A summary of the methodology for the Material Flow Analysis conducted for the International Aluminium Institute (IAI)

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# Introduction

On the behalf of the International Aluminium Institute (IAI), Eunomia has built a material flow model of the waste management systems for aluminium cans, PET and glass bottles in Europe, the US, Japan, Brazil and China. The following provides a summary of the methodological approach taken to build these models, and the sources of data used.

# Beverage Container Waste Management Material Flow Analysis

The developed model represents the mass flows of the waste management system of aluminium cans, PET and glass bottles in Europe[[1]](#footnote-2), the USA, Japan, Brazil and China for 2019. The system boundary begins at the point in which the beverage container is placed on the market (PoM), to where it becomes waste and is collected, sorted, and sent for recycling or disposal. The losses associated with each process in the waste management of a beverage container following its use are included. Finally, of those recycled beverage containers the model differentiates between closed and open loop recycling to show the key recycling routes for each type of material in each country.

## Placed on the market (PoM) data

Data for packaging placed on the market (PoM) was provided through a variety of sources, with each of the respective national aluminium associations providing PoM data. This data was supplemented and checked against other confidential data made available to Eunomia by Ball Packaging[[2]](#footnote-3). PoM data for PET and glass beverage containers was gathered through an extensive literature review and guidance from regional and national associations.

Table 2‑1: Data sources of placed on the market data.

|  |  |  |  |
| --- | --- | --- | --- |
| Region / Country | Material Type | Value (kt) | Data Source |
| Europe | Aluminium | 644 | European Aluminium[[3]](#footnote-4) |
| PET | 2,589 | EFBW, Petcore & PRE[[4]](#footnote-5) & Eunomia assumptions  |
| Glass | 17,330 | FEVE[[5]](#footnote-6) |
| USA | Aluminium | 1,244 | Aluminum Association and Can Manufacturers Institute[[6]](#footnote-7) |
| PET | 3,031 | Eunomia[[7]](#footnote-8) |
| Glass | 9,085 |
| Japan | Aluminium | 330 | Japanese Aluminium Can Recycling Association[[8]](#footnote-9) |
| PET | 539 | The Council for PET Bottle Recycling[[9]](#footnote-10) |
| Glass | 1,267 | Glass Bottle 3R Promotion Association[[10]](#footnote-11) |
| Brazil | Aluminium | 375 | Brazilian Aluminium Association (ABAL)2 |
| PET | 515 | National Information System on Solid Waste Management (SINIR)[[11]](#footnote-12) |
| Glass | 1,041 |
| China | Aluminium | 1,150 | Antiake2 |
| PET | 4,796 | Eunomia assumption |
| Glass | 36,386 |

## Collection data

Following use, the containers are collected for recycling or disposal. In certain European countries and US states, deposit return schemes (DRS) are in operation. Where a DRS is in operation, Reloop’s *Global Deposit Book 2020* provided information on the volume and product type of containers in-scope and the return rates by material type[[12]](#footnote-13). Based on this information and the PoM data, the percentage of containers in-scope for each country DRS was calculated. The return rates were then applied to calculate the tonnages collected via DRS. Those containers not in-scope were collected via separate collections. Table 2‑2 shows the sources of data used to compile collection rates used in the model.

Table 2‑2: Data sources for collection data.

|  |  |  |  |
| --- | --- | --- | --- |
| Region / Country | Material Type | Collection rate (%) | Data Source |
| Europe | Aluminium | Varies by country | European Aluminium3, Reloop12  |
| PET | Varies by country | UNESDA[[13]](#footnote-14), Reloop12 |
| Glass | Varies by country | FEVE6, Reloop12 |
| USA | All | Varies by state | Eunomia7, Reloop12 |
| Japan | Aluminium | 99.7% | Japanese Aluminium Can Recycling Association8 |
| PET | 92.2% | The Council for PET Bottle Recycling9 |
| Glass | 86.2% | Glass Bottle 3R Promotion Association10 |
| Brazil | Aluminium | 98.6% | ABAL2 |
| PET | 55.0% | Abipet (2019)[[14]](#footnote-15) |
| Glass | 47.0% | Sphera for Ball Packaging (2020)[[15]](#footnote-16) |
| China | Aluminium | 98.0% | Antiake3 |
| PET | 75.0% | Assumption |
| Glass | 35.0% | Assumption |

It should be noted that the collection systems in operation in Brazil and China are markedly different from those in Europe, the USA and Japan. In Brazil and China, a large proportion of recyclable material is collected by the informal sector due to the intrinsic value of the aluminium, PET and glass that forms beverage containers. The collections rates are highest for aluminium, the material with the greatest monetary value, and lowest for glass. As such, it is difficult to find accurate data on the true collection rates in these countries. In these instances, collection rates have been back-calculated from the ‘sorted for recycling rates’ made available to Eunomia by the regional aluminium associations. Due to the difference in collection systems, data for China and Brazil are not directly comparable to the European, US and Japanese equivalents.

Those containers that are not collected for recycling are then disposed of via incineration or landfill. The proportion disposed of via each method is shown in Table 2‑3.

Table 2‑3: Data sources for disposal method data.

|  |  |  |
| --- | --- | --- |
| Region / Country | Disposal Method | Data Source |
| Landfill | Incineration | Other |
| Europe (average) | 75.2% | 14.7% | 10.1% | Eurostat[[16]](#footnote-17) |
| USA | 80.9% | 19.1% | - | Environmental Protection Agency[[17]](#footnote-18) |
| Japan | 98.1% | 1.9% | - | Sakai (1996)[[18]](#footnote-19), Tanaka (1999)[[19]](#footnote-20), Niyati (2015)[[20]](#footnote-21) |
| Brazil | 100.0% | - | - | Alfaia et al. (2017)[[21]](#footnote-22) |
| China | 55.0% | 45.0% | - | Lee et al. (2020)[[22]](#footnote-23) |

For aluminium cans, the recovery of aluminium from incinerator bottom ash (IBA) was also considered. The mass recovered from IBA (3.0% of total incinerated tonnage) is included within open-loop recycling. It is categorised as recyclable, as its next use is often casting alloys in the automotive industry[[23]](#footnote-24).

## Sorting data

Following collection, material is then sorted to remove product residues, non-target material and other forms of contamination. For PET and glass beverage containers, there is also a colour sorting stage so that the recycled material is of a sufficient quality. These material losses during sorting are then disposed of via incineration or landfill. Table 2‑4 shows the data sources used to determine sorting efficiencies within the model. It should be noted that the type of sorting losses (contamination, non-target material or colour sorting) for all material types in Japan are not specified. In the absence of sorting data in Japan, . The figures shown are derivations based on the mass flows provided by each of the organisations stated below.

Table 2‑4: Data sources for sorting data.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Region / Country | Material Type | Sorting type | Losses (%) | Data Source |
| Europe | Aluminium | Non-target material | 1.0% | Industry interviews  |
| PET | Colour sorting | 10.0% | Industry interviews |
| Glass | Colour sorting | 15.0% | Zero Waste Scotland (2012)[[24]](#footnote-25) |
| Non-target material | 1.5% | Sphera for Ball Packaging (2020)14 |
| USA | All | Varies by state | Eunomia7, based on RRS (2015)[[25]](#footnote-26) and various MRF studies across the USA.  |
| Japan | Aluminium | Not specified | 1.6% | Japanese Aluminium Can Recycling Association8 |
| PET | Not specified | 9.4% | The Council for PET Bottle Recycling9 |
| Glass | Not specified | 15.0% | Glass Bottle 3R Promotion Association10 |

No sorting data specific for Brazil or China was made available to Eunomia. In the absence of this data, the European sorting losses were applied to calculate the sorting losses in Brazil and China.

## Re-processing data

Following sorting, the materials are re-processed so that they can be manufactured for another use. Each material has a distinct reprocessing method. Sorted aluminium cans are delacquered and remelted and cast into ingots; sorted PET bottles are washed and flaked and glass bottles are crushed into cullet and melted. During each of these processes, a proportion of the target material is lost, and is disposed of via incineration or landfill.

Table 2‑5 shows the data sources used to quantify the losses during the re-processing stage.

Table 2‑5: Data sources for re-processing data.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Region / Country | Material Type | Reprocessing stage | Losses (%) | Data Source |
| Europe / USA | Aluminium | Delaqcuering  | 2.0% | Stakeholder interview |
| Remelting | 4.5% | Boin & Bertram (2005)[[26]](#footnote-27) |
| PET | Wash & Flake | 26.5% | GVM[[27]](#footnote-28) |
| Extrusion | 1.0% | PETnology[[28]](#footnote-29) |
| Glass | Cullet production | 20.0% | Industry interview |
| Japan | Aluminium | Not specified | Japanese Aluminium Can Recycling Association8 |
| PET | Wash & Flake | 26.5% | GVM27 |
| Extrusion | 1.0% | PETnology28 |
| Glass | Cullet production | 4.1% | Glass Bottle 3R Promotion Association10 |

As in Section 2.3, where no specific re-processing data was made available to Eunomia for Brazil and China,the European re-processing losses were applied.

## Use of recycled material data

The total recycling rate consists of closed-loop recycling, where a beverage container is formed from the recycled material, and open-loop recycling, where another product is formed from the recycled material. Table 2‑6 highlights the proportion of recycled material that enters open-loop recycling.

Table 2‑6: Data sources for recycled material data.

| Region / Country | Material Type | Other use |  % split | Data Source |
| --- | --- | --- | --- | --- |
| Europe | Aluminium | Remelt to non-can uses | 37.5% | Assumption based on the 44.3% recycled content in EU aluminium cans19 |
| USA | Aluminium | Remelt to non-can uses | 7.4% | Aluminum Association and Can Manufacturers Institute6 |
| Europe / USA | PET | rPET to non-bottle uses | 72.0% | EFBW, Petcore & PRE4 |
| Glass | Cullet to non-bottle uses | 30.0% | British Glass[[29]](#footnote-30) |
| Japan | Aluminium | Exported recycling | 26.9% | Japanese Aluminium Can Recycling Association8 |
| Remelt to non-can uses | 33.3% |
| PET | Exported for recycling | 33.3% | The Council for PET Bottle Recycling9 |
| PET | Domestic rPET to non-bottle uses | 48.7% | The Council for PET Bottle Recycling9 |
| Glass | Cullet to non-bottle uses | 41.7% | Glass Bottle 3R Promotion Association10 |
| Brazil | Aluminium | Remelt to non-can uses  | 35.0% | ABAL3 |
|  | PET | rPET to non-bottle uses | 73.0% | Statista (2019)[[30]](#footnote-31) |
| China | Aluminium | Remelt to non-can uses | 99.0% | Antaike3 |
|  | PET | rPET to non-bottle uses | 95.9% | Ma et al. (2020)[[31]](#footnote-32) |
|  | Glass | Cullet for non-bottle uses  | 60.0% | Assumption |

In Japan, processed aluminium and PET is exported prior to being refabricated. In the case of aluminium, this material is exported to South Korea, where it is fabricated into beverage containers and therefore closed-loop recycling. The end destination of the PET flakes exported from Japan is unknown, and therefore cannot be attributed to open- or closed-loop recycling.

## Recyclability of non-beverage container uses

Although Table 2‑6 shows that a proportion of the recycled material is not part of the closed-loop system, some open-loop uses are recyclable. Table 2‑7 shows the proportion of non-beverage containers uses of recycled aluminium that are recyclable.

Table 2‑7: Data source for recyclability of non-beverage aluminium container uses data.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Region / Country | Material Type | Year | % of non-beverage container uses currently recyclable | Data Source |
| Europe | Aluminium | 2019 | 97.0% | International Aluminium Association2 |
| USA | 98.0% |
| Japan | 95.0% |
| Brazil | 92.0% |
| China | 96.0% |

For rPET, the other uses include trays, films, fibres and strapping. In Europe, the US and Japan, it has been assumed that 20% of trays are currently recycled. For glass, it has been assumed that no other uses are recyclable as the predominant other use is for aggregates.

1. Europe is defined as the 27 member states of the European Union, Iceland, Norway, Switzerland and the United Kingdom. [↑](#footnote-ref-2)
2. Personal communication. [↑](#footnote-ref-3)
3. Labberton, M. (2021) *Aluminium beverage can recycling remains at a high 76% in 2019*; available [here](https://www.european-aluminium.eu/media/3401/european-aluminium-mpe-alubevcan-2019-recycling-rate_press-release-16-december.pdf). [↑](#footnote-ref-4)
4. EFBW, Petcore Europe and Plastics Recyclers Europe (2020) *PET Market in Europe - State of Play: Production, Collection and Recycling Data*, 2020 [↑](#footnote-ref-5)
5. FEVE (2021) Glass Recycling Statistics (2018); available [here](https://feve.org/glass_recycling_stats_2018/). [↑](#footnote-ref-6)
6. Aluminium Association, and Can Manufacturers Institute (2021) The Aluminum Can Advantage Sustainability Key Performance Indicators [↑](#footnote-ref-7)
7. Eunomia Research & Consulting (2021) The 50 States of Recycling: A State-by-State Assessment of Containers and Packaging Recycling Rates [↑](#footnote-ref-8)
8. Japanese Aluminium Can Recycling Association (2021): <http://www.alumi-can.or.jp/publics/index/62/> [↑](#footnote-ref-9)
9. The Council for PET Bottle Recycling (2021): <https://www.petbottle-rec.gr.jp/english/> [↑](#footnote-ref-10)
10. Glass Bottle 3R Promotion Association (2021): <https://www.glass-3r.jp/> [↑](#footnote-ref-11)
11. SINIR (2018) Annex II-III-IV-V of ‘The Sector Agreement for the Implementation of the Reverse Packaging Logistics System in General’; available [here](https://sinir.gov.br/images/sinir/Embalagens%20em%20Geral/Anexo_II-III-IV-V.pdf). [↑](#footnote-ref-12)
12. Reloop (2020) *Global Deposit Book 2020: An Overview of Deposit Systems for One-way Beverage Containers* [↑](#footnote-ref-13)
13. UNESDA (2020) PET Collection Rates Across Europe; available [here](https://www.unesda.eu/pet-recycling-rates-across-europe/). [↑](#footnote-ref-14)
14. Abipet (2020) 11o *Censo do Reciclagem do PET no Brasil*. [↑](#footnote-ref-15)
15. Sphera for Ball Packaging (2020) Beverage Packaging: A Comparative Life Cycle Assessment. [↑](#footnote-ref-16)
16. Eurostat (2021) Municipal waste by waste management operations; available [here](https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wasmun&lang=en). [↑](#footnote-ref-17)
17. Environmental Protection Agency (2020) Advancing Sustainable Materials Management: 2018 Fact Sheet [↑](#footnote-ref-18)
18. Sakai, S. (1996) Municipal solid waste management in Japan, *Waste Management*, Vol.16 [↑](#footnote-ref-19)
19. Tanaka, M. (1999) Recent trends in recycling activities and waste management in Japan, *Journal of Material Cycles and Waste Management*, Vol.1, pp.1–10 [↑](#footnote-ref-20)
20. Niyati, M. (2015) A Comparative Study of Municipal Solid Waste Management in India and Japan [↑](#footnote-ref-21)
21. Alfaia, R., Costa, A., and Campos, J. (2017) Municipal solid waste in Brazil: A review, *Waste Management & Research: The Journal for a Sustainable Circular Economy*, Vol.35, No.12, pp.1195-1209. [↑](#footnote-ref-22)
22. Lee, R.P., Meyer, B., Huang, Q., and Voss, R. (2020) Sustainable waste management for zero waste cities in China: potential, challenges and opportunities, *Clean Energy*, Vol.4, No.3, pp.169–201 [↑](#footnote-ref-23)
23. Personal communication with Marlen Bertram (IAI) and Maarten Labberton (European Aluminium Association). [↑](#footnote-ref-24)
24. Zero Waste Scotland (2012) Glass Collection & Re-processing Options Appraisal in Scotland; available [here](https://www.zerowastescotland.org.uk/sites/default/files/Glass%20Collection%20%26%20Re-processing%20Options%20report.pdf). [↑](#footnote-ref-25)
25. RRS (2015) MRF Material Flow Study [↑](#footnote-ref-26)
26. Boin, U.M.J., and Bertram, M. (2005) Melting standardized aluminum scrap: A mass balance model for Europe, *JOM*, Vol.57, No.8, pp.26–33 [↑](#footnote-ref-27)
27. GVM (2020) Aufkommen und Verwertung von PET Getränkeflaschen in Deutschland 2019; available [here](https://newsroom.kunststoffverpackungen.de/wp-content/uploads/2020/10/2020-10-19-Kurzfassung-Verwertung-PET-Getraenkeflaschen-2019.pdf). [↑](#footnote-ref-28)
28. Hannemann, A. (2020) PET Bottle to Bottle Recycling with the MRS Extrusion Concept; available [here](https://www.petnology.com/competence-magazine/news-details/pet-bottle-to-bottle-recycling-with-the-mrs-extrusion-concept.html). [↑](#footnote-ref-29)
29. British Glass (2021) Response to ‘Consultation on Deposit Return Scheme (England, NI, Wales)’: available [here](https://www.britglass.org.uk/sites/default/files/British%20Glass%20DRS%20Consultation%20Response%20-%20final.pdf). [↑](#footnote-ref-30)
30. Statista (2021) Leading sectors of destination of recycled PET in Brazil in 2019; available [here](https://www.statista.com/statistics/1133827/brazil-recycled-pet-consumers-sector/). [↑](#footnote-ref-31)
31. Ma, Z., Ryberg, M.W., Wang, P., Tang, L., and Chen, W.-Q. (2020) China’s Import of Waste PET Bottles Benefited Global Plastic Circularity and Environmental Performance, *ACS Sustainable Chemistry & Engineering*, Vol.8, No.45, pp.16861–16868 [↑](#footnote-ref-32)