycled in country y} = \text{SUP of asset x in country y} \times \text{recycling rate of country y}$$

3. We then summed up the total SUP recycled for an asset in each country to calculate the total SUP recycled for a polymer producer. We then divided this number by the total SUP production to estimate the per cent age of materials outflow that ends up as waste.

$$\text{Materials outflow recycled (per cent)} = \frac{\text{Total SUP recycled (kt)}}{\text{Total SUP production (kt)}}$$

4. Question seven is asking for the per cent age of materials outflow that is not recirculated and hence we must carry out an additional step, as per the formula below.

   Materials outflow not recycled (per cent) = 1-Materials outflow recycled (per cent)

Triangulation of assessment

One analyst from Minderoo and one from SYSTEMIQ conducted the assessment for questions one to five independently (questions one to five were answered via desk-based research) for the top 100 producers over the course of two weeks in November 2020.

A project team meeting between Minderoo and SYSTEMIQ participants was held to discuss the results. After comparing both sets of results, there were approximately 30 scores (out of 500) that had a difference in scores of more than one point. A discussion was then had on these large discrepancies and source documentation reviewed again by the project team, with a final score determined by the project team lead. Where there was a difference of one point between the Minderoo and SYSTEMIQ scores, an average of two scores was taken.

Piles of separated recyclables inside waste facility in Slovinia.
Photo credit: AzmanL via Getty Images.

Scoring and weighting

Where possible, we followed the answer grids and scoring for each question as defined in *Circulytics* **(Figure 25)**. To create an overall score, the five Enabler scores were together given the same weighting as the two Outcome scores, thus giving an equal importance to commitments, policies and practices, as to achievement of circular business (**Figure 26**). Percentage scores were also converted into a letter score from A-E – A score of 'A' implies a fully circular business model or practice, while a score of 'E' implies a fully linear business model or practice. (**Figure 27**).

Figure 26

Overall scoring weighting

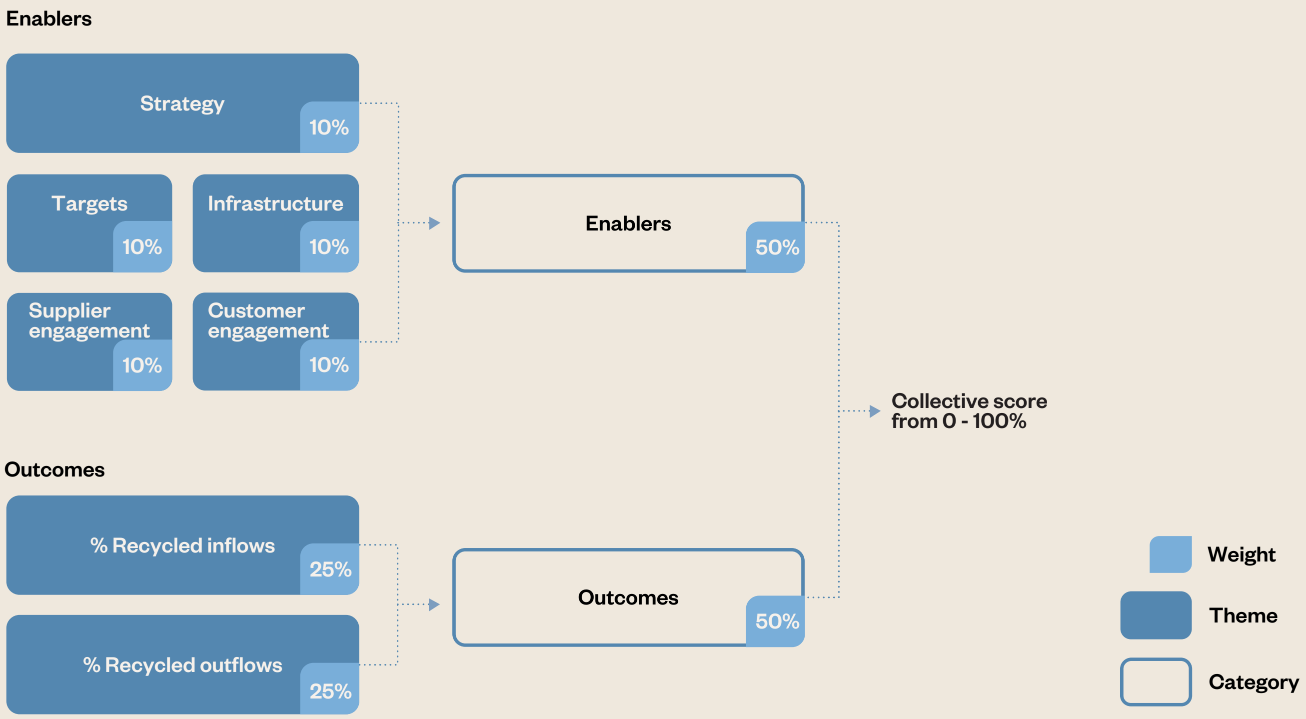


Figure 27

Conversion of percentage scores into grade scores.

Lower limit	Upper limit	Letter
88.89	100	A
77.78	88.89	A-
66.67	77.78	B
55.56	66.67	B-
44.44	55.56	C
33.33	44.44	C-
22.22	33.33	D
11.11	22.22	D-
0	11.11	E

Shredded bits of polypropene plastic. Most single-use plastics end up as mixed waste with little to no commodity value. Photo credit: Santiago Urquijo via Getty Images.

DEFINITIONS

Acronyms

ACC PIPS	American Chemistry Council Plastics Industry Producers' Statistics
C and I	Consumer and Institutional Products
CA	Circularity Assessment (conducted by Minderoo)
EMF	Ellen MacArthur Foundation
EPA	United States Environmental Protection Agency
ESG	Environmental, Social, and Governance
EU	European Union
F and O	Financing and Ownership (conducted by Minderoo)
GDP	Gross Domestic Product
HDPE	High-Density Polyethylene
IPO	Initial Public Offering
LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
MFA	Material Flow Analysis (conducted by Minderoo)
MMT	Million Metric Ton
MSW	Municipal Solid Waste
MSW-P	Municipal Solid Waste Plastic
OECD	Organisation for Economic Co-operation and Development
PA	Polyamide
PET	Polyethylene Terephthalate
PP	Polypropylene
PPPM	Polymer-Process-Product Matrix
PS	Polystyrene
PU	Polyurethane
PVC	Polyvinyl Chloride
rPET	Recycled Polyethylene Terephthalate
SMART	Specific, Measurable, Achievable, Relevant, and Time-Bound
SUP	Single-Use Plastic
UN	United Nations
US	United States
USD	United States Dollar
WM	Wood Mackenzie

Producer definition

Below we outline Minderoo's definition of a producer and the link between assets, operators, and owners.

ASSETS: Wood Mackenzie provided a global asset production database of in-scope polymers (pp, hdpe, ldpe, lldpe, and pet Resin) for 2019. The database comprises of 1,205 unique asset names, with a combined total production of in-scope polymers of 204MMT. An asset is a production site where hydrocarbons are converted into plastic polymers.

OPERATOR: The assets are operated across 425 unique operator names, which has also been provided by Wood Mackenzie. Operators are locally-incorporated companies that run the assets.

OWNER: Wood Mackenzie also provided the ownership structure of the operators. Planet Tracker then verified, and corrected, where necessary, the ownership structure of the operators, using Orbis as the source.

PRODUCER: Planet Tracker's ownership database initially comprised of both financial institutions as well as industrial companies as the primary owners of the Operators. We created an additional category – Producer – to provides a better representation of the organisations responsible for polymer production and, subsequently, leakage of fast-moving plastics. Our definition of a producer is detailed below.

The definition of a polymer producer is any company that either:

- directly owns 100 per cent of an operator, or
- directly part-owns multiple operators.

In addition, financial institutions are not considered to be polymer producers. The financial institutions stake in an operator is assigned to the operator itself, who, as a result, is therefore considered to be a producer. Furthermore, where a non-financial organization partly owns one operator only, their stake is therefore also assigned to the operator itself.

As an example of (i), Dow owns 100 per cent of Dow Chemical Canada (an operator) and is therefore considered a producer.

As an example of (ii), Mesaieed Petrochemical Company has a 49 per cent stake in Qatar Chemical Company Ltd. - (Q-Chem) and a 49 per cent stake in Qatar Chemical Company II Ltd. - (Q-Chem II). Mesaieed directly part-owns multiple operators and therefore is considered a producer.

On the contrary, Pushineh Polymer Industrial Group only part-owns one operator, its 36 per cent stake in Laleh Petrochemical Company, and hence is not considered a polymer producer. Pushineh's 36 per cent stake is therefore assigned to the operator, Laleh Petrochemical Company, who in turn is considered a producer.

Similarly, Justice Shares Broker directly part-owns multiple operators e.g. 15 per cent in Ilam Petrochemical Company and 30 per cent in Marun Petrochemical Company. However, given that Justice Shares Broker is considered a financial institution, we assign its stakes to the operators, who in turn are considered to be producers.

Financing and Ownership

Bookrunner

The term bookrunner refers to the primary underwriter or lead coordinator in the issuance of new equity, debt, or securities instruments. The book runner is the lead underwriting firm that runs or is in charge of the books in investment banking. Book runners may also coordinate with others to mitigate their risk. Bookrunners are also known in the industry as lead arrangers or lead managers. With IPOs, the bookrunner assesses a company's financials and current market conditions to arrive at the initial value and quantity of shares to be sold to private parties. While most often done during an IPO, bookrunners may also do this through a secondary offering.

Corporate Loans

The easiest way to obtain debt is to borrow money. In most cases, money is borrowed from commercial banks. Loans can be either short-term or long-term in nature. Short-term loans (including trade credits, current accounts, leasing agreements, et cetera) have a maturity of less than a year. They are mostly used as working capital for day-to-day operations. Short-term debts are often provided by a single commercial bank, which does not ask for substantial guarantees from the company.

A long-term loan has a maturity of at least one year, but generally of three to ten years. Long-term corporate loans are in particular useful to finance expansion plans, which only generate rewards after some period of time. The proceeds of corporate loans can be used for all activities of the company. Often long-term loans are extended by a loan syndicate, which is a group of banks brought together by one or more arranging banks. The loan syndicate will only undersign the loan agreement if the company can provide certain guarantees that interest and repayments on the loan will be fulfilled.

General corporate purposes/working capital

Often a company will receive a loan for general corporate purposes or for working capital. On occasion while the use of proceeds is reported as general corporate purposes, it is in fact earmarked for a certain project.

Project finance

One specific form of corporate loan is project finance. This is a non-recourse loan that is earmarked for a specific project.

Share issuances

Issuing shares on the stock exchange gives a company the opportunity to increase its equity by attracting a large number of new shareholders or increase the equity from its existing shareholders.

When a company offers its shares on the stock exchange for first time, this is called an Initial Public Offering (IPO). When a company's shares are already traded on the stock exchange, this is called a secondary offering of additional shares.

To arrange an IPO or a secondary offering, a company needs the assistance of one or more (investment) banks, which will promote the shares and find shareholders. The role of investment banks in this process therefore is very important.

The role of the investment bank is temporary. The investment bank purchases the shares initially and then promotes the shares and finds shareholders. When all issued shares that the financial institution has underwritten are sold, they are no longer included in the balance sheet or the portfolio of the financial institution. However, the assistance provided by financial institutions to companies in share issuances is crucial. They provide the company with access to capital markets and provide a guarantee that shares will be bought at a pre-determined minimum price.

Circularity Assessment

EMF has provided a definition list for its Circulytics assessment , which has been included below for Questions one to seven.

Question one – Strategy

Strategy: The current strategy of your company for a 5-year (or similar) period.

Strategic priorities: The next level of detail within the overall strategy, usually three-five priorities in total.

Question two – Targets

Measurable circular economy targets: Targets that are quantifiable (i.e. target is expressed with a number) and have a clear deadline i.e. limited by a date). SMART target defined below.

Smart targets: Refers to targets that are Specific (clearly defined), Measurable (expressed with a number), Achievable (ambitious but not unrealistic), Relevant (the target talks about circular economy concepts) and Time-bound (there is a deadline to achieve it).

Question three – Infrastructure

Infrastructure: All PPE assets (property, plant, and equipment). The physical infrastructure with a use period of one year or more that allows for circular way of doing business (e.g. reverse logistics, factory assets that collect by-products/waste, assets that allow for alternative materials to be used). For a product manufacturer this could mean reverse logistics infrastructure; for a food manufacturer a modified production plant to allow for different packaging methods. Note: The infrastructure does not necessarily need to be purpose built. Existing infrastructure is acceptable if it is capable of supporting a circular way of doing business.

Questions four and five – External engagement

Circular economy principles:

- Design out waste and pollution
- Keep products and materials in use
- Regenerate natural systems

Suppliers: Any company you procure from (can be more than one step upstream).

Ongoing programme: Regular engagement with relevant stakeholders oriented around a formal agreement between parties to realise pre-defined objectives

Customers: Any company or individual you sell, lease, or rent to (can be more than one step downstream).

Questions six and seven – Input and output

Materials (renewable and non-renewable) suitable for the technical cycle: That can be used, reused/redistributed, maintained/prolonged, refurbished/remanufactured, or recycled. This includes all non-renewable materials such as metals, plastics, and synthetic chemicals, as well as renewable materials that are designed to be part of the technical cycle, such as wood and cotton. Note that this category also includes materials of biological origin that are used as reactants in chemical processes (e.g. vegetable oil for plastics) and that form the basis of another materials or products that behave as technical material (e.g. pulp for paper).

Non-virgin: Material that has been previously used, including reused, refurbished, repaired, remanufactured, and recycled products, components, and materials.

Renewable: Material that can be continually replenished.

Materials sourced from regeneratively managed resources: Materials grown in ways that improve whole ecosystems, including by increasing soil health and carbon content, water quality, and biodiversity. The concept goes beyond retaining the status quo of natural systems and extends to improving their health and capacity to regenerate themselves.

Material sourced from sustainably managed resources: The material was grown in a way that preserves the ecosystem status quo without degrading it further, but falls short of being regenerative. Sustainable sourcing is considered a transition stage towards a regenerative way of managing renewable materials sourcing.

By-products: An inevitable secondary result of materials processing, while recognising all byproducts can be feedstock for another production.

Waste: Unwanted or unusable materials or substances, while recognising all waste can be feedstock for another production.

Renewable energy sources: Energy (electricity, heat, and fuel) is renewable if it is:

- Non-biomass based renewable sources:
  - Solar
  - Wind
  - Hydro (land-based, tidal, and wave)
  - Geothermal

- Biomass based energy that is

1. from a regeneratively/sustainably grown source and derived from residues

   and/or by-products when using virgin material, or
2. processed from by-products/waste streams. This excludes incineration for energy recovery, except when all the following conditions are met:
   - Other end of life options for the material, besides landfill, has been demonstrably exhausted;
   - The material is from a biological source;
   - The biological material is demonstrably traceable to a source of renewable and regenerative production;
   - The biological material is completely uncontaminated by technical materials, (including coatings, preservatives, and fillers except when these are demonstrably inert and non-toxic), and other biological materials which do not adhere to these restrictions;
   - Energy recovery is optimised to extract the maximum practical net energy content from the material and is usefully employed to displace non-renewable alternatives;
   - The by-products of the energy recovery are themselves 100 per cent biologically beneficial (e.g. as a soil conditioner), and are not detrimental to the ecosystems to which they are introduced.

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