
# Life Cycle Assessment of metal packaging in Europe - Update

Metal Packaging Europe

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## Glossary

| | |
|---|---|
| **Allocation**[1] | Partitioning the input or output flows of a process (e.g. recycling) or a product system between the product system under study and one or more other product systems.<br>Particular case: proportion of material in the input to the production that has been recycled from a previous system |
| **Characterization factor**[1] | Factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator |
| **Critical review**[1] | Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment |
| **Cut-off criteria**[1] | Specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study |
| **Elementary flow**[1] | Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation |
| **Energy flow**[1] | Input to or output from a unit process or product system, quantified in energy units |
| **Functional unit**[1] | Quantified performance of a product system for use as a reference unit |
| **Impact category**[1] | Class representing environmental issues of concern to which life cycle inventory analysis results may be assigned |
| **Life Cycle Assessment (LCA)** [1] | Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle |
| **Primary data**[2] | Directly measured or collected data from one or multiple facilities (site-specific data) that are representative for the activities of the company. It is synonymous to "company-specific data". |
| **Process**[1] | Set of interrelated or interacting activities that transforms inputs into outputs |

[1] Source: ISO 14044

| | |
|---|---|
| **Recycled content ($R_1$)**[2] | Proportion of material in the input to the production that has been recycled from a previous system |
| **Recycling rate ($R_2$)**[2] | Proportion of the material in the product that will be recycled (or reused) in a subsequent system |
| **Reference flow**[1] | Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit |
| **Sensitivity analysis**[1] | Systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study |
| **System boundaries**[1] | Set of criteria specifying which unit processes are part of a product system |

[2] Source: PEFCR guidance V6.3

# I. Introduction

Metal Packaging Europe (MPE) is the European federation of metal packaging makers. MPE brings together more than 760 manufacturers, suppliers and their national associations, to promote the benefits of rigid metal packaging. MPE supports more than 180,000 employees in 23 European countries. Each year, more than 98 billion units are produced and reach consumers every day. Packaging is made of steel or aluminium.

MPE has been created by the merger of Beverage Can Makers Europe (BCME) and European Metal Packaging (Empac).

MPE promotes the common interests of its members throughout Europe and is actively engaged in dialogue with European stakeholders and NGOs.

Consequently, MPE must rely on the most current environmental life cycle information on metal packaging production in order to promote continuous improvement of the environmental sustainability performance of metal packaging.

To accomplish this, MPE commissioned RDC Environment which is an independent consultancy based in Belgium with extensive experience in conducting LCA studies and facilitating critical stakeholder review processes. RDC Environment provided MPE and member companies with the present LCA study which has been conducted according to the requirements of the international standard ISO 14040/44.

# II. Goal and scope of the study

## II.1. Goal of the Study

The goals of the study are the following:

- To determine the environmental impacts and credits (i.e. avoided impact) along the life cycle of the metal packaging produced in Europe. This will be done by generating an LCA of the following packaging:
    - aluminium food can 125 ml
    - steel food can 425 ml
    - steel aerosol 420 ml
    - steel aerosol 520 ml
    - steel general line 2500 ml
    - steel closure
    - steel speciality
    - aluminium beverage can 250 ml
    - aluminium beverage can 330 ml
    - aluminium beverage can 500 ml

  The selection of packaging studied is presented in section II.2.2 Representative products of the report (page 15).
  The following system boundaries (see Figure 1) are analysed:
    - Cradle-to-gate + transport to filling site + End-of-Life.
    - Gate-to-gate

- To track performance of the metal packaging production in Europe by comparing the impacts of the 2018 production year with those ones of the previous MPE's LCA studies:
    - BCME, EAA, APEAL, PE International, Life Cycle Inventory and impact Analysis for Beverage Cans, 2009 (production year: 2006)
    - TNO, LCA model for metal packaging, 2012 (production years: 2000, 2006 and 2008)
    - Life Cycle Assessment of metal packaging in Europe, European Metal Packaging (Empac), 2016 (production year: 2013)
    - Life Cycle Assessment of Aluminium Beverage Cans in Europe, Metal Packaging Europe, 2019 (production year: 2016)
- To generate Life Cycle Inventories (LCIs) of the production phases and some selected further life cycle phases of the metal packaging produced in Europe according to the following system boundaries:
    - Cradle-to-gate + transport to filling site + End-of-Life.

The study has been performed according to ISO 14040/44 and provides LCIs and LCA report of the metal packaging produced in Europe as average across the industry and various technologies. Therefore, the intended applications of the study are:

- Internally to Metal Packaging Europe:
  - To increase the knowledge and to provide Metal Packaging Europe members with objective and reliable information about the environmental impacts and credits connected with the life cycle of the average metal packaging produced in Europe;
  - To provide to Metal Packaging Europe members with objective and reliable information about the performance of the average metal packaging production in Europe in 2018.
    For packaging other than beverage cans, the results for 2018 are compared with those for 2013, 2008, 2006 and 2000 (previous study: "Life Cycle Assessment of metal packaging in Europe" (2016) realised for Empac by RDC).
    For beverage cans, the results for 2018 are compared with those for 2016 and 2006 (previous study: "Life Cycle Assessment of Aluminium Beverage Cans in Europe" (2019) realised for MPE by RDC).
- Externally to Metal Packaging Europe:
  - To communicate to external stakeholders the environmental impacts and credits connected with the life cycle of the average metal packaging produced in Europe;
  - To share the report and the LCIs with LCA practitioners willing to include metal packaging in their LCA applications.

The study is not intended to support comparative assertions to be disclosed to the public. The use of Metal Packaging Europe study results in further comparative studies shall be under the responsibility of the future LCA practitioner. This responsibility includes the check of ISO requirements regarding communication of comparative results to the public.

The intended audience of the study includes Metal Packaging Europe and its members, the manufacturers of metal packaging, government, customers and retailers, non-governmental organizations and LCA practitioners. The LCA report was developed in compliance with the international standard ISO 14040/44 for reporting to third party.

A third-party critical reviewer was engaged to ensure that the highest level of compliance with the ISO 14040/44 standards was met.

## II.2. Scope of the study

This section describes the scope of the study in order to achieve the above stated goals:

- The product system and its function, the definition of the functional unit and the system boundaries.
- The data requirements including cut-off criteria and limitations.
- The data quality requirements and the allocation procedures.
- The LCIA methodology to be used.
- The type of critical review performed.

### *II.2.1. Product System description*

Figure 1 shows the life cycle flow diagram for the system analysed. Each box is a life cycle phase of the metal packaging.

Two scopes are highlighted on this figure:

- Gate-to-gate scope (orange box): the manufacture of the product at the MPE member plants.
- Cradle-to-gate + transport to filling site + End-of-Life (blue box excluding the white box): the production of raw and secondary (recycled) materials, the manufacture of metal packaging, the transport to filling site and the End-of-Life scenarios.

  The white area indicates processes excluded from the product system analysed in the study: these processes are related to the specific applications of the packaging, i.e. the filling of the packaging, its distribution to the market and its use. These phases/processes are excluded from the study in accordance with its goal (in particular tracking performance of the metal packaging production in Europe and generating LCIs of product phases and some further selected life cycle phases) as well as they are not under the direct control of MPE members.

  The filling phase also includes the associated processing step. It consists in the manutention of the bodies/ends and cans inside the filling plant, the seaming of the end to the body and the final inspection of the cans.

  **Warning**: The future users of Metal Packaging Europe LCIs must be aware of the exclusion of filling, distribution and use phases. Those phases must be accounted additionally for a complete life cycle assessment of the metal packaging.

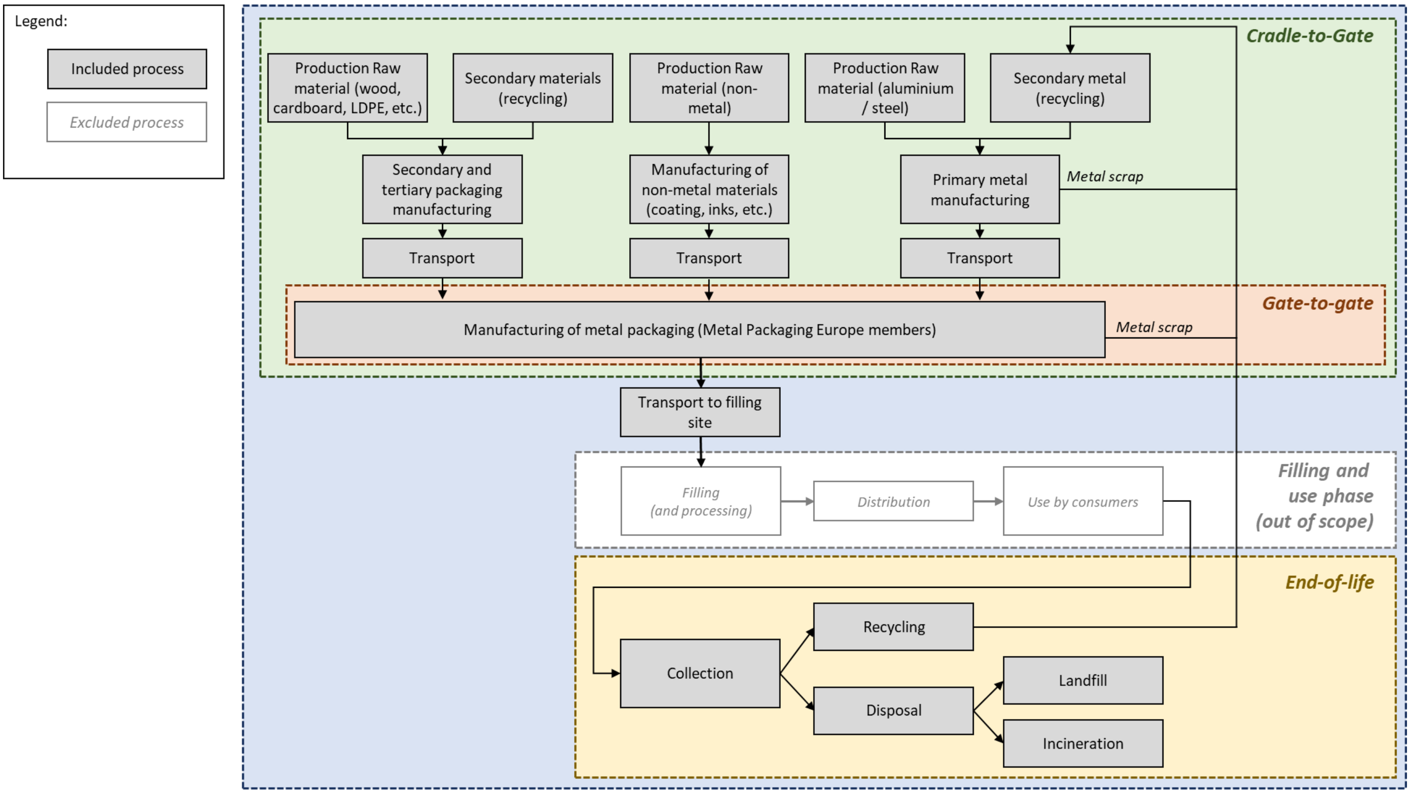


*Figure 1 – Life cycle flow diagram for the system analysed*

**<u>Note:</u>** As shown in Figure 1, a closed loop scenario is considered to model the recycling step in the base case. In addition, sensitivity analyses are performed considering open loop recycling. Two parameters are then studied: the allocation factor A and the recycling rate $R_1$ (cf. chapter "2 Sensitivity analysis: open-loop scenario", page 27).

**<u>Note:</u>** It is important to identify the two types of packaging mentioned in the report:

- Metal packaging: i.e. the steel and aluminium packaging under study (e.g. aluminium food can 125 ml, steel food can 425 ml, steel aerosol 420 ml)
- Secondary and tertiary packaging: packaging used to transport the metal packaging (e.g. interlayer cardboard, LDPE film, pallet).

### *II.2.2. Representative products*

Metal packaging is used throughout the retail, wholesale, commercial and industrial sectors, therefore it comes in many shapes and sizes and can package virtually any product. Metal packaging are standardised products complying with international standards but must respond to the requests of the market (e.g. fillers and their customers) in terms of design, specifications, applications, marketing, etc., therefore it is impossible to replicate the endless list of metal packaging within the LCA.

The approach taken for the study is the same as for the previous studies, i.e. to focus on the most representative size of each packaging category (e.g. food, beverage, general line, aerosol, etc.) present on the market[3].

For the majority of these packaging categories, the sizes of the packaging have not changed over the last years. In aluminium food cans, the 425 ml can lost some market share according to the can-makers, and the most sold size is currently the 125 ml. In steel aerosol, the 420 ml can is not new in the market but gained market shares comparable to the 520 ml can (already present in the previous LCA).[3]

Thus, compared to previous studies:

- The volume of the aluminium food can has changed (from 425 ml to 125 ml)
- Steel aerosol can with a volume of 420 ml was added

Despite it was originally intended to include the aluminium aerosol (420 ml) and aluminium closures in this study, it has not been possible to gather data from enough can makers and therefore, due to confidentiality reasons, these two packaging are excluded from the study.

Note: These two packages were not included in the previous study "Life Cycle Assessment of metal packaging in Europe" realised for Empac by RDC (2016).

In order to analyse the evolution of impacts in the packaging manufacturing industry, some data and results of this study have been compared with the previous studies "Life Cycle Assessment of metal packaging in Europe" realised for Empac by RDC (2016) and "Life Cycle Assessment of Aluminium Beverage Cans in Europe" realised for MPE by RDC (2019). To ensure a concordance for the comparisons, the same standardized volumes were retained.

The representativeness of the study regarding the European production is studied in the chapter II.2.6 Data quality requirements (section "Representativeness of the study", page 20).

Table 1 provides the standardized units and average weight of final products. The standardized units are identified based on MPE members data. The weight of the representative products is defined as the average weight calculated across the data provided by the can-makers. Ten can makers were consulted to estimate the weight of the standardized units.

The improvement in light weighting packaging comparing to the previous years can be observed in the annual evolution of data (See section V.3.4 Sensitivity analysis: evolution of can-manufacturing over time).

[3] Source: MPE data

*Table 1 - Standardized units and average weight of final products (data from 10 members).*

| Main component | Sectorial | Standard unit | Average weight (g) |
|---|---|---|---|
| Steel | Steel food can | *A unit of can (volume 425 ml)* | *49.6* |
| | Steel aerosol can | *A unit of can (volume 420 ml)* | *71.2* |
| | Steel aerosol can | *A unit of can (volume 520 ml)* | *80.5* |
| | Steel general line can | *A unit of can (volume 2500 ml)* | *315.0* |
| | Steel closure | *A unit of closure* | *7.7* |
| | Steel speciality | *A unit of steel box* | *164.2* |
| Aluminium | Alu food can | *A unit of can (volume 125 ml)* | *14.9* |
| | Aluminium beverage can | *A unit of can (volume 250 ml)* | *10.2* |
| | Aluminium beverage can | *A unit of can (volume 330 ml)* | *12.1* |
| | Aluminium beverage can | *A unit of can (volume 500 ml)* | *14.8* |

Note: Table 2 provides a description of general line, closure and speciality packaging.

*Table 2 - Description of general line, closure and speciality packaging*

| Packaging | Description | Picture[4] |
|---|---|---|
| General line | General line are metal packaging with metal closure used for consumer products such as paints, chemical, food, etc. |   |
| Closure | Closures are metal vacuum closures used for metal and other packaging (e.g. glass bottle and jars). |   |

[4] Sources: www.webpackaging.com for general line, www.crowncork.com for closure and speciality

| Packaging | Description | Picture[4] |
|---|---|---|
| Speciality | Specialities are metal packaging developed for promotion or specific application. |  |

Note: Except for closures, the packaging consists of the body, bottom and top end (i.e. the lid) of the can. For simplicity, in the report the body and the bottom end are referred to the "body" whereas the top end is referred to the "end" (Figure 2 [5]).

For food cans, beverage cans and general line can, data collection distinguishes between bodies and ends, as the production of the two parts of the packaging is independent (some factories produce only bodies for example).

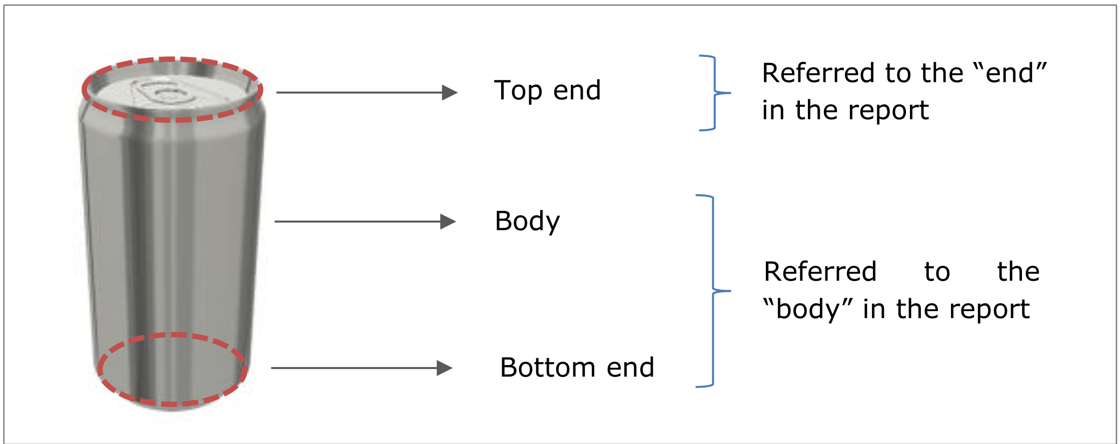


*Figure 2 - Illustration of the concepts of body and end*

### *II.2.3. Functional Unit*

The functional unit of an LCA study represents the quantified performance of a product system for use as a reference unit.

In this study, the provided function of the metal packaging is defined as: 'to contain, protect and decorate standard unit of content' and is quantified as 1000 units.

[5] Source for can image: www.webpackaging.com

Therefore, in accordance with the goals of this study, the functional unit is defined as:

| **The use of thousand (1,000) units of packaging to contain, protect and decorate thousand standard units of content for each of the sectorial packaging types: steel food cans, steel aerosol cans, steel general line cans, steel closures, steel speciality packaging, aluminium food cans and aluminium beverage cans.** |
| --- |

**WARNING: a direct comparison between packaging systems is not valid because:**

- **the life cycle is not complete (filling, distribution and use phases are excluded),**
- **the functional unit is not expressed in terms of volume of contained product, and the volumes of contained product are different according to the packaging.**

As mentioned in the section II.1 Goal of the Study, **the study is not intended to support comparative assertions to be disclosed to the public**.

### *II.2.4. System boundaries*

The system boundaries define all phases that are included in the selected scope.

As shown on Figure 1, the **study includes** the following phases (cradle-to-gate + transport to filling site + End-of-Life):

- Upstream processing and production of raw and recycled materials
- Upstream production of secondary and tertiary packaging (e.g. interlayer cardboard, LDPE film, pallet)
- Transport of raw materials, secondary and tertiary packaging to the metal packaging manufacturer
- manufacturing of metal packaging and infrastructure of the plants
- Transport to filling sites
- End-of-Life of used packaging: disposal, incineration and recycling

The following **steps are not included** in the study:

- Filling (and processing)
- Distribution (distribution includes packaging of final products, and transport to warehouse and to final customer)
- Use of the product

Justification for exclusion of some steps of the life cycle of the product:

- The steps of filling, distribution and consumption are mainly defined by the content and the manufacturer of the content. Besides, regarding the distribution, it is assumed that the weight of the packaging is much lower than the weight of the transported content, hence the influence of the packaging weight on the transport impact is assumed to be negligible.

### II.2.5. Cut-off criteria

In LCA practice, it is not always possible to obtain data for each flow or process of the life cycle due to lack of information, time or resources. Some flows or processes were excluded from the study in accordance with ISO 14044:2006, which defines criteria based on mass, energy and environmental significance in order to assess whether a flow or process can be neglected.

An exclusion threshold of 5% has been established in the study. This means that the sum of all elementary flows belonging to the excluded processes must be less than 5% of the contribution in terms of mass, energy and environmental significance of the life cycle. This threshold is a compromise between precision and feasibility (especially data availability). In this study, the process excluded according to the cut-off criteria are linked to the maintenance and operation of packaging manufacturing equipment (i.e: the equipment used for the manufacture of the body/end in MPE member's plants).

These excluded processes are not expected to contribute to more than 5% to any of the three criteria, as detailed below.

- *Mass criteria*: based on expert judgement, the process of maintenance and operation of packaging manufacturing equipment are not expected to contribute to more than 5% to the mass criteria.
- *Energy criteria*: based on expert judgement, the process of maintenance and operation of packaging manufacturing equipment are not expected to contribute significantly to the energy criteria.
- *Environmental significance*: based on expert judgement, they are not expected to contribute to more than 5% to each impact category assessed in the study.

### II.2.6. Data quality requirements

#### Temporal validity

Primary data (i.e. data from MPE member plants, representative of their activities – see also Glossary) were collected on metal packaging manufacturing for the year 2018. The year 2018 is considered a normal year for the operations and production volume of metal packaging manufacturing.

Electrical data and secondary datasets come from ecoinvent database v3.5.

Considering that there is no major technological evolution underway for the metal packaging manufacturing, the time validity of this study is 3 – 5 years.

*Representativeness of the study*

There is no official data detailing the European market of metal packaging (except for aluminium beverage cans), therefore an estimation of the representativeness of this study is provided based on the available information.

APEAL (Association of European Producers of steel for packaging) and EAA (European Aluminium Association) were consulted to estimate the total production of steel and aluminium packaging in Europe (EU28 and Turkey) for the year 2018.

The European production of steel for packaging (tinplate & Electrolytic Chromium Coated Steel - ECCS) was estimated for 2017 (latest available information) by Eurofer as equal to ≈4 300 kt of steel. Around 26% of this production was exported out of Europe and Eurofer considers that ≈500 kt of steel for packaging was imported in Europe in 2017. The amount of steel aimed to be transformed by the European packaging manufacturers is then estimated to ≈3 700 kt in 2017. APEAL considers that 15% of this production is used for beverage cans (not part of this LCA study) and 3% is not used for packaging production, hence the European production of steel for packaging (excluding beverage) is assumed to be ≈3 020 kt in 2017. Assuming that the average pre-consumer scrap generated at the can manufacturing plants in Europe is equivalent to the average scrap of the can makers analysed in this study, which is about 11% of the incoming steel sheets, the steel cans produced in Europe are about 2 688 kt. Therefore, the representativeness of this study is calculated as the ratio between the production of steel cans communicated by MPE members via the questionnaire (1 139 kt) and the estimation of the total production of steel cans in Europe (2 688 kt - excluding beverage) derived from Eurofer data, which corresponds to 42%.

The European production of aluminium sheets for rigid packaging applications (i.e. without foil stock) was estimated for 2017 (latest available information) by European Aluminium as equal to ≈1 040 kt. In addition, Europe imported about 520 kt of aluminium sheet and exported about 480 kt of aluminium sheets. Within the 1 080kt, about 90% of the volume (972 kt) is related to can stock (i.e. sheets for producing beverage cans and food cans). Assuming that the average pre-consumer scrap generated at the can manufacturing plants in Europe is equivalent to the average scrap of the can makers analysed in this study, which is about 20% of the incoming aluminium sheets, the aluminium cans produced in Europe are about 778 kt. Therefore, the representativeness of this study is calculated as the ratio between the production of aluminium cans communicated by MPE members via the questionnaire (638 kt) and the estimation of the total production of aluminium cans in Europe (778 kt) derived from European Aluminium data, which corresponds to 82%.

Only for aluminium beverage cans, the available market data[6] allows to estimate the range of 70-80% for year 2018 as the market share of the can makers involved in this LCA, therefore the representativeness of the study only for aluminium beverage cans is between 70-80%.

[6] Source: MPE

The next table shows the 7 sectorial packaging types included in this study and the global representativeness for steel and aluminium.

*Table 3 – Representativeness regarding the European production.*

| Main component | Sector | Metal packaging production based on collected data | Share of the EU metal packaging production |
|---|---|---|---|
| Steel | Steel food can | *796 341 t* | *Total MPE: 1 139 kt*<br>*Total EU: 2 688 kt*<br>*Share: 42%* |
| | Steel aerosol can | *94 001 t* | |
| | Steel general line can | *66 632 t* | |
| | Steel closure | *140 847 t* | |
| | Steel speciality | *40 860 t* | |
| Aluminium | Aluminium food can | *19 508 t* | *Total MPE: 638 kt*<br>*Total EU: 778 kt*<br>*Share: 82%* |
| | Aluminium beverage can | *618 675 t* | |

## *Technology coverage*

In the study, site-specific data are representative of current technology used in Europe for steel packaging manufacturing and aluminium packaging manufacturing for the reference year 2018.

Data collection corresponds to 116 manufacturing plants, distributed among 20 countries (distributed among 10 companies) and approximately 1 139 kt of produced steel packaging and 638 kt of produced aluminium packaging: 619 kt of aluminium beverage cans and 20 kt of aluminium food cans[7].

To model the aluminium production and the aluminium recycling at the End-of-Life, the datasets provided by European Aluminium in 2017 were used in the study. These datasets are based on primary data from 2015 and are the most up-to-date datasets regarding the produced aluminium in Europe.

To model the steel production and the steel recycling at the End-of-Life, the datasets provided by APEAL were used in the study (primary data from 2015 for steel production, and 2012 for steel recycling). These datasets are not the most up-to-date datasets regarding the produced steel in Europe. These data are used to allow comparison of results with previous studies.

Worldsteel data is the most up to date data for tinplate production in Europe: the 2020 version covers the production up to year 2019, whereas the 2018 version covers the production up to year 2017. However, APEAL and Worldsteel databases cannot be compared because are different in terms of representativity, population, technological coverage, LCA methodology.

[7] *The difference is due to rounding*

The main goal of the MPE LCA is to analyse the evolution of can manufacturing over time. Therefore the results must be compared with the previous MPE's LCA studies in which the APEAL dataset was used, therefore the current study uses APEAL dataset. This is a conservative approach but serves the main goal of the study.

On top of that, MPE LCA also provides a separate assessment of the evolution of the tinplate production over time: given that the APEAL dataset for tinplate production has not changed in the current and previous LCAs, the only way to assess the improvements made by the tinplate production industry is to use the Worldsteel data (cf. section V.3.5).

Thus the MPE LCA provides a comprehensive approach by including two perspectives: the improvement made over time by the metal packaging supply chain (based on APEAL data) and the improvement made over time only by the tinplate production (based on Worldsteel data).

### *Geographical coverage*

The geographical coverage is metal packaging produced in the EU 28+Turkey+Switzerland.

Table 4 shows the country share based on the produced tonnages (for which RDC collected data). It also gives the number of responding plants in each country.

*Table 4 - Geographical coverage: representativeness by country*

| Country | # plants | Share of sold tons |
|---|---|---|
| Spain | 15 | 10-20% |
| France | 15 | 10-20% |
| United Kingdom | 14 | 10-20% |
| Italy | 11 | 10-20% |
| Turkey | 20 | 10-20% |
| Germany | 6 | 5-10% |
| Poland | 8 | <5% |
| Denmark | 6 | <5% |
| Austria | 3 | <5% |
| Greece | 5 | <5% |
| Portugal | 2 | <5% |
| Slovakia | 2 | <5% |
| Hungary | 2 | <5% |
| Switzerland | 1 | <5% |
| Sweden | 1 | <5% |
| Netherlands | 1 | <5% |
| Ireland | 1 | <5% |
| Finland | 1 | <5% |
| Slovenia | 1 | <5% |
| Czech Republic | 1 | <5% |
| **TOTAL** | **116** | **100%** |

### *Precision*

As regards the data collected at the metal packaging plants, the precision of these data is considered very good for bill of materials, energy and water consumption. This is due to the fact this information is under control of the metal packaging manufacturers.

As regards the data collected for emissions to air and effluents, the precision of these data is considered fair, due to the fact that a limited number of plants answered to the questionnaires for all emissions to air and water (it is assumed that the margin of error is under 30%).

As regards ecoinvent v3.5 database, the precision of the database is considered as fair to good, depending on the specific dataset. For further details, see v3.5 documentation.

### *Completeness*

All relevant, specific processes were considered in the study. As regards the emissions at the metal packaging plants, beside the tracked emissions reported in the questionnaire, other emissions associated to fossil fuels combustion were assessed based on secondary databases.

As regards ecoinvent v3.5 database, the completeness of these databases is considered as good to very good, depending on the datasets. For further details, see ecoinvent v3.5 documentation.

### *Consistency*

Consistency of the study has been considered through three different aspects:

- As regards the primary data, plausibility checks of each data were done through cross-checks and comparison to average. See further for details on primary data validation.
- As regards the methodological consistency, most of the background datasets come from the same database (ecoinvent v3.5 – "Allocation, cut-off by classification") and few processes come from other datasets suppliers (e.g. European Aluminium, APEAL). Some methodological differences between datasets belonging to different databases are possible. Based on expert judgement, the consequences of these methodological discrepancies have no significant consequences on the results.
- As regards the consistency of the LCA model, cross-checks regarding mass and energy flows were carried out.

### *Reproducibility*

As far as possible, all considered assumptions and data are detailed in the LCA report to allow reproducibility and transparency. An external audience may not be able to reproduce all life cycle phases, however experienced LCA practitioners should find key data and assumptions in the current study.

### *Uncertainty of the information*

Uncertainty of the results were considered through two different aspects:

- As regards the primary data, a precision assessment was carried out while collecting data from the plants. Uncertainty is very low for the bill of material composition, energy and water consumptions. Uncertainty is medium to high regarding emissions (such as carbon dioxide, nitrogen oxide, sulphur oxide, VOC and dust).
- As regards the background databases, uncertainty is considered as low except for elementary flows contributing to Toxicity (human and ecotoxicity) and Resources depletion for which the uncertainty is considered as high.

## *II.2.7. Allocations*

### *II.2.7.1. Recycling allocation and End-of-Life modelling*

The End-of-Life modelling was calculated according to the following formula. This formula is compliant with the ISO standard for open-loop and closed-loop formula[8].

$$E = E_V + A \times R_1 \times (E_r - E_D - E_V) + E_D + (1 - A) \times R_2 \times (E_r - E_D - E_V)$$

*Equation 1: End-of-Life formula*

With this formula, the allocation of environmental credits due to the recycling is shared between the supplier of the recyclable material and the incorporator of the recycled material (into the next life cycle). The parameters of the formula are explained as follows:

**A:** allocation factor of burdens and credits between supplier and user of recycled materials.

**$R_1$:** proportion of material, that has been recycled from a previous system, incorporated as input to the production of the new product.

**$R_2$:** proportion of the material in the product that will be recycled (or reused) in a subsequent system. $R_2$ shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. $R_2$ shall be measured at the output of the recycling plant.

**$E_V$:** specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.

**$E_R$:** specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.

[8] *Application of the ILCD handbook: "International Reference Life Cycle Data System – General guide for Life Cycle Assessment – Detailed guidance. 2010. Recycling in consequential modelling."*

**$E_D$:** specific emissions and resources consumed (per functional unit) arising from disposal (i.e. landfill and incineration) of waste material at the End-of-Life.

Values for allocation factors and proportion of materials for each destination ($R_1$ and $R_2$) for secondary and tertiary packaging materials (e.g. interlayer cardboard, LDPE film, pallet) were taken from the Annex C of the PEF methodology[9, 10].

### *II.2.7.2. Recycling allocations and End-of-Life modelling of the post-consumer metal packaging*

*1. Base case: closed-loop scenario*

As base case, the End-of-Life of post-consumer metal packaging is modelled considering a closed-loop system, which means that metal packaging is recycled in the same production system as its previous use without any changes to its inherent properties (e.g. aluminium sheet for beverage application). Recycled material displaces virgin material, hence there is no need to define the allocation.

According to the closed-loop formula, the value for $R_1$ and $R_2$ are equal and there is no need to define the allocation factor A. The Equation 1 becomes (with $R_1 = R_2 = R$):

$$\boldsymbol{E} = (\boldsymbol{1} - \boldsymbol{R}) \times \boldsymbol{E_V} + \boldsymbol{R} \times \boldsymbol{E_R} + (\boldsymbol{1} - \boldsymbol{R}) \times \boldsymbol{E_D}$$

*Equation 2: closed-loop formula*

In the base case, R is equal to:

- 76.1% for aluminium according to the latest recycling rate published by European Aluminium in 2018[11]
- 82.5% for steel according to the latest recycling rate published by APEAL in 2018[12]

These recycling rates were the most up to date value for metal packaging recycling in Europe at the time the study was started.

Sensitivity analysis is performed with different recycling rate (from 40% to 95%). The parameters for the base case and the sensitivity analysis are indicated in Table 5.

[9] *http://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm*

[10] In closed-loop scenario, the end-of-life formula (equation 2) corresponds to the Circular Footprint Formula (CFF) as defined in the PEF methodology if the following parameters are considered in CFF: the allocation factor of burdens and credits between supplier and user of recycled materials (A) is equal to 1 and the proportion of the material in the product that is used for energy recovery at EoL (R3) is equal to 0.

[11] European Aluminium, Metal Packaging Europe, https://metalpackagingeurope.org/article/aluminium-beverage-can-recycling-europe-hits-record-761-2018

[12] APEAL, https://www.apeal.org/news/steel-packaging-hits-a-new-recycling-milestone-of-82-5/

Modelling of primary aluminium production / recycled aluminium production

For this study, the dataset used for primary aluminium production is the 'Aluminium primary ingot used in Europe' provided by European Aluminium (used both for the base case and sensitivity analysis).

The "used in Europe" primary LCI dataset (A) corresponds to the production of 1 tonne of ingot from primary aluminium, i.e. from bauxite mining up to the sawn aluminium ingot ready for delivery. This dataset includes all the environmental aspects of the various process steps and raw materials used to deliver 1 tonne of sawn primary ingot. It includes the aluminium which is produced by the European smelters and the aluminium which is imported into Europe and which represent 49% of the primary aluminium used in Europe in 2015.

For this study, the dataset used for recycled aluminium production is the 'Aluminium remelting' provided by European Aluminium (used both for the base case and sensitivity analysis) which is described in the next paragraph.

Modelling of primary steel production / recycled steel production

For this study, the dataset used for primary steel production is the 'Steel tinplate without EoL recycling - 1 kg (typical thickness between 0.13 - 0.49 mm) at plant' provided by APEAL (2015) (used both for the base case and sensitivity analysis).

For this study, the dataset used for recycled steel production is the 'Recycling Steel, 2012' provided by APEAL.

2. *Sensitivity analysis: open-loop scenario*

In some countries and for some markets, used metal packaging are recycled into other applications (e.g. aluminium sheet for non-beverage application). Therefore, in this sensitivity analysis, it is modelled that used metal packaging are recycled in the same production system but with changes to its inherent properties (condition for open-loop allocation according to the ISO standard 14040/44).

As sensitivity analysis, the End-of-Life of post-consumer metal packaging is modelled considering an open-loop system. For this system, the Equation 3 is used.

$$E = E_V + A \times R_1 \times (E_r - E_D - E_V) + E_D + (1 - A) \times R_2 \times (E_r - E_D - E_V)$$

*Equation 3: Open loop formula*

Two types of sensitivity analyses are performed for each material:

- For aluminium:
  a. A sensitivity analysis with different allocation factors (A varying from 0 to 100%; $R_2$ = 76.1% and $R_1$ = 40%). According to European Aluminium, this value of $R_1$ = 40% corresponds to the average recycled content for

aluminium products and is not specific to packaging (including imports from outside Europe)[13].

b. A sensitivity analysis with different recycling rates ($R_1$ = 40%, 50%, 60% and 80%; $R_2$ = 76.1%; A varying from 0 to 100%)
Note: as in the previous sensitivity analysis, the results are presented by varying the allocation factor A between 0 and 100% to illustrate the influence of this methodological choice.

- For steel:
  a. A sensitivity analysis with different allocation factors (A varying from 0 to 100%; $R_2$ = 82.5% and $R_1$ = 58%). According to APEAL, this value of $R_1$ = 58% corresponds to the average recycled content for steel products and is not specific to packaging[14].
  b. A sensitivity analysis with different recycling rates ($R_1$ = 10%, 15%, 20%, 40% and 58%; $R_2$ = 82.5%; A varying from 0 to 100%)
  Note: as in the previous sensitivity analysis, the results are presented by varying the allocation factor A between 0 and 100% to illustrate the influence of this methodological choice.

Modelling of recycled aluminium production

For this study, the European Aluminium recycling dataset for "remelting" aluminium has been used[15] for $E_R$.

According to European Aluminium[16]: *"the 'remelting' process LCI dataset correspond to the transformation of the aluminium (pre or post-consumer) scrap into a wrought alloy ingot (i.e. aluminium alloys used for e.g. sheet or extrusion where the final product shape is generated by mechanically forming the solid metal) ready for delivery to the user. It also includes the recycling of dross and skimmings. This dataset should be used for the recycling of process scrap as well as for the recycling of some specific end-of-life products using well controlled collection schemes like big aluminium pieces in building or aluminium beverage*

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[13] European Aluminium, https://www.european-aluminium.eu/media/1644/recycled-content-vs-end-of-life-recycling-rate-may-2016.pdf

[14] APEAL, data 2017, https://www.apeal.org/wp-content/uploads/2020/05/The-recycled-Content-of-Steel-for-Packaging.pdf

[15] *Another scenario of open-loop occurs when aluminium is recycled in a different production system compared to its previous use and with changes to its inherent properties (e.g. aluminium casting); in this case, the European Aluminium recycling dataset for "refining" aluminium should be used, however this scenario has been excluded from the current report for simplicity and could be covered in the next update of the study.*

*According to European Aluminium: "The 'refining' process LCI dataset correspond to the transformation of the aluminium (pre or post-consumer) scrap into a casting alloy ingot (i.e. aluminium alloys used for the production of castings where the final product shape is generated by pouring molten metal into a mould) ready for delivery to the user. This dataset includes the melting, purifying and casting operations. It also includes the salt slag processing. The refining data related to the year 2015 are still under preparation, the previous one refers to year 2010".*

[16] *European Aluminium, Environmental Profile Report: Life-cycle inventory data for aluminium production and transformation processes in Europe, 2017*

*cans collected through specific collection networks. The 'remelting' data are based on the year 2015"*.

<u>Modelling of recycled steel production</u>

For this study, the dataset used for recycled steel production is the 'Recycling Steel, 2012' provided by APEAL.

### *3. Summary of parameters for the post-consumer metal packaging*

The parameters for these sensitivity analyses are indicated in Table 5 and Table 6.

*Table 5 - End-of-Life parameters for post-consumer aluminium packaging*

| Post-consumer aluminium packaging | | | |
|---|---|---|---|
| **Scenarios** | **$R_1$** | **$R_2$** | **A** |
| Base case: closed-loop | *Equal to $R_2$* | *76.1%* | - |
| Sensitivity analysis 1: closed-loop | *Equal to $R_2$* | *40-95%* | - |
| Sensitivity analysis 2: open-loop - Variation of allocation factor (A) | *40%* | *76.1%* | *0-100%* |
| Sensitivity analysis 3: open-loop - Variation of recycled content ($R_1$) | *40%, 50% 60%, 80%* | *76.1%* | *0-100%* |

*Table 6 - End-of-Life parameters for post-consumer steel packaging*

| Post-consumer steel packaging | | | |
|---|---|---|---|
| **Scenarios** | **$R_1$** | **$R_2$** | **A** |
| Base case: closed-loop | *Equal to $R_2$* | *82.5%* | - |
| Sensitivity analysis 1: closed-loop | *Equal to $R_2$* | *40-95%* | - |
| Sensitivity analysis 2: open-loop - Variation of allocation factor (A) | *58%* | *82.5%* | *0-100%* |
| Sensitivity analysis 3: open-loop - Variation of recycled content ($R_1$) | *10%, 15%, 20%, 40%, 58%* | *82.5%* | *0-100%* |

As explained above, the European Aluminium recycling dataset for "remelting" aluminium and the APEAL dataset for recycling steel have been used for the closed-loop scenario as well as for the open-loop scenario.

The reader should understand that the above described open-loop and closed-loop scenarios of metal recycling and production follow the ISO methodology for LCA modelling; despite these open-loop and closed-loop scenarios may represent specific real cases, a mix of the two scenarios is what occurs usually in reality. As no statistics are available to model a realistic share of the two scenarios, the sensitivity analysis described at paragraph V.3.3 enables the reader to derive the environmental performance of the metal packaging based on a chosen mix of the two scenarios.

### *II.2.7.3. Recycling allocations and End-of-Life modelling of the pre-consumer material scrap*

The End-of-Life of pre-consumer material scrap is modelled considering a closed-loop system. This is valid for every scenario.

The totality of the pre-consumer material scrap is recycled (hence, R=100%).

With this value of R, the Equation 2 for the pre-consumer material, can be written as:

$$\boldsymbol{E} = \boldsymbol{E}_R$$

*Equation 4: closed-loop formula with R = 100%*

For the closed-loop scenario, the European Aluminium recycling dataset for “remelting” aluminium and the APEAL dataset for recycling steel have been used.

**Warning:** the future users of the results of the study must be aware that the recycling credits are already included in the LCI, hence they should *not* be accounted additionally.

### *II.2.7.4. Background dataset*

The background datasets used in the study come from the database ecoinvent v3.5 – “Allocation, cut-off by classification”, and RDC models based on COPERT 5 (for transport by truck).

No change was made to the allocation rules used by ecoinvent.

## *II.2.8. Selection of life cycle impact assessment methods*

The choice of the life cycle impact assessment (LCIA) methods aims at giving an overall view of environmental impacts of metal packaging production in Europe.

Total results are presented for 16 impact categories. The impact categories come from the category set referred as ‘ILCD 2017’, recommended by the EF (Environmental Footprint methodology by the European Commission) in 2017[17].

The list of the impact categories is indicated in Table 7.

[17] JRC, Suggestions for updating the Product Environmental Footprint (PEF) method, 2019

*Table 7 - LCIA methods applied in the study*

| Impact categories | Units | Indicator | Impact assessment model | Source of CFs | Robustness |
|---|---|---|---|---|---|
| Climate change | *kg CO2 eq.* | Radiative forcing as Global Warming Potential (GWP100) | Baseline model of 100 years of the IPCC (based on IPCC 2013) | EC-JRC, 2017 | I |
| Ozone depletion | *kg CFC-11 eq.* | Ozone Depletion Potential (ODP) | Steady-state ODPs as in (WMO 1999) | EC-JRC, 2017 | I |
| Human toxicity, cancer | *CTUh* | Comparative Toxic Unit for humans (CTUh) | USEtox model (Rosenbaum et al, 2008) | EC-JRC, 2017 | III/interim |
| Human toxicity, non-cancer | *CTUh* | Comparative Toxic Unit for humans (CTUh) | USEtox model (Rosenbaum et al, 2008) | EC-JRC, 2017 | III/interim |
| Ecotoxicity for aquatic freshwater | *CTUe* | Comparative Toxic Unit for ecosystems (CTUe) | USEtox model, (Rosenbaum et al, 2008) | EC-JRC, 2017 | III/interim |
| Particulate matter | *disease incidence* | Impact on human health | PM method recomended by UNEP (UNEP 2016) | EC-JRC, 2017 | I |
| Ionising radiation, human health | *kBq* $U^{235}$ *eq* | Human exposure efficiency relative to U235 | Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000) | EC-JRC, 2017 | II |
| Photochemical ozone formation | *kg NMVOC eq* | Tropospheric ozone concentration increase | LOTOS-EUROS model (Van Zelm et al, 2008) as implemented in ReCiPe 2008 | EC-JRC, 2017 | II |
| Acidification | *mol H+ eq.* | Accumulated Exceedance (AE) | Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008) | EC-JRC, 2017 | II |
| Terrestrial eutrophication | *mol N eq.* | Accumulated Exceedance (AE) | Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008) | EC-JRC, 2017 | II |
| Freshwater eutrophication | *kg P eq.* | Fraction of nutrients reaching freshwater end compartment (P) | EUTREND model (Struijs et al, 2009) as implemented in ReCiPe | EC-JRC, 2017 | II |
| Marine eutrophication | *kg N eq.* | Fraction of nutrients reaching marine end compartment (N) | EUTREND model (Struijs et al, 2009) as implemented in ReCiPe | EC-JRC, 2017 | II |
| Land use | Dimensionless (pt) | • Soil quality index • Biotic production • Erosion resistance<br>• Mechanical filtration<br>• Groundwater replenishment | Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016) | EC-JRC, 2017 | III |
| Resource depletion water | *m³ of water-eq* | User deprivation potential (deprivation-weighted water consumption) | Available WAter REmaining (AWARE) as recommended by UNEP, 2016 | EC-JRC, 2017 | III |

| Impact categories | Units | Indicator | Impact assessment model | Source of CFs | **Robustness** |
|---|---|---|---|---|---|
| Resource use, minerals and metals | *kg Sb eq.* | Abiotic resource depletion (ADP ultimate reserves) | CML 2002 (Guinée et al., 2002) and van Oers et al. 2002. | EC-JRC, 2017 | III |
| Resource use, fossils | MJ | Abiotic resource depletion – fossil fuels (ADP-fossil) | CML 2002 (Guinée et al., 2002) and van Oers et al. 2002 | EC-JRC, 2017 | III |

The robustness classification determined by the EU Joint Research Center (JRC) is as follows:

| | |
|---|---|
| **I** | Recommended and satisfactory |
| **II** | Recommended but in need of some improvements |
| **III** | Recommended, but to be applied with caution |
| **Interim** | In development |

**Warning:** the future user of the LCI must be aware of the use of ILCD 2017 (PEF method) in this report.

The LCIA methods have been updated since the previous studies: RDC study published in 2016[18] and RDC study published in 2019[19]. The LCIA methods have an influence on the results obtained.

These include:

- the resource depletion is separated into two indicators in ILCD 2017 method: depletion of fossil resources (expressed in MJ) and depletion of minerals and metals (expressed in Sb eq);
- the reference model for resource depletion of minerals and metals has changed from reserve base to ultimate reserves, leading to a change in the characterisation factors[20];
- the methodology for assessing the water depletion indicator has changed between the previous study published in 2016 (Swiss Ecoscarcity model 2008) and this study (ILCD 2017, AWARE method) (no change between the study published in 2019 and this study).

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[18] Study "Life Cycle Assessment of metal packaging in Europe" realised for EMPAC by RDC environment covers the production year 2013 (packaging studied: steel food can (425 ml), steel aerosol (520 ml), steel general line (2500 ml), steel closure and steel speciality)

[19] Study "Life Cycle Assessment of Aluminium Beverage Cans in Europe" realised for MPE by RDC environment covers the production year 2016 (packaging studied: aluminium beverage can 250 ml, can 330 ml and can 500 ml)

[20] JRC, Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment method, 2018

The details results by life cycle stages are only presented for 7 impact categories identified as the most relevant categories for the metal packaging sector (cf. section V):

- Climate change;
- Resource use, fossils;
- Resource use, minerals and metals;
- Particulate matter;
- Acidification;
- Photochemical ozone formation;
- Water depletion.

*Table 8 - Description of the impact categories*

| Impact categories | Unit | Definition |
|---|---|---|
| Climate change | kg $CO_2$ eq | The greenhouse effect is a natural global warming process involved in the earth's radiation balance. It is caused by the emission of greenhouse gases (GHGs) into the atmosphere, notably carbon dioxide ($CO_2$) and methane ($CH_4$). This natural phenomenon is becoming a problem due to the increase in greenhouse gases from human activities. |
| Resource use, fossils | MJ | This category assesses the depletion of non-renewable natural resources associated with the systems studied. These resources relate to fossil fuels only. Consumption is assessed on the basis of available reserves on earth and current rates of depletion. |
| Resource use, minerals and metals | kg Sb eq. | This category assesses the depletion of non-renewable natural resources associated with the systems studied. These resources relate to minerals and metals only. Consumption is assessed on the basis of available reserves on earth and current rates of depletion. |
| Particulate matter | disease incidence | This category corresponds to the change in mortality due to particulate matter emissions. Particles can either be released directly into the air (e.g. emissions from road transport) or they can result from a chemical reaction (particles are formed as a result of chemical reactions in the air from other pollutants). |
| Acidification | mol H+ eq | Acidification is caused by the emission of acidifying substances into the air (mainly $NH_3$, $NO_x$ and $SO_2$ from combustion). They cause the phenomenon of "acid rain" which occurs hundreds or even thousands of kilometres away from the place of their emission. |
| Photochemical ozone formation | kg NMVOC eq | This impact category accounts for the formation of ozone at the ground level of the troposphere. This is caused by photochemical oxidation of Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight. High concentrations of ozone at the ground level of the troposphere damage vegetation, human respiratory tracts and manmade materials through reaction with organic materials. |
| Water use | $m^3$ | This category assesses the amount of freshwater consumed. Consumption is defined as the difference between water withdrawn from ground water or surface water bodies (lakes, rivers…) and water release. Water scarcity is assessed by country. |

### *II.2.9. Critical review*

As the study is intended to be used for communication purpose to third party and the LCIs could be used in other studies (including comparative assertion), the critical review was performed by the LCA expert: Delphine Bauchot, Director at Solinnen.

The critical review process ensured that:

- The methods used to carry out the LCA are consistent with this International Standard ISO 14040/44:2006.
- The methods used to carry out the LCA are scientifically and technically valid.
- The data used are appropriate and reasonable in relation to the goal of the study.
- The interpretations reflect the limitations identified and the goal of the study.
- The study report is transparent and consistent.

The conclusions of the critical review are listed hereunder:

***<u>Conclusions of the review:</u>***

*The CR first set of 95 comments covered the following points:*

*– Deviation (9 comments),*

*– Recommendation (69 comments),*

*– Editorial comments and other miscellaneous comments (17 comments).*

*Out of these comments, 40 covered methodological issues, 19 about Data and technical issues, 14 about Analysis and Interpretation, 22 covered other and miscellaneous issues.*

*An exhaustive work has been done by RDC Environment and Romeo Pavanello from Metal Packaging Europe to provide a final report integrating answers to all the CR points, and the final result has improved as compared to the first one.*

*As a whole, the expert considers that the final report answers to the goals which have been set up, within the scope of the limitations that are mentioned in the report.*

The critical review report is available in Annex as for further detailed references of the peer reviewer.

# III. Limitations of the study

## III.1. General LCA methodology limitations

As preliminary warning, general limitations of LCIA (Life Cycle Impact Assessment) are reminded according to ISO 14040:2016 (chapter 5.4.3):

- The LCIA addresses only the environmental issues that are specified in the goal and scope. Therefore, LCIA is not a complete assessment of all environmental issues of the product system under study.
- LCIA cannot always demonstrate significant differences between impact categories and the related indicator results of alternative product systems. This may be due to:
  - Limited development of the characterization models, sensitivity analysis and uncertainty analysis for the LCIA phase,
  - Limitations of the LCI phase, such as setting the system boundary, that do not encompass all possible unit processes for a product system or do not include all inputs and outputs of every unit process, since there are cut-offs and data gaps,
  - Limitations of the LCI phase, such as inadequate LCI data quality which may, for instance, be caused by uncertainties or differences in allocation and aggregation procedures, and
  - Limitations in the collection of inventory data appropriate and representative for each impact category.
- The lack of spatial and temporal dimensions in the LCI results introduces uncertainty in the LCIA results. The uncertainty varies with the spatial and temporal characteristics of each impact category.
- There are no generally accepted methodologies for consistently and accurately associating inventory data with specific potential environmental impacts. Models for impact categories are in different phases of development.

Uncertainty about the toxicity impact method: the level of uncertainty of the toxicity indicators are very high, especially for metals, due to the elementary flows (inventory) and the characterisation factors (USEtox methodology). Toxicity indicators should be used with caution. See paragraph II.2.6 and Table 13 for more details.

## III.2. Specific limitations from this study

In this study the main limitations are related to the quality of the background datasets and the approach to average the information collected from the involved members. The list of limitations is detailed below.

- **Limitation due to potential methodological inconsistencies between background databases:** most of the background datasets used in the study come from ecoinvent v3.5 – "Allocation, cut-off by classification". The use of different background databases can lead to inconsistencies due to different methodological rules applied in the databases.
  As a rough estimation, the influence of this limitation on the results is assumed, based on expert judgement, to be lower than 10%.

- **Limitation due to the approach to average the information collected from the different members**: when modelling the average production occurring at different sites, two approaches can be used:
  - *Horizontal averaging*, which consists in weighting each collected primary data (e.g., amount of primary steel, amount of natural gas, etc.) according to the sales volume of the plant, and then averaging them in order to produce a virtual plant. The LCIs and LCIA are then calculated based on the virtual average plant.
    - ⇨ This approach was used in the study because it is the best compromise between quality of the results and time and resource availability.
    - ⇨ It is a less accurate approach than the vertical averaging (for instance, in case of regionalized methods, there could be a loss of accuracy in locating the emissions).
  - *Vertical averaging*, which consists in calculating each LCI per plant based on its specific data and then averaging the LCIs based on the sales volume per plant.
    - ⇨ This approach gives more precise results, but it is time and resources consuming as 116 plants have to be modelled separately. Hence, this approach was not used for this study.

  In both cases, the weighting applied is the quantity of each packaging produced by each responding plant.

  It is assumed, based on expert judgement, that the influence of this limitation on the results has an order of magnitude of one percent (1%).

- **Limitation due to filling missing data:** when empty cells were found in the filled questionnaires, they were assumed to be a "no data entry" (instead of a "zero value") and the average value was calculated excluding the empty cells. This approach can maximize the bill of materials and the energy consumption and therefore can overestimate the overall environmental impacts. Hence, the results of the study can be considered as conservative.

It is assumed, based on expert judgement, that the influence of this limitation on the results has an order of magnitude of one percent (1%).

An exception is made to fill in the data gap related to transport modes (cf. chapter IV.1.5 Filling data gaps, page 41).

- **Limitation due to simplified modeling for some minor raw materials:** Coatings, inks and sealing are modelled considering average compositions of solvent, solid substances and water. The composition of inks, sealing and the solvent part of packaging other than aluminium beverage can is derived from a previous study carried out by RDC Environment and does not represent the average composition used by MPE members. This proxy is used as these raw materials are not available in the used background database.

  It is assumed, based on expert judgement, that the influence of this limitation on the results has an order of magnitude of one percent (1%).

- **Limitations due to the use of average recycling rate:** only the recycling rate of aluminium beverage cans and steel packaging (as a whole) in Europe is known and are provided respectively by European Aluminium (for year 2018) and APEAL (for year 2018). This information is used as proxy for the packaging categories represented in the study. It is assumed, based on expert judgement, that the influence of this limitation on the results has an order of magnitude of one percent (1%).

- **Limitations due to the geographical scope:** the study refers to the average European production, including Switzerland and Turkey. However, differences between countries exist regarding recycling rates, emissions norms (emission norms for truck, for electricity production, for can production), electricity mix and the surrounding environment. The average value is thus not reflecting any individual country and the reader should keep in mind that the LCA of the metal packaging in a specific country/plant might lead to different results compared with this study. This limitation is also due to the fact that data collected from the plants were anonymized due to confidential reasons.

  Besides, an estimation of the metal packaging recycled content (as provided by European Aluminium and APEAL) is used as European average. The specific recycled content was not asked in the questionnaire sent to the members participating to the study.

- **Limitations due to non-regionalized water consumption:** except for the aluminium LCI, the other water flows used in the LCA model of this study are not regionalized.

- **Limitations due to the use of APEAL dataset for steel modelling:** APEAL datasets are based on primary data from 2015 (for steel production) and 2012 (for steel recycling). These datasets are not the most up-to-date datasets regarding the produced steel in Europe. These data are used to allow comparison of results with previous studies.

**Limitations due to the exclusion of the transport of scraps:** the results presented in this report do not take into account the transport of scraps to recycling. The sensitivity analysis carried out on this point (cf. sections 0 and VII.3 Sensitivity analysis: transport of pre-consumer scrap) shows that the contribution of this step is limited. The inclusion of the transport of scraps leads to an increase in impacts for the functional unit of maximum 1.1% for aluminium packaging and 0.8% for steel packaging.

# IV. Inventory analysis

## IV.1. Data collection and quality

This section describes the process followed by RDC Environment to collect the data used in the study. Data concern the gate-to-gate processes (packaging manufacturing and printing) and the upstream transport.

### *IV.1.1. Data sources*

Data were collected for metal packaging manufacturing with:

- 116 responding plants
- 1777 thousand tons of metal packaging

The following measures have been taken to ensure confidentiality of collected data: RDC signed a non-disclosure agreement with the Metal Packaging Europe members involved in the study. Individual company data, collected by RDC on a strict bilateral basis, is accessible only to the team of RDC in charge of the project. In addition, RDC has taken the necessary steps to ensure that the information made available in the study is sufficiently aggregated and does not allow the identification of individual confidential company data.

In addition to the 116 responding plants mentioned previously, 10 plants answered the questionnaire but were excluded from the analysis as their production data could not be validated (only their data on the average weight of packaging was taken into account in the study). The total number of responding plants was thus 126 before the exclusions and 116 after the exclusions.

### *IV.1.2. Questionnaires*

A questionnaire was sent to the 10 members participating to the study. It was developed based on a discussion with Metal Packaging Europe. RDC Environment experience was also used as basis for the questionnaire.

The questionnaire concerns the data related to the manufacturing plant. Thirteen sectorial types of packaging were clearly identified: aluminium food open can, aluminium food end, steel food open can, steel food end, aluminium beverage open can, aluminium beverage end, aluminium aerosol, steel aerosol, steel general line open can, steel general line lid, aluminium closure, steel closure and steel speciality can.

Notes:

- for food cans, beverage cans and general line can, data collection distinguishes between bodies and ends, as the production of the two parts of the packaging is independent (some factories produce only bodies for example);
- the identification process of packaging studied is presented in the section II.2.2 Representative products (page 15 of this report);

- for aluminium aerosol and aluminium closure, it has not been possible to gather data from enough plants and therefore, due to confidentiality reasons, it has been decided to exclude these two packaging from this study.

Three kinds of plants were identified:

- Single sectorial production. Only one type of the sectorial types of packaging is manufactured in the plant (77 plants).
- Multiple sectorial production. Several types of packaging are produced in the plant (36 plants).
- Semi-finished production. The plant produces only semi-finished products (3 plants).

### *IV.1.3. Data validation*

Several checks were made in order to validate the data received from the metal packaging manufacturing plants. When questionable data were identified, an email was sent to the metal packaging manufacturing plant to validate the data. More than 296 correction responses from members helped to ensure that data collection was of high quality. In addition, further discussions were held with members to refine the data (especially for the most relevant parameters and for parameter showing large variations among all members).

Three types of data quality tests were performed as part of the data validation process. These tests are presented in this section along with a list of examples. These lists are non-exhaustive.

#### *Logical tests*

These tests aim to check the consistency of data provided by each member:

- $Total\ waste = \sum(individual\ wastes)$ ?
- $\sum(raw\ materials) > Total\ output$ ?

#### *Comparison tests*

These tests aim to check whether the data of one specific issue (energy, waste, water…) are in a range of acceptable values. When data is out of range, it is important to find the reason (technological reason for example):

- Comparison of energy consumption “GJ/ton” for each plant
- Comparison of water consumption “$m^3$/ton” for each plant

*Value tests*

After validating data per member (logical tests) and data per issue for all members (comparison tests), the average values weighted by volumes were calculated (for the 116 plants) and value tests were performed. These tests aim to check whether average values are in line with the range of values commonly used and the standards:

- Are atmospheric emissions in the ranges observed with other plants from the same company (i.e: the same MPE member) or with plants from other companies (i.e: from the other MPE member)?
- Are water consumption values (in & out) in the ranges observed with other plants from the same company (i.e: the same MPE member) or with plants from other companies (i.e: from the other MPE member)?
- Are emissions in natural environment acceptable regarding European directive?

### *IV.1.4. Data averaging*

A horizontal averaging approach was performed to average data across the manufacturing plants. The horizontal averaging approach consists in weighting each collected primary data (e.g., amount of aluminium or steel, amount of natural gas, etc.) according to the sales volume of the plant, and then averaging them in order to produce a virtual plant. A vertical averaging approach would be more accurate, but it also requires modelling every plant separately and then average them on the basis on their sales volume (see also section III).

### *IV.1.5. Filling data gaps*

In the questionnaires it was clearly stated to answer the questions by differentiating between "no data entry" and "zero value".

When empty cells were found in the filled questionnaires, they were assumed to be a "no data entry" and the average value was calculated excluding the empty cells.

This approach mainly concerned:

- Secondary and tertiary packaging (e.g. interlayer cardboard, LDPE film, pallet).
- The emissions to the natural environment (air, water).

A different approach was used to fill in the data gap related to transport modes, as there were clear reasons to think that some of the empty cells correspond to zero values:

- In case of a questionnaire partially filled in but presenting also empty cells as regards all transport modes, the empty cells were considered as "zero value".
- In case of a questionnaire completely empty as regards all transport modes, the cells were considered equal to the average of the answers of other questionnaires.

### IV.1.6. Foreground data quality assessment

#### Activities at MPE member plants

The following Table 9 shows a qualitative description of the activities occurring at MPE member plants which are responsible for the consumption of energy, heat, water and for the VOC emissions.

Note: regarding the office activity at MPE member plants, the questionnaire stated that, where possible, gas consumption for heating plant/offices (and more generally the inputs and outputs linked with plant infrastructure) should be excluded. Beyond this statement, no additional questions were asked of MPE members regarding the integration or not of infrastructure data. Thus, it is possible that the electricity, water and heat consumptions from offices have been included for some plants whereas excluded for other plants. However, based on our experience, these consumptions are negligible compared to the total consumptions of an industrial plant.

*Table 9 - List of activities*

| Process | Electricity | Heat | Water | VOC emissions to air |
|---|---|---|---|---|
| Coil handling | x | | | |
| Can forming | x | | x | |
| End forming | x | | | |
| Can coating/printing | x | x | | x |
| Can washing/drying | x | x | x | |
| End sealing | x | x | | x* |
| End printing/decoration | x | x | | x |
| Transport / Palettizing | x | | | |
| Testing | x | | | |
| Auxiliaries (HVAC, compressor etc.) | x | x | x | |
| Offices | x | x | x | |
| Warehousing | x | x | | |
| * End sealing usually is a VOC emission free process, however some plants may still use solvent based tab lubes (tab lubes are used to lubricate / protect the little tab on the ends, they can be based on paraffin and solvent) | | | | |

#### Data quality assessment

In the questionnaire, it was required for the compiler to encode an estimation of the quality for each provided data, according to three ranges of data quality (see the next table where "X" represents the uncertainty of the encoded value). RDC associated respectively the values 1, 2 and 3 to the ranges in order to calculate an "average data quality". Data quality is then weighted by the sold volume of metal packaging.

*Table 10 – Data quality in the questionnaire*

| Category | Ranges proposed in the questionnaire to evaluate the data quality | Value associated by RDC | Comments |
|---|---|---|---|
| Cat 1 | X < 5% | 1 | Very low uncertainty |
| Cat 2 | 5%< X < 15% | 2 | Medium uncertainty |
| Cat 3 | X > 15% | 3 | Large uncertainty |

The Figure 3 shows the different levels of uncertainty according to the data quality.

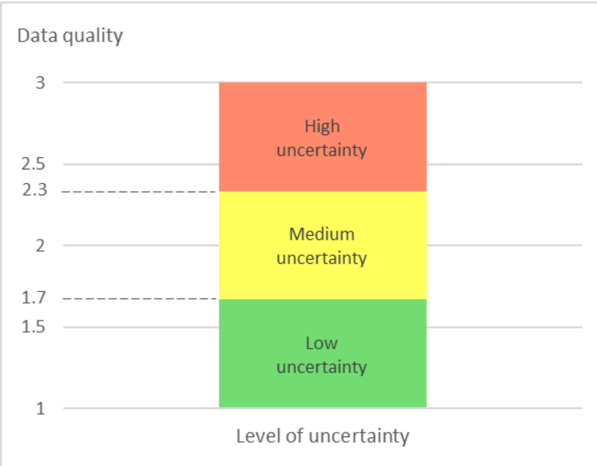


*Figure 3 – Qualitative assessment of the uncertainty*

Quantified estimation of the uncertainty by the manufacturing plant is judged of limited reliability; however, the qualitative estimation is considered as giving a good insight to assess the precision and the representativeness of the data.

Data quality is weighted by the production of metal packaging (volume in tons). In addition, RDC calculated one percentage of response to each main parameter. For a given parameter, this percentage represents the ratio of metal packaging volume accounted for the members which gave a value for this parameter divided by the total volume of metal packaging produced by all members involved in the study.

Table 11 shows an example of data quality and percentage of responses for VOC emissions. On the 116 sets of data, 37 plants did not encode a value for this parameter. The percentage of responses of this parameter is the total production of the 79 plants having filled in the data divided by the total production covered by the data collection. This represents 70% of the volume production covered by this study. The uncertainty of this value is medium (weighted quality = (1*233+2*506+3*40)/(233+506+40) = 1.75). More than half of the responses were given with an uncertainty of between 5 and 15%.

*Table 11 – Data quality example – VOC emissions*

| VOC emissions | No value encoded | Encoded values but no estimation of quality | Estimation of quality | | | Total |
|---|---|---|---|---|---|---|
| | NV | NQ | Cat1 | Cat2 | Cat3 | |
| N plants [#] | 37 | 32 | 17 | 26 | 4 | 116 |
| Production [kt] | 530 | 471 | 233 | 506 | 40 | 1781 |

| | |
|---|---|
| Percentage of responses | 70% |
| Data quality | 1.75 |

The Table 12 shows the percentage of responses and the uncertainty for the main inputs and outputs of the manufacturing plant (ranked by percentage of responses).

*Table 12 – Percentage of responses and uncertainty for the main inputs and outputs of the manufacturing plant*

| Main inputs and outputs of the manufacturing plant | Coverage (percentage of responses) | Uncertainty (data quality) |
|---|---|---|
| Raw materials consumption to produce the metal packaging (aluminium / steel) | Very good coverage (100%) | Low uncertainty (1.12 to 1.16) The amount of scrap metal has a slightly higher uncertainty (1.46). |
| Electricity consumption | Very good coverage (100%) | Low uncertainty (1.08) |
| Heat consumption | Very good coverage (100%) | Low uncertainty (1.15) |
| Water consumption | Very good coverage (98%) | Low uncertainty (1.10) |
| Waste production | Very good coverage (95%) | Low uncertainty (1.03 to 1.57) |
| Heat mix consumption | Very good coverage (94%) | *Producers were not asked to assess data quality in this case.* |
| VOC emissions | Good coverage (70%) | Medium uncertainty (1.75) |
| Secondary and tertiary packaging | Good coverage (from 60% to 80% depending on the packaging) | Low to medium uncertainty (1.23 to 2) |
| Transport of coatings, ink and sealing | Medium coverage (62%, 37% and 17% respectively) | *Producers were not asked to assess data quality in this case.* |
| Transport of steel | Medium coverage (45% for coil, and 17% for sheet) | *Producers were not asked to assess data quality in this case.* |
| Water emissions | Low coverage (13 to 27% for emissions to public water system) | Low uncertainty (1 to 1.47) |
| Atmospheric emissions of $CO_2$, $NO_x$, $SO_x$, $NH_3$ and particles | Low coverage (12 to 27%) | Low uncertainty (1.0 to 1.58) |
| Transport of aluminium | Low coverage (20% for coil, and 4% for sheet) | *Producers were not asked to assess data quality in this case.* |

During data collection, specific effort has been made to collect the most relevant parameters (identified based on previous studies). In addition, special attention was paid to the relevant parameters during the validation of the data (cf. IV.1.3 Data validation, page 40).

### *IV.1.7. Background data quality assessment*

Background datasets used in the study mostly come from ecoinvent v3.5 – "Allocation, cut-off by classification" and RDC models based on COPERT 5. The following table assesses the data quality of the background datasets by considering the influence on results (based on contribution to LCIA results) and the data quality (based on expert judgement).

Note: the list of all datasets used is available in annex (cf. VII.2 Datasets used, page 93).

**Legend**

| **Influence on the results** | | **Data quality** | |
|---|---|---|---|
| + | Low influence | + | Low quality data |
| ++ | Medium influence | ++ | Fair quality data |
| +++ | High influence | +++ | Good quality data |

*Table 13 - Data quality assessment*

| Data | Influence on results | Data quality | Comments |
|---|---|---|---|
| Energy carrier | | | |
| Natural gas supply | ++ | ++ | Datasets from ecoinvent v3.5 – "Allocation, cut-off by classification" with a good geographical and technological representativeness but low time representativeness |
| Propane | + | ++ | |
| Liquefied gas | + | ++ | |
| Heavy fuel oil | + | ++ | |
| Electricity | +++ | ++ | |
| Raw materials production | | | |
| Aluminium | +++ | ++ | Dataset from European Aluminium 2017 with a good time, geographical and technological representativeness. |
| Steel production | +++ | ++ | Datasets from APEAL 2015 (for steel production) and 2012 (for steel recycling) with a good geographical and technological representativeness. Time representativeness is lower, this mainly concerns electricity production that has changed since then. Note: as aggregated datasets are available, the electricity has not been updated. |

| Data | Influence on results | Data quality | Comments |
|---|---|---|---|
| Lacquers, coatings, varnishes | + | ++ | Datasets from ecoinvent v3.5 – "Allocation, cut-off by classification". with a good geographical. Technological representativeness and Time representativeness are lower. |
| Printing inks | + | ++ | |
| Sealing compounds | + | ++ | |
| Transports | | | |
| Truck emissions | + | ++ | Datasets produced by RDC according to Copert V methodology, considering truck classes, pollution norm, real payload, etc.<br>Emission from Diesel production are already considered in ecoinvent v3.5 – "Allocation, cut-off by classification". |
| Train | + | ++ | Datasets from ecoinvent v3.5 – "Allocation, cut-off by classification". with a good geographical, technological and time representativeness. |
| Ship | + | ++ | Datasets from ecoinvent v3.5 – "Allocation, cut-off by classification". with a good geographical, technological and time representativeness. |
| Infrastructure | | | |
| Metal working factory (used as infrastructure for metal packaging plants) | +++ | + | Datasets from ecoinvent v3.5 – "Allocation, cut-off by classification".<br>Process highly influent on a limited number of impact categories: Human toxicity, Ecotoxicity, Abiotic resources depletion, Land use. The quality of these impact categories is seen as limited, leading to a high uncertainty for these indicators. |
| Waste and wastewater treatment | | | |
| Hazardous and non-hazardous waste disposal | + | + | Generic process for waste treatment from ecoinvent v3.5 – "Allocation, cut-off by classification". |

## IV.2. Life cycle model description

### *IV.2.1. Categories*

Ten categories are used to present the data (some packaging result of the combination of one body and one end, as described below):

- Aluminium beverage can 250 ml: consisting of one 250ml body and one 250ml end
- Aluminium beverage can 330 ml: consisting of one 330ml body and one "330-500ml" end
- Aluminium beverage can 500 ml: consisting of one 500ml body and one "330-500ml" end
- Aluminium food can 125 ml: consisting of one body and one end
- Steel food can 425 ml: consisting of one body and one end
- Steel aerosol 420 ml
- Steel aerosol 520 ml

- Steel general line 2500 ml: consisting of one body and one lid
- Steel closure
- Steel speciality

Note: the same end may be used for 330 ml cans or for 500 ml cans. Therefore, these ends are named in this report as “330-500 ml” ends.

### *IV.2.2. Packaging production*

Production of packaging is expressed in 1000 tonnes (kt). The next figures give the total production by sectorial types covered in the study.

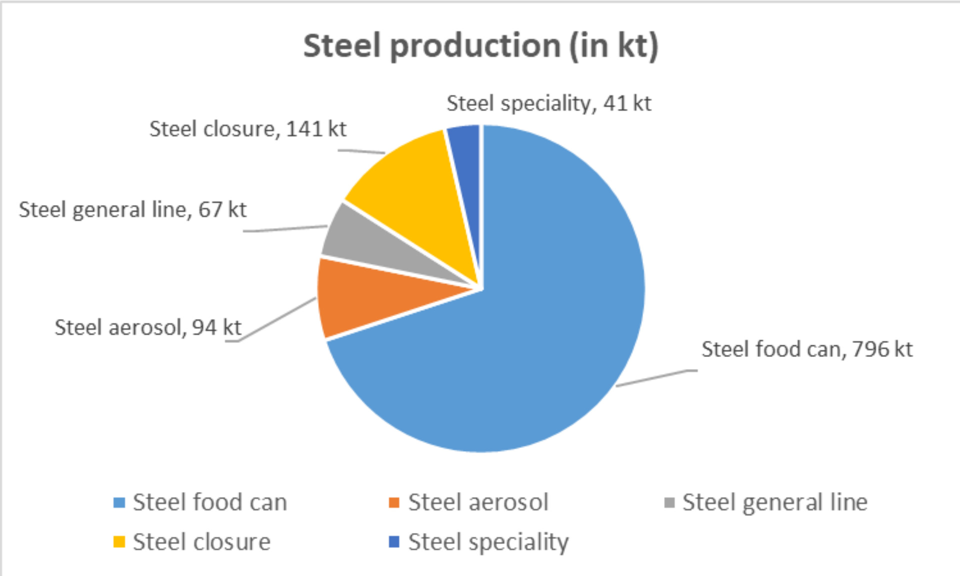


*Figure 4 - Steel production (in kt) (total steel packaging: 1139 kt) - Source: member data*

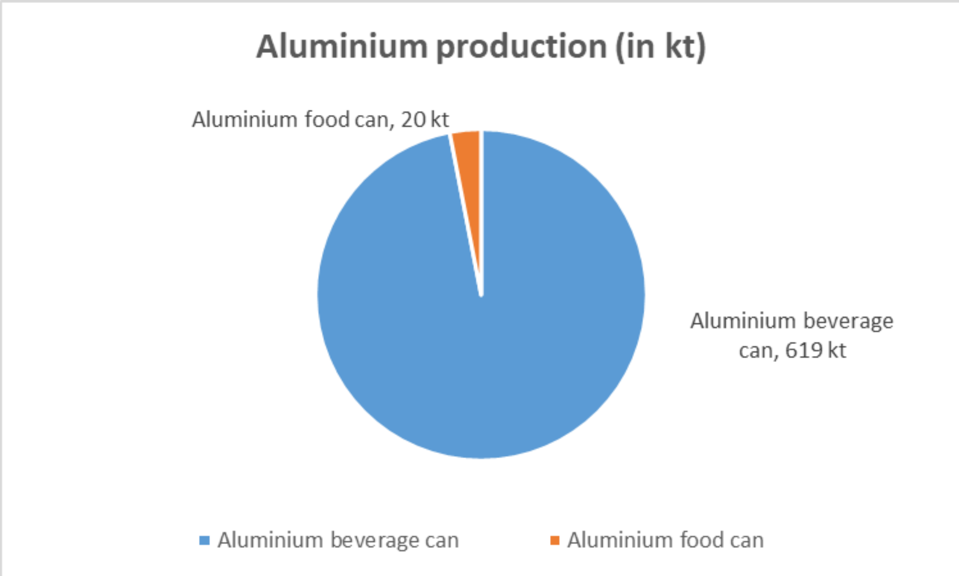


*Figure 5 - Aluminium production (in kt) (total aluminium production: 638 kt) - Source: member data*

### *IV.2.3. Raw materials for primary packaging*

#### *Data collected*

The weight of the average final products (body and end) has been calculated from member's data (Table 14 and Table 15).

*Table 14 - Weight of average final products for aluminium packaging - Source: member data (2018)*

| Weight of products (g) | Aluminium beverage can 250 ml | Aluminium beverage can 330 ml | Aluminium beverage can 500 ml | Aluminium food can 125 ml |
|---|---|---|---|---|
| Body | 7.8 | 9.5 | 12.2 | 8.5 |
| End | 2.5 | 2.6 | 2.6 | 6.4 |
| **TOTAL** | **10.2** | **12.1** | **14.8** | **14.9** |

*Table 15 - Weight of average final products for steel packaging - Source: member data (2018)*

| Weight of products (g) | Steel food can 425 ml | Steel aerosol can 420 ml | Steel aerosol can 520 ml | Steel general line 2500 ml | Steel closure | Steel speciality |
|---|---|---|---|---|---|---|
| Body | 38.6 | 71.2 | 80.5 | 258.8 | | 164.2 |
| End | 11.0 | | | 56.2 | 7.7 | |
| **TOTAL** | **49.6** | **71.2** | **80.5** | **315.0** | **7.7** | **164.2** |

Consumption of raw materials was calculated in kg per 1,000 produced units according to members' data (**Error! Reference source not found.** and **Error! Reference source not fo**

**und.**). The average data are weighted by the production volume of the manufacturing plants.

Metal scrap (i.e. metal sheet skeletons remaining after can manufacturing and any manufactured can non-compliant with quality standard) is calculated as the ratio between the total consumption of metal sheets minus the total can production, divided by the total consumption of metal sheets:

$$Metal_{scrap} = \frac{Total_{Consumed} - Total_{Produced}}{Total_{Consumed}}$$

*Equation 5: calculation of metal scrap*

Metal scrap depends on the efficiency of the packaging manufacturing process which varies according to the packaging product.

Concerning the consumption of other raw materials (i.e. internal and external coating, printing inks, sealing compounds), respect to the previous LCAs, MPE has collected the following information from its members:

- Average "dry film" weight, i.e. the final amount of coating, ink and sealing remaining on the packaging based on technical information. Information is available for external coating, internal coating, ink and sealing compounds.
- Average coating compositions: the composition of internal and external coatings is available for the following packaging: aluminium food can, steel food can, steel aerosol, steel general line, steel closure and steel speciality. An average composition (for both internal and external coating) is available for aluminium beverage cans.

The use of specific data for the quantities of coatings, inks and sealings, and the coating compositions is an improvement compared to previous LCAs.

This information has been used to calculate the quantities of raw materials consumed (wet weight, with solvent).

Note: the study takes into account that metal scrap of food cans production is mainly coated. Thus, for food cans, the coating quantities were calculated taking into account the metal scraps.

### *IV.2.4. Secondary and tertiary packaging*

#### *Data collected*

Consumption of secondary and tertiary packaging was calculated for bodies and ends. Six materials were included in the questionnaire to encode the data, see table below.

Note: the Figure 6 [21] illustrates the three types of packaging: primary, secondary and tertiary packaging.

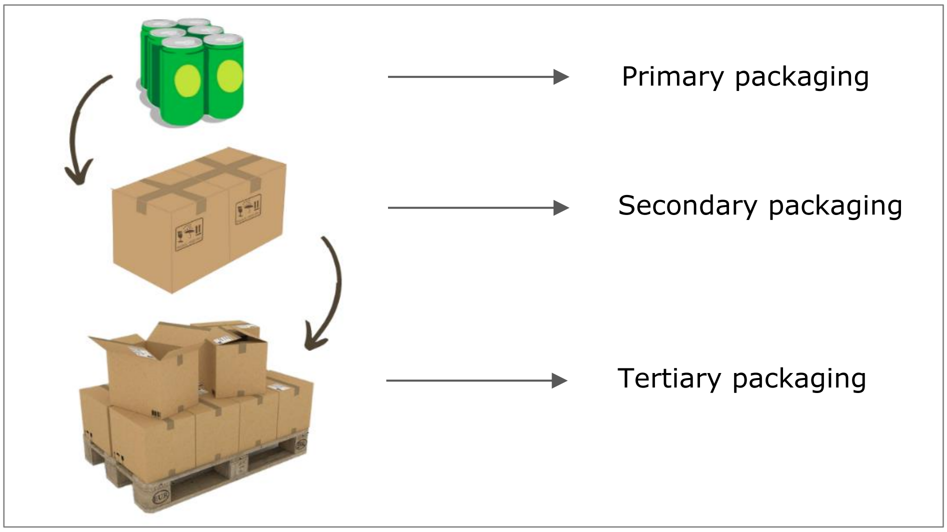


*Figure 6 – Illustration of primary, secondary and tertiary packaging*

Based on expert judgement, it is assumed that interlayer cardboard and alveolar polypropylene (PPA) consumptions are similar no matter the type of packaging (aluminium or steel). All the information was treated as a single set associated to the global metal packaging manufacturing (steel and aluminium).

In addition, metal top frame is considered in the model only for aluminium beverage cans.

The data encoded for the wooden pallet and HDPE pallet was not used due to lack of robust data. Assumptions were made to evaluate the number of pallets required for the transport to the filler. Those take into account the volume of standard units and the maximal volume available in trucks during the transport. The data calculated for the pallet was split between wooden pallet (41%) and HDPE pallet (59%) (distribution calculated from member data). It is considered that the HDPE pallets are reused 60 times before disposal whereas the wooden pallets are reused 15 times (RDC assumptions validated by MPE members).

The consumption of LDPE film is calculated according to the number of pallets. (assumption: 400 g of LDPE film / pallet[22]).

[21] Source for picture: https://www.zambellipackaging.com/

[22] Valipac, Panorama des poids de référence des emballages industriels, 2019

*Table 16 - Secondary and tertiary packaging for aluminium packaging products – Source: member data (2018) and calculations for LDPE film and pallets*

| Materials for 2ary and 3ary packaging (g/1000 units) | Aluminium beverage can 250 ml | Aluminium beverage can 330 ml | Aluminium beverage can 500 ml | Aluminium food can 125 ml |
|---|---|---|---|---|
| Interlayer cardboard | 247 | 292 | 357 | 359 |
| Alveolar polypropylene (PPA) | 0 | 0 | 0 | 0 |
| Metal top frame (steel) | 461 | 568 | 727 | 0 |
| LDPE film | 85 | 108 | 167 | 53 |
| Wood pallet (reused 15 times on average) | 118 | 150 | 230 | 73 |
| HDPE pallet (reused 60 times on average) | 43 | 54 | 83 | 26 |

*Table 17 - Secondary and tertiary packaging for steel packaging products – Source: member data (2018) and calculations for LDPE film and pallets*

| Materials for 2ary and 3ary packaging (g/1000 units) | Steel food can 425 ml | Steel aerosol can 420 ml | Steel aerosol can 520 ml | Steel general line 2500 ml | Steel closure | Steel speciality |
|---|---|---|---|---|---|---|
| Interlayer cardboard | 1195 | 1716 | 1940 | 7593 | 185 | 3959 |
| Alveolar polypropylene (PPA) | 0 | 1 | 1 | 2 | 0 | 1 |
| Metal top frame (steel) | 0 | 0 | 0 | 0 | 0 | 0 |
| LDPE film | 129 | 125 | 147 | 839 | 4 | 228 |
| Wood pallet (reused 15 times on average) | 179 | 173 | 203 | 1160 | 6 | 315 |
| HDPE pallet (reused 60 times on average) | 65 | 63 | 73 | 419 | 2 | 114 |

### *IV.2.5. Energy data*

Consumption data were calculated from members' data for both consumption of electricity and consumption of heat. It was assumed that **heat and electricity consumptions are proportional to the weight of the packaging**, therefore heat and electricity consumptions were allocated based on the mass of the packaging. This approach is aligned with the previous LCA studies on metal packaging commissioned by MPE (i.e. study on food and non-food applications, study on beverage cans).

#### *Consumption of electricity*

The consumption of electricity is entirely based on members' data. The total annual consumption of electricity of all the participating members is expressed in kWh per 1,000 units of produced packaging.

### *Electrical mixes*

The electricity consumption to produce the raw materials is already accounted and included in the datasets used to model the production of those materials (sources: APEAL, European Aluminium, ecoinvent). See section *IV.2.3 Raw materials for primary packaging* and *IV.2.4 Secondary and tertiary packaging* for more details.

For the manufacturing of packaging, participating members encoded the total consumption of electricity consumed during a full year of production (2018). The average electrical mix was calculated per energy source from the countries of all participating members (weighted by the production in each country). The next figure gives the final electrical mix calculated for the manufacturing (Figure 7), decomposed by energy source. More information on the modelling of the electrical mix is available in annex VII.1.

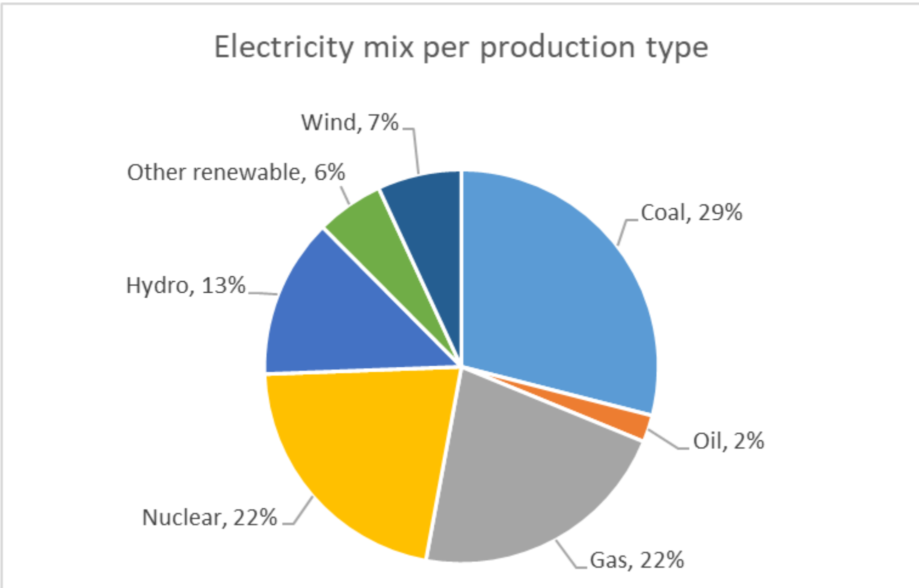


*Figure 7 - Electrical mix per energy source - Source: member data (2018)*

### *Consumption of heat*

The consumption of heat is entirely based on member's data. The total annual consumption of heat of all the participating members is expressed in MJ per 1,000 units of produced packaging. The consumption of heat is explained by the use of drying ovens for the drying of lacquers, varnishes or painting.

The source of energy is almost exclusively natural gas (97.9%). Some members mentioned other sources as heavy fuel oil, liquefied gas and propane but in neglecting consumption (they represent around 2% of the heat mix).

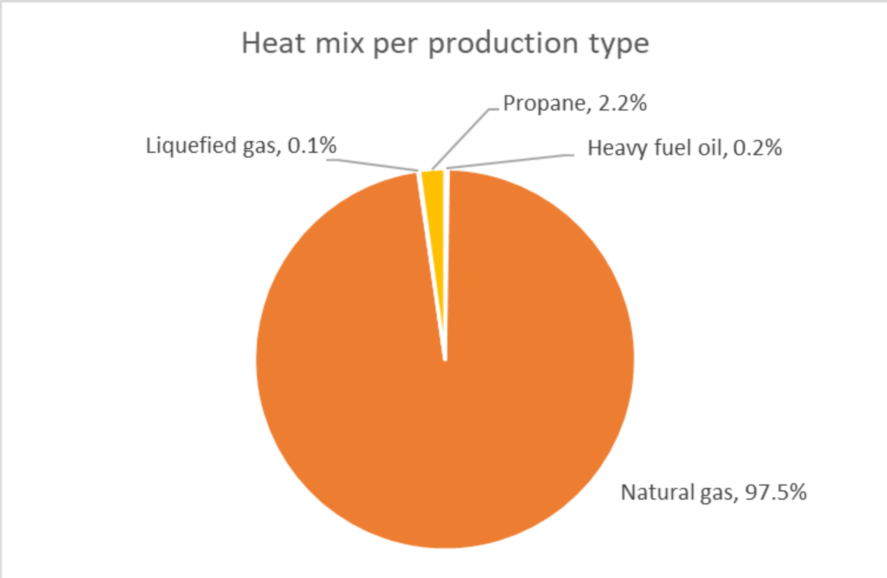


*Figure 8 - Heat mix - Source: member data (2018)*

### *IV.2.6. Water consumption and effluent*

#### *Water consumption*

The gross consumption of water (water withdrawal) is entirely based on members' data. These data cover the water consumption linked with metal packaging production, and may also include the water used for sanitation and cleaning. The total annual consumption of water of all the participating members is expressed below in litres per 1000 units of produced packaging. It was assumed that **water consumption is proportional to the weight of the packaging**, therefore water consumption was allocated based on the mass of the packaging. This approach is aligned with the previous LCA studies on metal packaging commissioned by MPE (i.e. study on food and non-food applications, study on beverage cans).

#### *Water emissions*

The wastewater output volume is released either to the natural environment or to a public water system, according to primary data filled in the questionnaire. This is represented in Figure 9.

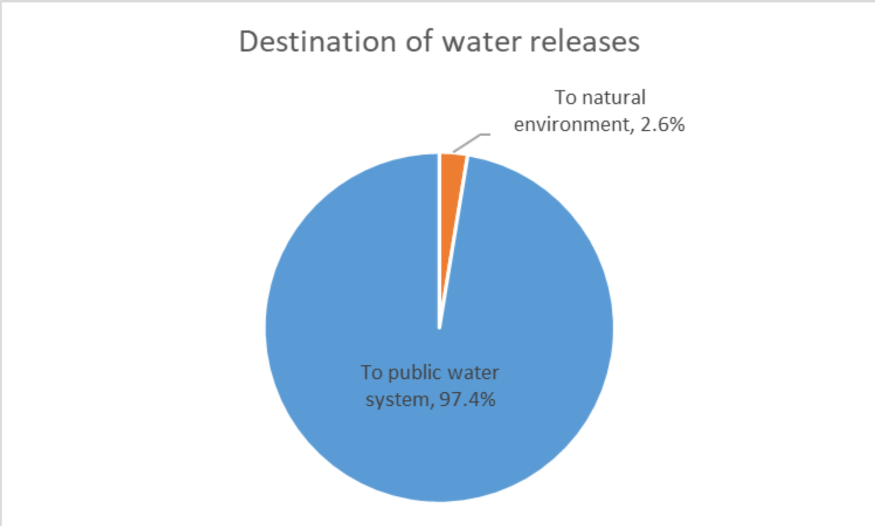


*Figure 9 - Destination of water releases*

### *IV.2.7. Other waste*

The model considers the production of two types of waste during the metal packaging manufacturing at MPE member plants (manufacturing of body & end):

- Metal scrap: pre-consumer aluminium or steel scrap which is considered as fully recycled; see for more details paragraph II.2.7.3.
- Other waste: waste calculated from members data. The data collection covered the following categories:
    - Incinerated non-hazardous waste
    - Landfilled non-hazardous waste
    - Recycled non-hazardous waste
    - Hazardous waste
    - Unspecified waste

The waste is allocated on the weight of the packaging (i.e. mass allocation) and is thus different for packaging.

Table 18 below explains which process, from the ecoinvent database, has been used for the modelling of the waste. Swiss datasets are used as proxy due to the lack of available datasets for Europe. Due to a lack of information on non hazardous waste recycling and treatment of unspecified waste, an assumption is used for modelling:

- 1/3 treatment of municipal solid waste, incineration
- 1/3 treatment of municipal solid waste, sanitary landfill
- 1/3 treatment of hazardous waste, hazardous waste incineration

*Table 18 - Modelling of other waste*

| Modelling of other waste | ecoinvent process |
| --- | --- |
| Incinerated non hazardous waste | treatment of municipal solid waste, incineration - Switzerland |
| Landfilled non hazardous waste | treatment of municipal solid waste, sanitary landfill - Switzerland |
| Hazardous waste | treatment of hazardous waste, hazardous waste incineration - Europe without Switzerland |
| Recycled non hazardous waste & unspecified waste | Assumption:<br>1/3 treatment of municipal solid waste, incineration - Switzerland<br>1/3 treatment of municipal solid waste, sanitary landfill - Switzerland<br>1/3 treatment of hazardous waste, hazardous waste incineration - Europe without Switzerland |

### *IV.2.8. Atmospheric emissions*

*Table 19 – Modelling of atmospheric emissions*

| Modelling of emissions to air | Elementary flow | |
| --- | --- | --- |
| | Compartment and subcompartment | Name |
| Unburnt VOC emisions | Emissions to air / Emissions to non-urban air or from high stacks | Volatile organic compound |
| Carbon dioxide ($CO_2$) | Emissions to air / Emissions to non-urban air or from high stacks | Carbon dioxide (fossil) |
| Nitrogen oxide (NOx) | Emissions to air / Emissions to non-urban air or from high stacks | Nitrogen oxides |
| Sulfur oxide (SOx) | Emissions to air / Emissions to non-urban air or from high stacks | Sulfur oxides |
| Ammonium ($NH_3$) | Emissions to air / Emissions to non-urban air or from high stacks | Ammonium |
| Dust (PM 10) | Emissions to air / Emissions to lower stratosphere and upper troposphere | Particles (> PM10) |
| Dust (PM 2.5) | Emissions to air / Emissions to lower stratosphere and upper troposphere | Particles (PM2.5 - PM10) |
| Dust (PM unspecified) | Assumption: 50% Dust (PM 10), 50% Dust (PM 2.5) | |

### IV.2.9. Transport

The main transports occur in the following three phases of the life cycle:

- Transport of raw materials to the manufacturing plant
- Transport of produced cans from manufacturing plant to the filler
- Transport of used packaging: waste collection, and then transport from collection sites to the recycler at End-of-Life

**Note:** The results presented in this report do not take into account the transport of pre-consumer metal scrap to recycling. A sensitivity analysis was performed to investigate the influence of this transport.

The pre-consumer metal scrap is recycled either by the metal suppliers or by other recyclers,therefore for the sensitivity analysis it is assumed a conservative distance of 500 km by truck.

The results of the sensitivity analysis indicate that this transport leads to an increase in impacts for the functional unit:

- from 0.1% to 1.1% for aluminium packaging
- from 0.04% to 0.8% for steel packaging

The results by product and by indicator are available in the annex VII.3 Sensitivity analysis: transport of pre-consumer scrap (page 97).

*Distances*

Distances are averaged across members data, as regards the raw materials and the transport to filler, or estimated based on literature. The Table 20 gives the repartition of transport for raw materials, for the transport of secondary and tertiary packaging (e.g. interlayer cardboard, LDPE film, pallet) and the transport at the end-of-life phase.

*Table 20 - Distances for main transports*

| Transport | | | Truck | Train | Boat |
|---|---|---|---|---|---|
| Raw material transport | Aluminium coil | Distance (km) | 487 | 0 | 649 |
| | Aluminium sheet | Distance (km) | 897 | 0 | 428 |
| | Steel coil | Distance (km) | 437 | 173 | 939 |
| | Steel sheet | Distance (km) | 493 | 138 | 1259 |
| | Lacquers, coatings, varnishes | Distance (km) | 604 | 55 | 264 |
| | Printing inks | Distance (km) | 738 | 0 | 53 |
| | Sealing compounds | Distance (km) | 2202 | 0 | 23 |
| Transport | | | Truck | Comment, source | |

| Transport | | | Truck | Train | Boat |
|---|---|---|---|---|---|
| $2^{ary}$ and $3^{ary}$ | From supplier to members – distance (km) | | 250 | Estimation agreed between RDC Environment and MPE | |
| Transport at the End-of-Life phase | Waste collection | Non selective (km) | 12.2 | ADEME 2012[23] | |
| | | Selective (km) | 86 | | |
| | Transport to the recycler (km) | | 395 | Assumption | |

### *Modes of transportation*

*Transport by truck*

Fuel consumptions and airborne emissions from trucks are obtained from the COPERT 5 methodology (version 5.0).

The trucks considered in this study:

- Have a maximum payload of 24 Tons;
- Are "Articulated 34-40 Tons" (framework);
- The impact of the truck is modelized as follows:
  - When the truck is fully loaded, its impact (per km) is equal to 100% of its maximal impact.
  - When the truck is travelling empty, its impact (per km) is equal to 70% of its maximal impact. The factor 70% is a coarse average value derived from the Copert 4 methodology by considering a set of trucks of various gross vehicle weights for both speed used respectively for rural and urban transportation;
  - The 30% remaining varies linearly with the ratio of load to maximum payload (the hypothesis of linearity comes from Copert 3 methodology).
- The empty return rate (part of the trip that the truck must achieve empty before being reloaded) is assumed to be 30% (European average published by Eurostat, 2008).

The repartition in Euro Code is indicated in Figure 10. This comes from MPE members data (previous study on Beverage cans, 2019).

[23] Data for 2007, published in 2009. « La collecte des déchets par le service public en France » Ademe.

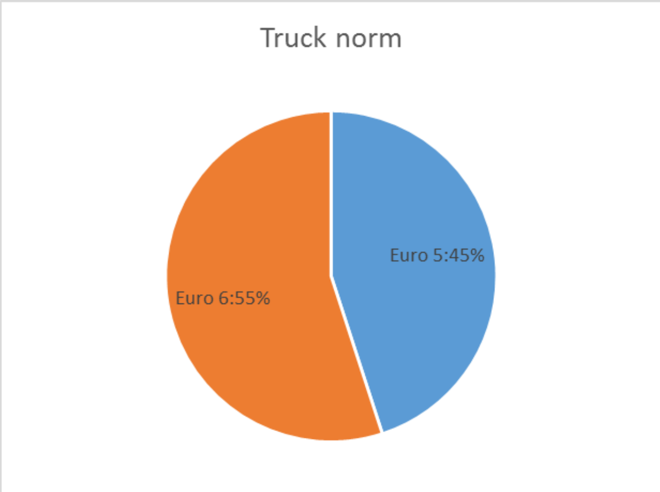


*Figure 10 - Truck norm according to Euro Code*

For the transport of raw material, trucks are assumed to be fully loaded.

The transport of empty packaging to the filler is constraint by the volume available in the truck (except for the transport of ends and closures, in this case, the transport is constraint by the weight), it means that the payload is assumed to be under 100% (i.e. lower than the maximum payload). Table 21 and Table 22 shows the payload for the different packaging.

*Table 21 – Loading rates for aluminium packaging*

| Delivery | Aluminium beverage can 250 ml | | Aluminium beverage can 330 ml | | Aluminium beverage can 500 ml | | Aluminium food can 125 ml | |
|---|---|---|---|---|---|---|---|---|
| | BODY | END | BODY | END | BODY | END | BODY | END |
| No. pallets / truck | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| Loaded pallet weight (kg/pallet) | 57 | 727 | 56 | 727 | 50 | 727 | 89 | 727 |
| Load / truck (t) | 1890 | 24000 | 1847 | 24000 | 1645 | 24000 | 2930 | 24000 |
| Payload for 24t truck (%) | 8% | 100% | 8% | 100% | 7% | 100% | 12% | 100% |

*Table 22 – Loading rates for steel packaging*

| Delivery | Steel food can 425 ml | | Steel aerosol can 420 ml | Steel aerosol can 520 ml | Steel general line 2500 ml | | Steel closure | Steel speciality |
|---|---|---|---|---|---|---|---|---|
| | BODY | END | - | - | BODY | END | - | - |
| No. pallets / truck | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| Loaded pallet weight (kg/pallet) | 145 | 727 | 248 | 239 | 148 | 727 | 727 | 308 |
| Load / truck (t) | 4795 | 24000 | 8177 | 7902 | 4897 | 24000 | 24000 | 10164 |
| Payload for 24t truck (%) | 20% | 100% | 34% | 33% | 20% | 100% | 100% | 42% |

*Transport by train*

Two types of traction are modelled: either electric or diesel. In this study all transports by train are modelled by a "train Europe".

*Transport by boat*

Impacts of transport by transoceanic boat are calculated per container (global dataset). This allows taking into account the loading rate of the containers. Indeed, the number of containers required for a transport depends on this loading rate.

### *IV.2.10. End of life*

#### *End of life of pre-consumer metal scrap*

The pre-consumer metal scrap produced during the packaging manufacturing phase is assumed to be 100% recycled in closed loop, both in the base case scenario and in the sensitivity analyses (including in the open loop sensitivity analysis). The transport distance is assumed to be the same as for post-consumer packaging.

#### *End of life of post-consumer metal packaging*

The post-consumer metal packaging is assumed to be either recycled or sent to elimination (landfill and incineration). Parameters for End-of-Life of post-consumer metal packaging are indicated in Table 5 and Table 6 for the different scenarios. The transport distance is indicated in Table 20.

#### *End of life of secondary and tertiary packaging*

The secondary and tertiary packaging are assumed to be either recycled or sent to elimination (landfill and incineration). Parameters for End-of-Life of secondary and tertiary packaging are indicated in the next table.

*Table 23 - End-of-Life parameters for secondary and tertiary packaging*

| End-of-Life parameters for secondary and tertiary packaging (for all End-of-Life scenarios) | | | | **Source** |
|---|---|---|---|---|
| 2dary and 3ary packaging | Recycled content ($R_1$) | Recycling rate ($R_2$) | Allocation factor (A) | |
| Interlayer cardboard | 88% | 75% | 20% | PEF project – Annex C[24] |
| Alveolar polypropylene (PPA) | 0% | 0% | 50% | |
| LDPE film | 0% | 28% | 50% | |
| HDPE pallet | 0% | 28% | 50% | |
| Wood pallet | 0% | 30% | 80% | |
| Metal top frame (steel) | 83% | 83% | 0% | Cf. modelling of steel packaging |

[24] *http://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm - Annex C*

# V. Life Cycle Impact Assessment (LCIA)

## V.1. System considered and methodology

Figure 11 shows the system boundaries considered for the study: cradle-to-gate + transport to filling site + End-of-Life.

LCA coverage

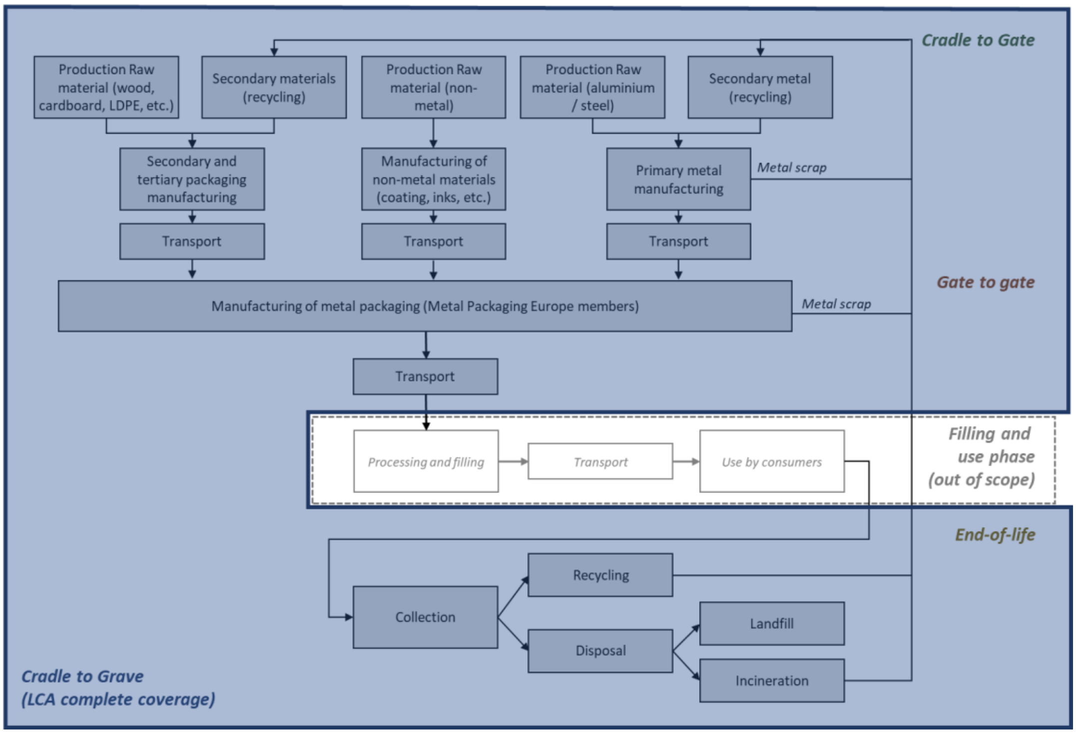


*Figure 11 – LCA system boundaries*

The environmental results are calculated for all the packaging included in the scope of the study and for the 16 impact categories recommended by the EU Environmental Footprint (EF) methodology.

Detailed results per life cycle phases are then analysed for the most relevant impact categories. The most relevant impact categories are identified for each packaging through a normalisation and weighting calculation of the results[25]. Indicators that cover 80% of the impacts were selected as relevant.

The most relevant indicators for the aluminium packaging are: climate change, resource use (fossils), particulate matter and acidification.

For steel packaging, the most relevant indicators are: climate change, resource use (minerals and metals), resource use (fossils), particulate matter and acidification.

[25] Global normalisation factors and weighting factors for Environmental Footprint as defined in the Annex A of Product Environmental Footprint Category Rules Guidance, version 6.3, May 2018

The following figures show the ranking of the indicators for the average aluminium packaging and the average steel packaging[26] following the normalisation/weighting.

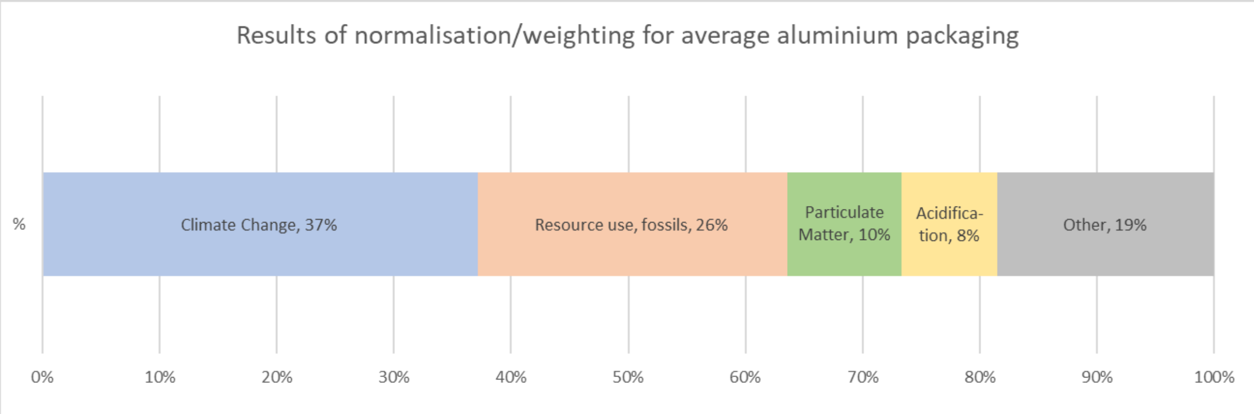


*Figure 12 – Results of normalisation/weighting (in %) for average aluminium packaging*

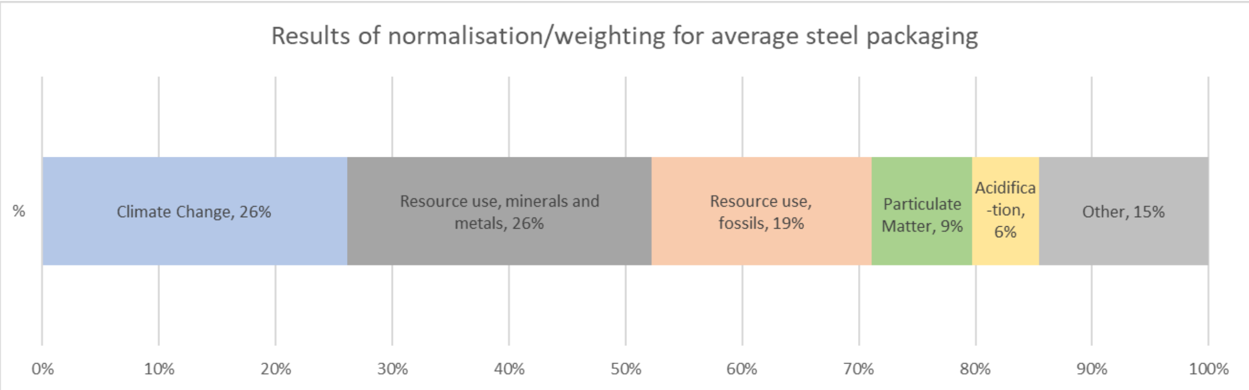


*Figure 13 – Results of normalisation/weighting (in %) for average steel packaging*

On top of the most relevant impact categories the indicator "water depletion" has been added as in the previous LCA studies, as well as the indicator "photochemical ozone formation" which is of interest to MPE.

These sensitivity analyses were assessed (see also section II.2.6):

- Closed-loop scenario with different recycling rates
- Open-loop scenario with different allocation factors

[26] Average aluminium packaging is defined as the average of the results for the following packages: aluminium food can 125 ml and aluminium beverage can 250 ml, 330 ml and 550 ml. Average steel packaging is defined as the average of the results for the following packages: steel food can 425 ml, steel aerosol can 420 ml and 520 ml, steel general line 2500 ml, steel closure and steel speciality.

- Open-loop scenario with different allocation factors for different recycled content scenarios
- Evolution of the environmental impacts over time
- Evolution of the environmental impacts of tinplate production with Worldsteel datasets

## V.2. Results – Base case scenario

The base case scenario assumes a closed-loop approach, i.e. all the used packaging are collected and recycled in same production system that generated it (without any changes to inherent properties), hence there is no need to define an allocation factor and the recycling rate and the recycled content are equal ($R_1 = R_2$).

The recycling rate of aluminium packaging is set to 76.1% and for steel packaging to 82.5%.

The formula for the End-of-Life modelling is according to the Equation 2.

### *V.2.1. Environmental impacts of the closed-loop scenario*

Table 24 and Table 25 show the environmental impacts for each impact category (16) for the 10 packaging. Results are expressed per functional unit, i.e. 1,000 units of packaging.

*Table 24 - Impact results based on the closed-loop scenario for* ***aluminium packaging*** *– Results* ***are expressed by 1000 units of packaging***

| Impact categories | Unit | Aluminium beverage can 250 ml | Aluminium beverage can 330 ml | Aluminium beverage can 500 ml | Aluminium food can 125 ml |
|---|---|---|---|---|---|
| Climate Change | kg CO2-Eq. | 5.1E+01 | 6.1E+01 | 7.8E+01 | 7.5E+01 |
| Resource use, fossils | Energy, MJ | 7.6E+02 | 9.1E+02 | 1.2E+03 | 1.1E+03 |
| Particulate Matter | disease incidence | 2.6E-06 | 3.1E-06 | 3.9E-06 | 3.7E-06 |
| Acidification | Moles H+-eq. | 2.7E-01 | 3.2E-01 | 4.1E-01 | 3.8E-01 |
| Photochemical ozone formation - human health | kg NMVOC-eq. | 1.6E-01 | 1.9E-01 | 2.4E-01 | 2.4E-01 |
| Eutrophication terrestrial | Moles N-eq. | 7.0E-01 | 8.4E-01 | 1.1E+00 | 9.4E-01 |
| Resource use, minerals and metals | kg Antimony eq. | 7.6E-05 | 9.2E-05 | 1.2E-04 | 1.3E-04 |
| Eutrophication freshwater | kg P-eq. | 8.2E-03 | 9.9E-03 | 1.3E-02 | 7.3E-03 |
| Water use | Volume m3-world eq. | 1.2E+01 | 1.4E+01 | 1.9E+01 | 1.3E+01 |
| Land Use | dimensionless (pt) | 3.3E+02 | 4.0E+02 | 5.5E+02 | 5.9E+02 |

| | | | | | |
|---|---|---|---|---|---|
| Eutrophication marine | kg N-eq. | 5.0E-02 | 6.0E-02 | 7.6E-02 | 7.5E-02 |
| Ozone depletion | kg CFC11-eq. | 2.9E-06 | 3.5E-06 | 5.0E-06 | 5.3E-06 |
| Ionising radiation - human health | kBq Uranium-235 eq. | 7.4E+00 | 8.9E+00 | 1.1E+01 | 9.5E+00 |
| Cancer human health effects | CTUh | 2.0E-07 | 2.5E-07 | 3.3E-07 | 3.3E-07 |
| Non-cancer human health effects | CTUh | 2.4E-06 | 2.9E-06 | 3.7E-06 | 3.2E-06 |
| Ecotoxicity freshwater | CTUe | 7.8E+00 | 9.5E+00 | 1.3E+01 | 1.2E+01 |

*Table 25 - Impact results based on the closed-loop scenario for **steel packaging** – Results **are expressed by 1000 units of packaging***

| Impact categories | Unit | Steel food can 425 ml | Steel aerosol can 420 ml | Steel aerosol can 520 ml | Steel general line 2500 ml | Steel closure | Steel speciality |
|---|---|---|---|---|---|---|---|
| Climate Change | kg CO2-Eq. | 1.0E+02 | 1.6E+02 | 1.8E+02 | 6.1E+02 | 1.9E+01 | 3.6E+02 |
| Resource use, minerals and metals | kg Antimony eq. | 2.1E-03 | 3.0E-03 | 3.4E-03 | 1.3E-02 | 3.2E-04 | 7.1E-03 |
| Resource use, fossils | Energy, MJ | 1.6E+03 | 2.4E+03 | 2.7E+03 | 9.1E+03 | 3.2E+02 | 5.5E+03 |
| Particulate Matter | disease incidence | 6.4E-06 | 9.5E-06 | 1.1E-05 | 3.9E-05 | 1.1E-06 | 2.3E-05 |
| Acidification | Moles H+-eq. | 5.3E-01 | 8.1E-01 | 9.1E-01 | 3.2E+00 | 9.4E-02 | 1.9E+00 |
| Photochemical ozone formation - human health | kg NMVOC-eq. | 4.1E-01 | 6.0E-01 | 6.8E-01 | 2.5E+00 | 7.8E-02 | 1.4E+00 |
| Eutrophication terrestrial | Moles N-eq. | 1.6E+00 | 2.4E+00 | 2.7E+00 | 9.4E+00 | 2.7E-01 | 5.4E+00 |
| Water use | Volume m3-world eq. | 5.3E+01 | 7.6E+01 | 8.5E+01 | 3.2E+02 | 8.9E+00 | 1.9E+02 |
| Eutrophication marine | kg N-eq. | 1.3E-01 | 2.0E-01 | 2.2E-01 | 8.1E-01 | 2.2E-02 | 4.6E-01 |
| Eutrophication freshwater | kg P-eq. | 1.2E-02 | 2.0E-02 | 2.3E-02 | 6.0E-02 | 2.7E-03 | 4.3E-02 |
| Ozone depletion | kg CFC11-eq. | 1.0E-05 | 1.6E-05 | 1.8E-05 | 5.9E-05 | 1.9E-06 | 3.9E-05 |
| Land Use | dimensionless (pt) | 7.5E+02 | 1.1E+03 | 1.3E+03 | 4.6E+03 | 1.2E+02 | 2.7E+03 |
| Ionising radiation - human health | kBq Uranium-235 eq. | 1.2E+01 | 1.8E+01 | 2.1E+01 | 6.7E+01 | 2.0E+00 | 4.1E+01 |
| Cancer human health effects | CTUh | 8.0E-07 | 1.2E-06 | 1.4E-06 | 5.0E-06 | 1.4E-07 | 3.1E-06 |
| Non-cancer human health effects | CTUh | 3.1E-05 | 4.6E-05 | 5.2E-05 | 1.9E-04 | 4.8E-06 | 1.1E-04 |
| Ecotoxicity freshwater | CTUe | 4.5E+01 | 6.5E+01 | 7.4E+01 | 2.8E+02 | 7.2E+00 | 1.6E+02 |

### *V.2.2. Climate change*

The climate change impact of 1000 metal packaging units is:

- **51 kg** of $CO_2$ equivalents for **aluminium beverage can (250 ml)**
- **61 kg** of $CO_2$ equivalents for **aluminium beverage can (330 ml)**
- **78 kg** of $CO_2$ equivalents for **aluminium beverage can (500 ml)**
- **75 kg** of $CO_2$ equivalents for **aluminium food can (125 ml)**
- **103 kg** of $CO_2$ equivalents for **steel food can (425 ml)**
- **157 kg** of $CO_2$ equivalents for **steel aerosol can (420 ml)**
- **178 kg** of $CO_2$ equivalents for **steel aerosol can (520 ml)**
- **606 kg** of $CO_2$ equivalents for **steel general line (2500 ml)**
- **19 kg** of $CO_2$ equivalents for **steel closure**
- **363 kg** of $CO_2$ equivalents for **steel speciality**

The impact of raw materials production accounts for the impact of the virgin metal production minus the avoided impact of the quote of metal production substituted thanks to the packaging recycled at the end-of-life of the product. On average, the avoided impact of climate change thanks to recycling is around 59% of the impact due to the virgin production. For example, for the steel general line, the impact of the virgin metal production is 745 kg $CO_2$ eq per 1000 metal packaging units, and the avoided impact of the virgin metal production thanks to the recycling of post-consumer packaging and pre-consumer metal scrap is -339 kg $CO_2$ eq. The impact of the steel production is therefore 406 kg $CO_2$ eq, and the avoided impact of climate change thanks to recycling is 50% of the impact due to the virgin steel production.

Regarding the impact of the steel production, almost 90% is due to carbon dioxide emissions from the blast furnaces. Combined with methane emissions, the furnace is responsible of 95% of the impact on climate change at the raw material production.

For aluminium production, the environmental impact mainly comes from the electrolysis which is an energy-intensive process (it requires 15,460 kWh/ton of produced aluminium[27]).

Regarding the impact of the aluminium production, almost 97% is due to the electricity used at the smelters (38%), the fuel consumption mostly at the alumina refineries (28%) and the processing i.e. mostly the carbon anode consumption (31%)[28]. Due to the aggregated European Aluminium datasets, it is not possible to further specify the contribution of the direct and indirect emissions of the electrolysis process.

The environmental credit for recycling aluminium and steel at the end of life is due to the fact that recycling avoids the production of virgin metal, and that recycling processes have less impact than the production of virgin metal.

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[27] *European Aluminium, Environmental Profile Report: Life-cycle inventory data for aluminium production and transformation processes in Europe, 2017*

[28] *European Aluminium, Environmental Profile Report: Life-cycle inventory data for aluminium production and transformation processes in Europe, 2017. Table 4-17.*

The manufacturing stage is the second highest contribution to the environmental impact. Table 26 shows the main contributors of the manufacturing stage for the most produced steel and aluminium packaging covered in this study in terms of tonnes, i.e. the steel food can 425 ml and the aluminium beverage can 330 ml.

*Table 26 - Climate Change – Main contributions for manufacturing stage (in percent)*

| Main contributors | Steel food can 425 ml | Aluminium beverage can 330 ml |
|---|---|---|
| Indirect emissions linked to the consumption of electricity at the manufacturing plants | 30% | 55% |
| Indirect and direct emissions linked to respectively the extraction of natural gas and consumption at the manufacturing plants (mainly used in the drying oven for coating and inks treatments) | 29% | 27% |
| Infrastructure of the manufacturing plants<br>This takes into account an average impact for the buildings, roads and parking spaces on the premises as well as other land occupation. It is based on an average standard impact from ecoinvent for a 27 ha metal factory. | 15% | 5% |
| Incineration of hazardous waste | 10% | 4% |
| **Total** | **84%** | **91%** |

### *V.2.3. Resource use, fossils*

The resource use (fossils) impact of 1000 metal packaging units is:

- **755 MJ** for **aluminium beverage can (250 ml)**
- **907 MJ** for **aluminium beverage can (330 ml)**
- **1166 MJ** for **aluminium beverage can (500 ml)**
- **1086 MJ** for **aluminium food can (125 ml)**
- **1558 MJ** for **steel food can (425 ml)**
- **2391 MJ** for **steel aerosol can (420 ml)**
- **2712 MJ** for **steel aerosol can (520 ml)**
- **9062 MJ** for **steel general line (2500 ml)**
- **317 MJ** for **steel closure**
- **5521 MJ** for **steel speciality**

Note: in ILCD 2017 method, the resource depletion is separated into two indicators: depletion of fossil resources (expressed in MJ) and depletion of minerals and metals (expressed in Sb eq). This section is relative to this first indicator.

For the steel production, 84% of the impact is explained by the consumption of hard coal used for blast furnace.

For aluminium production, the impact is due to the production of aluminium ingot. More specifically, the impacts come from the consumption of natural gas (it represents 33% of the impact of aluminium production), hard coal (30%) and crude oil (16%).

These high resource consumptions are due to the energy-intensive nature of aluminium and steel production.

The manufacturing stage is the second highest contribution to the environmental impact

Table 27 shows the main contributors of the manufacturing stage for the most produced steel and aluminium packaging covered in this study in terms of tonnes, i.e. the steel food can 425 ml and the aluminium beverage can 330 ml.

*Table 27 - Resource use, fossils – Main contributions for manufacturing stage (in percent)*

| Main contributors | Steel food can 425 ml | Aluminium beverage can 330 ml |
|---|---|---|
| Consumption of electricity (with consumption of different resources: hard coal, nuclear, and lignite) | 38% | 59% |
| Consumption of natural gas for heat production | 31% | 26% |
| Infrastructure | 14% | 4% |
| **Total** | **83%** | **89%** |

The consumption of crude oil for the production of diesel explains the impact associated with transport to filling (transport by truck).

### *V.2.4. Resource use, minerals and metals*

The resource use (minerals and metals) impact of 1000 metal packaging units is:

- **7.6E-5 kg Sb eq.** for **aluminium beverage can (250 ml)**
- **9.2E-5 kg Sb eq.** for **aluminium beverage can (330 ml)**
- **1.2E-4 kg Sb eq.** for **aluminium beverage can (500 ml)**
- **1.3E-4 kg Sb eq.** for **aluminium food can (125 ml)**
- **2.1E-3 kg Sb eq.** for **steel food can (425 ml)**
- **3.0E-3 kg Sb eq.** for **steel aerosol can (420 ml)**
- **3.4E-3 kg Sb eq.** for **steel aerosol can (520 ml)**
- **1.3E-2 kg Sb eq.** for **steel general line (2500 ml)**
- **3.2E-4 kg Sb eq.** for **steel closure**
- **7.1E-3 kg Sb eq.** for **steel speciality**

Note: in ILCD 2017 method, the resource depletion is separated into two indicators: depletion of fossil resources (expressed in MJ) and depletion of minerals and metals (expressed in Sb eq). This section is relative to this second indicator.

For steel packaging, the main contribution is due to the steel production. For the steel production, 99% of the impact from the raw material production is explained by the consumption of tin, with 8 g of tin by kg of steel produced. This overtakes all the other consumptions which appear negligible.

For aluminium packaging, the low contribution of aluminium production is related to the method used to calculate the depletion of minerals and metals. In 'ILCD 2017' category set, the reference model for resource depletion of minerals and metals corresponds to "ultimate reserves" version[29]. In this method the characterisation factor of aluminium is low: 1 kg of aluminium resource corresponds to 1.09E-9 kg Sb eq (e.g. the impact related to the use of the aluminium resource is 1.4E-8 kg Sb eq. for aluminium beverage can 250 ml).

At the manufacturing phase of aluminium and steel packaging, the impact is mainly due to the infrastructure, for which the main contributions are cadmium and lead. The consumption of cadmium and lead when building the infrastructures of the plants seems overestimated and may be due to assumptions on the use of rare elements for buildings.

Table 28 shows the contribution of infrastructure to the manufacturing stage for the most produced steel and aluminium packaging covered in this study in terms of tonnes, i.e. the steel food can 425 ml and the aluminium beverage can 330 ml.

*Table 28 - Resource use, minerals and metals – Main contributions for manufacturing stage (in percent)*

| Main contributors | Steel food can 425 ml | Aluminium beverage can 330 ml |
|---|---|---|
| Infrastructure | 98% | 94% |
| **Total** | **98%** | **94%** |

At the distribution phase (transport to fillers), around 56% of the contribution is linked to the truck production, and 36% is due to the maintenance of the lorry. The main contributions come from cadmium, gold and lead.

[29] Evolution of "Resource use, minerals and metals" indicator in 'ILCD 2017' category set: the reference model for resource depletion of minerals and metals has changed from reserve base to ultimate reserves *(JRC, Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment method, 2018)*

### V.2.5. Particulate matter

The particulate matter impact of 1000 metal packaging units is:

- **2.6E-6 disease incidence** for **aluminium beverage can (250 ml)**
- **3.1E-6 disease incidence** for **aluminium beverage can (330 ml)**
- **3.9E-6 disease incidence** for **aluminium beverage can (500 ml)**
- **3.7E-6 disease incidence** for **aluminium food can (125 ml)**
- **6.4E-6 disease incidence** for **steel food can (425 ml)**
- **9.5E-6 disease incidence** for **steel aerosol can (420 ml)**
- **1.1E-5 disease incidence** for **steel aerosol can (520 ml)**
- **3.9E-5 disease incidence** for **steel general line (2500 ml)**
- **1.1E-6 disease incidence** for **steel closure**
- **2.3E-5 disease incidence** for **steel speciality**

At the metal production, the main contributions are the emissions of 2.5 µm particles (64% of the impact at the raw material production stage for the aluminium production and 69% for the steel production), emissions of sulphur dioxide (32% and 8% respectively for aluminium and steel production) and emissions of sulphur oxides (11% for steel production).

The manufacturing stage is the second highest contribution to the environmental impact. Table 29 shows the main contributors of the manufacturing stage for the most produced steel and aluminium packaging covered in this study in terms of tonnes, i.e. the steel food can 425 ml and the aluminium beverage can 330 ml.

*Table 29 - Particulate matter – Main contributions for manufacturing stage (in percent)*

| Main contributors | Steel food can 425 ml | Aluminium beverage can 330 ml |
|---|---|---|
| Production of electricity | 39% | 73% |
| Infrastructure | 44% | 18% |
| **Total** | **83%** | **91%** |

### V.2.6. Acidification

The average acidification potential of 1000 metal packaging units is:

- **0.27 moles H eq.** for **aluminium beverage can (250 ml)**
- **0.32 moles H eq.** for **aluminium beverage can (330 ml)**
- **0.41 moles H eq.** for **aluminium beverage can (500 ml)**
- **0.38 moles H eq.** for **aluminium food can (125 ml)**
- **0.53 moles H eq.** for **steel food can (425 ml)**
- **0.81 moles H eq.** for **steel aerosol can (420 ml)**
- **0.91 moles H eq.** for **steel aerosol can (520 ml)**
- **3.22 moles H eq.** for **steel general line (2500 ml)**
- **0.09 moles H eq.** for **steel closure**
- **1.89 moles H eq.** for **steel speciality**

At the raw material production for steel packaging, the impact on acidification is caused by nitrogen oxides emissions (38%), sulphur oxides emissions (35%) and sulphur dioxide emissions (26%) occurring at the blast furnace. At the raw material production for aluminium packaging, the impact on acidification is caused by sulphur dioxide emissions (71%) and nitrogen dioxide emissions (28%).

The manufacturing stage is the second highest contribution to the environmental impact. Table 30 shows the main contributors of the manufacturing stage for the most produced steel and aluminium packaging covered in this study in terms of tonnes, i.e. steel food can 425 ml and aluminium beverage can 330 ml.

*Table 30 – Acidification – Main contributions for manufacturing stage (in percent)*

| Main contributors | Steel food can 425 ml | Aluminium beverage can 330 ml |
|---|---|---|
| Indirect emissions at the electricity production stage | 23% | 57% |
| Nitrogen oxides emissions measured at MPE member plants | 39% | 21% |
| Sulphur oxides emissions measured at MPE member plants | 20% | 11% |
| Infrastructure | 11% | 6% |
| **Total** | **93%** | **95%** |

### V.2.7. Photochemical ozone formation

The photochemical ozone formation of 1000 metal packaging units is:

- **0.16 kg NMVOC eq.** for **aluminium beverage can (250 ml)**
- **0.19 kg NMVOC eq.** for **aluminium beverage can (330 ml)**
- **0.24 kg NMVOC eq.** for **aluminium beverage can (500 ml)**
- **0.24 kg NMVOC eq.** for **aluminium food can (125 ml)**
- **0.41 kg NMVOC eq.** for **steel food can (425 ml)**
- **0.60 kg NMVOC eq.** for **steel aerosol can (420 ml)**
- **0.68 kg NMVOC eq.** for **steel aerosol can (520 ml)**
- **2.51 kg NMVOC eq.** for **steel general line (2500 ml)**
- **0.08 kg NMVOC eq.** for **steel closure**
- **1.43 kg NMVOC eq.** for **steel speciality**

The manufacturing stage is the main contribution to the environmental impact. Table 31 shows the main contributors of the manufacturing stage for the most produced steel and aluminium packaging covered in this study in terms of tonnes, i.e. steel food can 425 ml and aluminium beverage can 330 ml.

*Table 31 – Photochemical ozone formation – Main contributions for manufacturing stage (in percent)*

| Main contributors | Steel food can 425 ml | Aluminium beverage can 330 ml |
|---|---|---|
| Emissions of nitrogen oxides from the drying oven | 60% | 49% |
| Emissions of VOC from the drying oven | 21% | 17% |
| Indirect nitrogen oxides emitted due to the productions of electricity from coal, lignite, natural gas and oil | 5% | 19% |
| **Total** | **86%** | **85%** |

At the steel production stage, most of the impact (above 95%) is caused by three emissions: nitrogen dioxide (71%), carbon monoxide (20%) and sulphur oxides (5%). For the aluminium production, 84% of the impact is due to nitrogen oxides emissions, 10% to sulphur dioxide and 4% to NMVOC emissions.

### V.2.8. Resource depletion – water

The water depletion of 1000 metal packaging units is:

- **12 m³** for **aluminium beverage can (250 ml)**
- **14 m³** for **aluminium beverage can (330 ml)**
- **19 m³** for **aluminium beverage can (500 ml)**
- **13 m³** for **aluminium food can (125 ml)**
- **53 m³** for **steel food can (425 ml)**
- **76 m³** for **steel aerosol can (420 ml)**
- **85 m³** for **steel aerosol can (520 ml)**
- **317 m³** for **steel general line (2500 ml)**
- **9 m³** for **steel closure**
- **186 m³** for **steel speciality**

At the steel production stage, river water is mainly consumed. Water is required in particular for cooling operations, descaling and dust scrubbing[30]. No further analysis can be done for steel production due to APEAL dataset (the production of steel and the sheet manufacturing stage are aggregated).

At the aluminium production stage, the water consumed for the aluminium ingot production (including alumina production and electrolysis) accounts for almost 94.2% of the impact, while the sheet manufacturing stage is responsible for 5.8% of the impact.

Table 32 shows the main contributors of the manufacturing phase for the most produced steel and aluminium packaging covered in this study in terms of tonnes, i.e. steel food can 425 ml and aluminium beverage can 330 ml.

*Table 32 – Water depletion – Main contributions for manufacturing stage (in percent)*

| Main contributors | Steel food can 425 ml | Aluminium beverage can 330 ml |
|---|---|---|
| Indirect water usage to produce the electricity consumed by the can manufacturing plants (i.e. cooling water of power plants and for hydroelectric energy production - see Figure 7 for more details) | 46% | 40% |
| Direct water consumption at the can manufacturing plants [31] | 24% | 54% |
| Infrastructure<br>This takes into account an average impact for the buildings, roads and parking spaces on the premises as well as other land occupation; it is based on an average standard impact from ecoinvent for a 27-ha metal factory. | 20% | 4% |
| **Total** | **90%** | **98%** |

[30] Worldsteel, Water management in the steel industry, 2020

[31] Members' data cover the water consumption linked with metal packaging production, and may also include the water used for sanitation and cleaning

## V.3. Sensitivity analysis

The sensitivity analyses focus on climate change indicator.

### V.3.1. Sensitivity analysis: variation of the recycling rate

The purpose of the analysis is to evaluate the influence of the recycling rate of used packaging on the impact results.

In this scenario, metal packaging is considered recycled in a closed-loop (as per the base case scenario) and the recycling rate ($R_2$) varies from 40% to 95% in order to represent the different recycling rates of the main European countries.

As it is a closed-loop scenario (recycling in same production system), hence there is no need to define an allocation factor and the recycling rate and the recycled content are equal ($R_1 = R_2$) and varies accordingly.

The formula for the End-of-Life modelling is according to Equation 2. The other parameters are unchanged compared to the base case scenario.

The sensitivity analysis focuses on aluminium food can (125 ml), steel food can (425 ml) and aluminium beverage can (330 ml). The conclusions are the same for other packaging.

The influence of the recycling rate is shown in Figure 14, Figure 15 and Figure 16 (for aluminium food can 125 ml, steel food can 425 ml and aluminium beverage can 330 ml respectively). It can be seen that an increase of the recycling rate allows a decrease of the environmental impact. Inversely, a decrease of the recycling rate is responsible for an increase of the impact.

In the closed-loop scenario, any percentage increase of the recycling rate avoids producing an equivalent amount of virgin material and therefore decreases the total impact.

This trend is the same whatever the indicator studied, and whatever the packaging studied. The influence of the parameter is more or less important (slope of the line on the graphs) depending on the contribution of the production of raw materials on the indicator studied.

Compared to the base case scenario, an increase of the recycling rate by 1% would allow reducing the climate change impact by:

- 1.68% in the case of aluminium food cans (125ml)
- 0.68% in the case of steel food cans (425 ml)
- 1.68% in the case of aluminium beverage cans (330 ml)

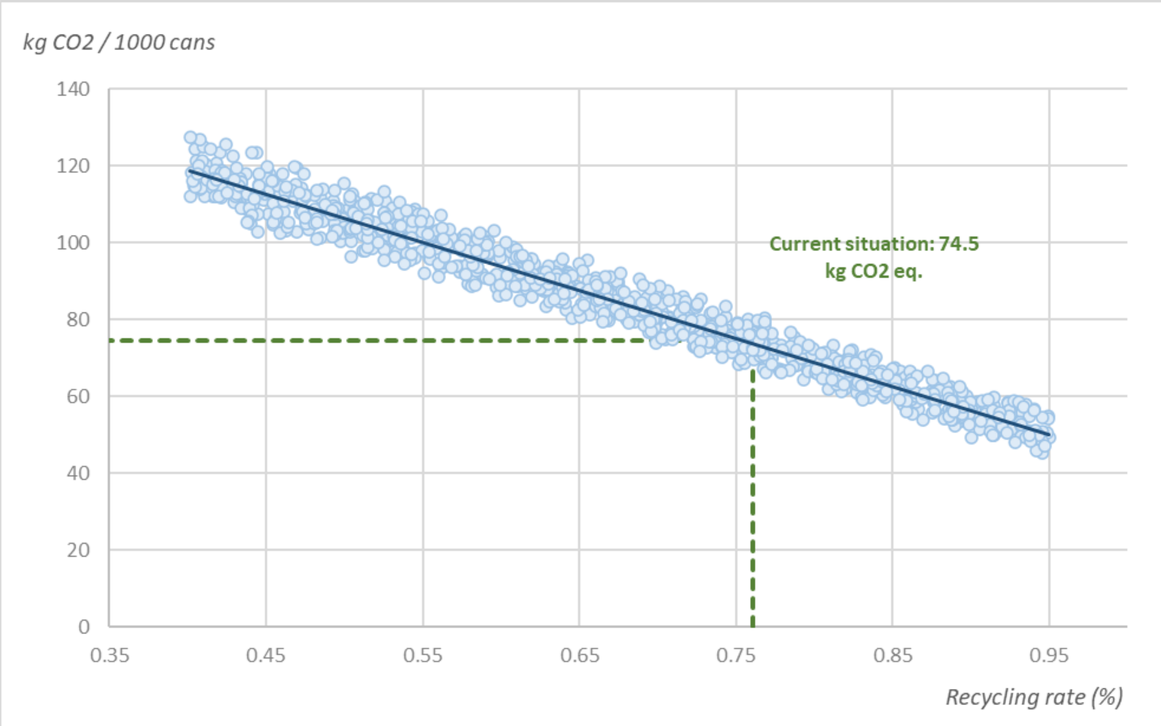


*Figure 14 - Influence of recycling rate on climate change indicator for aluminium food cans (125ml)*

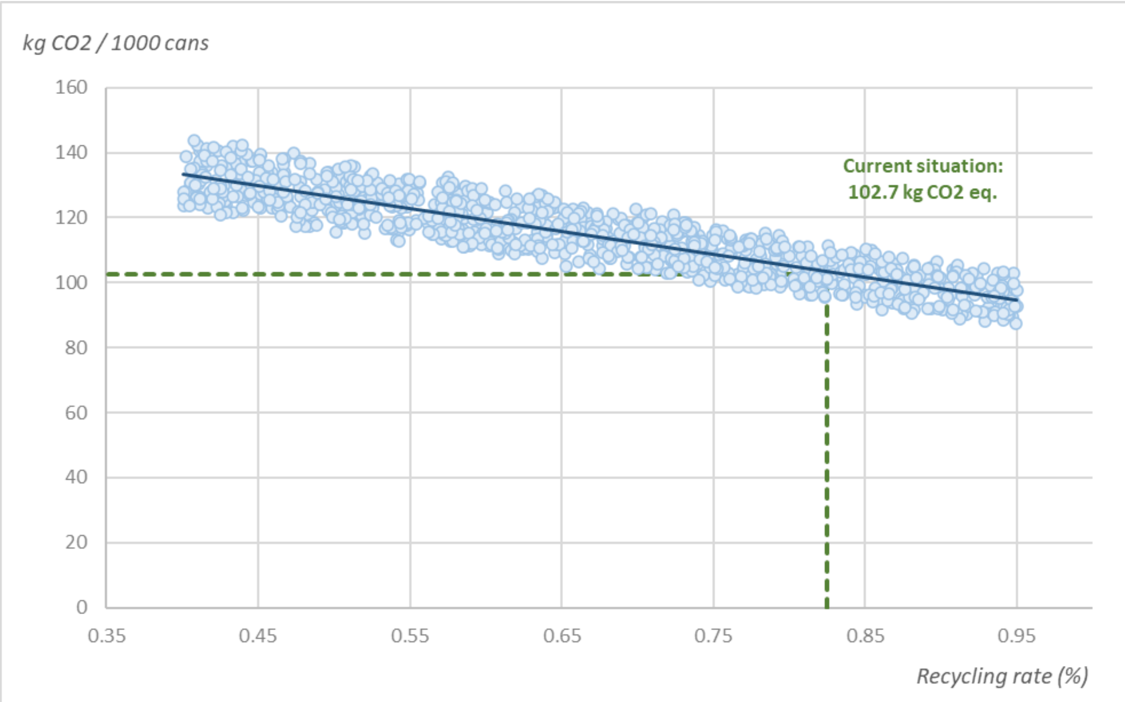


*Figure 15 - Influence of recycling rate on climate change indicator for steel food cans (425 ml)*

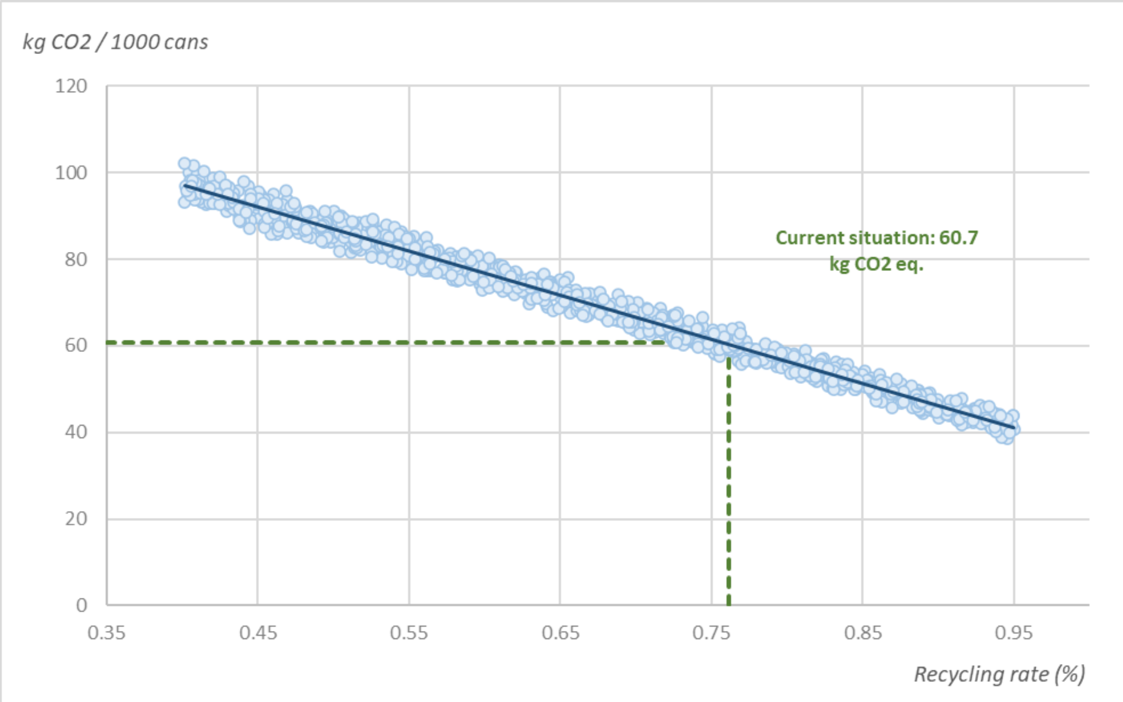


*Figure 16 - Influence of recycling rate on climate change indicator for aluminium beverage cans (330 ml)*

### *V.3.2. Sensitivity analysis: variation of the allocation factor*

The purpose of this analysis is to evaluate the influence of the allocation factor on the impact results. The selection of the allocation factor (A) is a methodological choice. It varies from 0% to 100%. It reflects different methods for allocating the impact of the recycling process at the End-of-Life and the credit of avoiding an equivalent virgin material production between the first life cycle (i.e. the one providing the recyclable material, such as the used beverage can) and the next life cycle (i.e. the one incorporating the recycled material).

In order to study the influence of the allocation factor, it is assumed that the metal is recycled in an open-loop[32]: this is the case of some countries and some metal markets for which it is not always possible (for technical, logistic and economic reasons) to recycle used metal packaging into new metal sheet for packaging use, and therefore the metal is recycled into metal sheet for non-packaging application[33].

The formula for End-of-Life modelling is according to Equation 3 (see section II.2.7 Allocations) where the recycled content ($R_1$) is set equal to 40% for aluminium (according to European Aluminium - not beverage cans specific) and 58% for steel (according to

*[32] In the closed-loop scenario, there is no need to define the allocation factor.*

*[33] Source: MPE*

APEAL), and the recycling rate ($R_2$) remains equal to 76.1% for aluminium and 82.5% for steel. The allocation factor (A) varies from 0% to 100%, meaning that:

- A=0% corresponds to the so-called "End-of-Life" or "0:100" allocation approach, which is the allocation supported by MPE, APEAL and European Aluminium. This allocation method accounts for the impact of the recycling process at the End-of-Life (i.e. collection, sorting, remelting) in the first life cycle (i.e. the one providing the recyclable material, such as the used beverage can) as well as for the credit of avoiding an equivalent virgin material production in the next life cycle (i.e. the one incorporating the recycled material) which are calculated proportionally to the recycling rate[34]. Therefore, in this allocation approach, the recycled content does not affect the results.
- A=20% corresponds the "20:80" allocation approach set by the PEF (Product Environmental Footprint) methodology for metals (and other) materials. It means that 80% of the impact of the recycling process and its credit are allocated to the first life cycle, whereas the 20% are allocated to the next one.
- A=50% corresponds to the allocation approach "50:50" set by some LCA methodologies (such as the PEF for plastic materials). It means that the impact of the recycling process and its credit are equally split between the first life cycle and the next one.
- A=100% corresponds to the so-called "Recycled content" or "100:0" allocation approach. This allocation method considers the recycling process at the End-of-Life of the first life cycle as belonging entirely to the second life cycle (i.e. the one incorporating the recycled material) and accounts for its impact and credit proportionally to the recycled content of the new product, hence reducing the need of virgin material. Therefore, in this allocation approach, the recycling rate does not affect the results.

The sensitivity analysis focuses on aluminium food can (125 ml), steel food can (425 ml) and aluminium beverage can (330 ml). The conclusions are the same for other packaging.

The influence of the allocation factor is shown in Figure 17, Figure 18 and Figure 19 (for aluminium food can 125 ml, steel food can 425 ml and aluminium beverage can 330 ml respectively), where it can be seen that an increase of the allocation factor is responsible for an increase of the impact because more weight is given to the recycled content of the product in the next life cycle and less to the recycling rate of the product in the current life cycle: as the recycled content is lower than the recycling rate, it follows that the credit decreases by increasing the allocation factor.

As for the previous sensitivity analysis, the influence of the parameter is more or less important (slope of the line on the graphs) depending on the contribution of the production of raw materials on the indicator studied.

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*[34] Guidance to the use and interpretation of Life Cycle Assessment (LCA) results through the Instant LCA tool – MPE. Version of 23rd August 2018.*

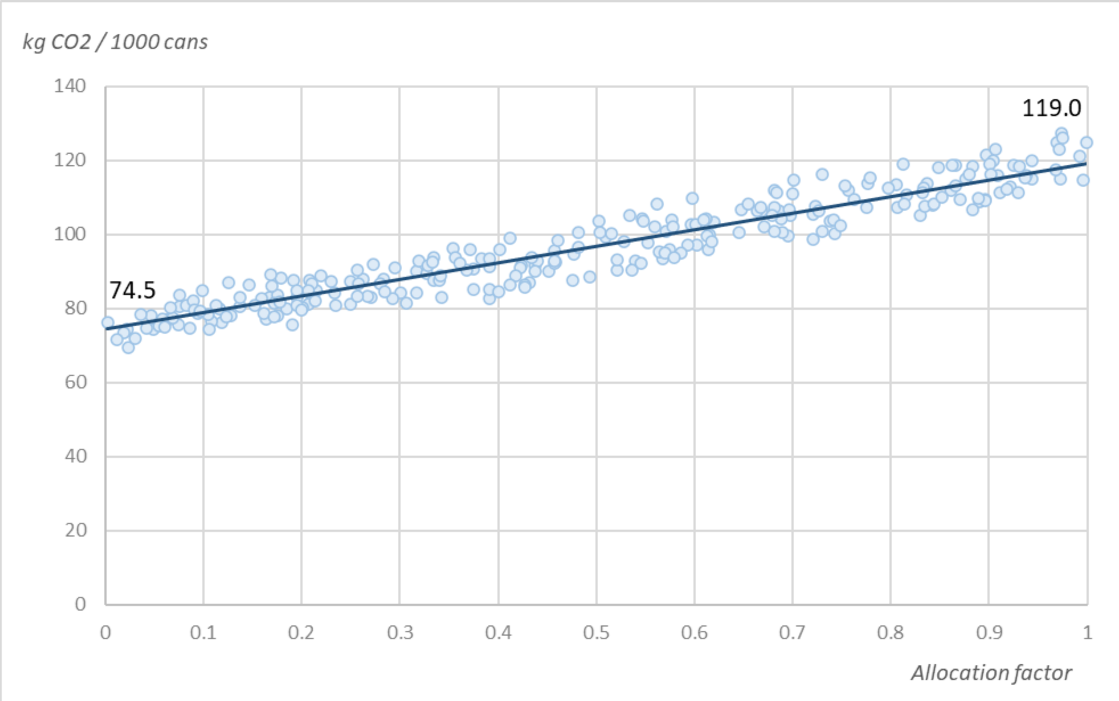



*Figure 17 - Influence of allocation factor on climate change indicator for aluminium food cans (125 ml) ($R_1$ = 40%)*

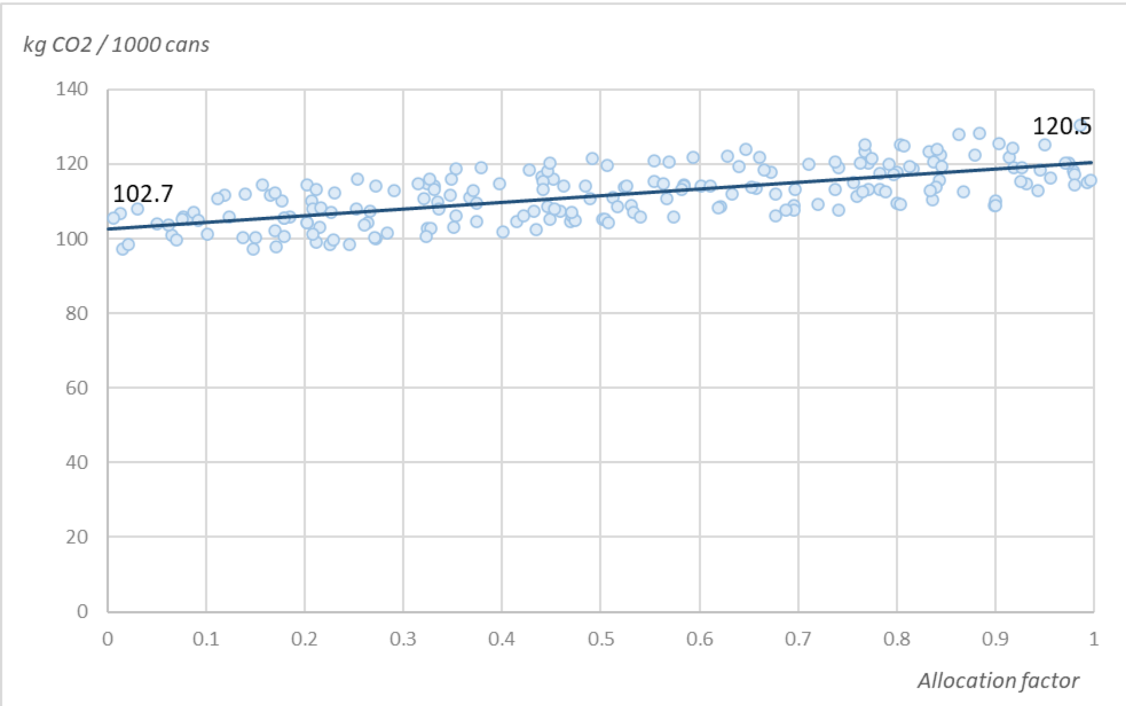



*Figure 18 - Influence of allocation factor on climate change indicator for steel food cans (425 ml) ($R_1$ = 58%)*

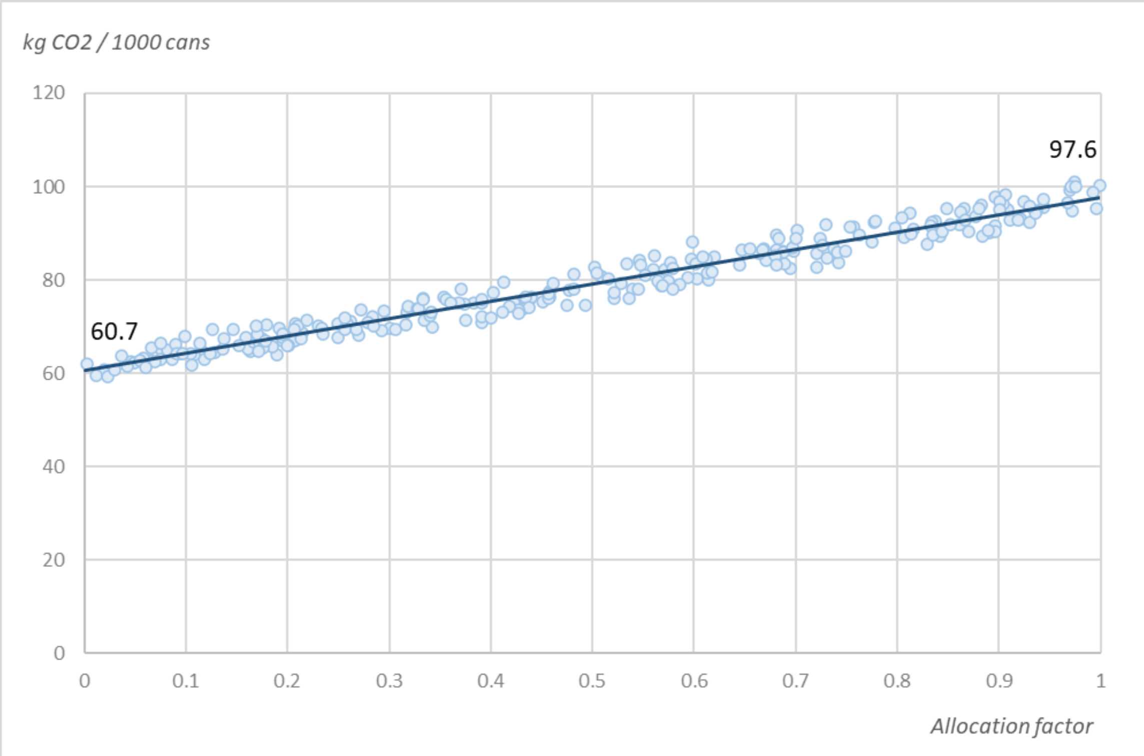



*Figure 19 - Influence of allocation factor on climate change indicator for aluminium beverage cans (330 ml) ($R_1$ = 40%)*

### V.3.3. Sensitivity analysis: variation of the recycled content

The purpose of the analysis is to evaluate the influence of the recycled content ($R_1$) of aluminium and steel on the impact results. As in the previous sensitivity analysis, the results are presented by varying the allocation factor A between 0% and 100% to illustrate the influence of this methodological choice.

As for the previous sensitivity analysis, it is assumed that the metal packaging is recycled in an open-loop and the recycled content ($R_1$) is equal to the following scenarios: 40%, 50%, 60% and 80% for aluminium packaging; 10%, 15%, 20%, 40% and 58% for steel packaging. The allocation factor also varies from 0% to 100%. The recycling rate remains equal to 76.1% and 82.5% for aluminium and steel respectively.

The formula for End-of-Life modelling is according to Equation 3 (see section II.2.7 Allocations).

The sensitivity analysis focuses on aluminium food can (125 ml), steel food can (425 ml) and aluminium beverage can (330 ml). The conclusions are the same for other packaging.

Regarding the results of this section, it should be noted that:

- The variation of the allocation factor from 0% to 100% corresponds to transfer the recycling credits from the End-of-Life stage of the current life cycle (i.e. the recycler) to the production stage of the next life cycle (i.e. the incorporator).
- The recycling credit at the end-of-life depends on the recycling rate (R2): the higher the recycling rate, the higher the credit.
- The recycling credit at the production stage depends on the recycled content (R1): the higher the recycled content, the higher the credit.
- When the recycled content is equal to the recycling rate, according to the equation 1, the allocation factor does not influence the results.
- **When the recycling rate ($R_2$) is lower than the recycled content ($R_1$)**, by increasing the allocation factor more credits are transferred to the production stage and consequentially the total impact decreases.
- **When the recycling rate ($R_2$) is higher than the recycled content ($R_1$)**, by increasing the allocation factor less credits are transferred to the production stage and consequentially the total impact increases.

Example: the sensitivity analysis carried out on aluminium food can (Figure 20) shows that:

- **When the recycling rate ($R_2$ = 76.1%) is lower than the recycled content ($R_1$ = 80%)**, by increasing the allocation factor more credits are transferred to the production stage and consequentially the total impact decreases. The yellow line decreases.
- **When the recycling rate ($R_2$ = 76.1%) is higher than the recycled content ($R_1$ = 40, 50% or 60%)**, by increasing the allocation factor more credits are transferred to the production stage and consequentially the total impact increases. The blue ($R_1$ = 40%), the green ($R_1$ = 50%) and the red ($R_1$ = 60%) lines increase.

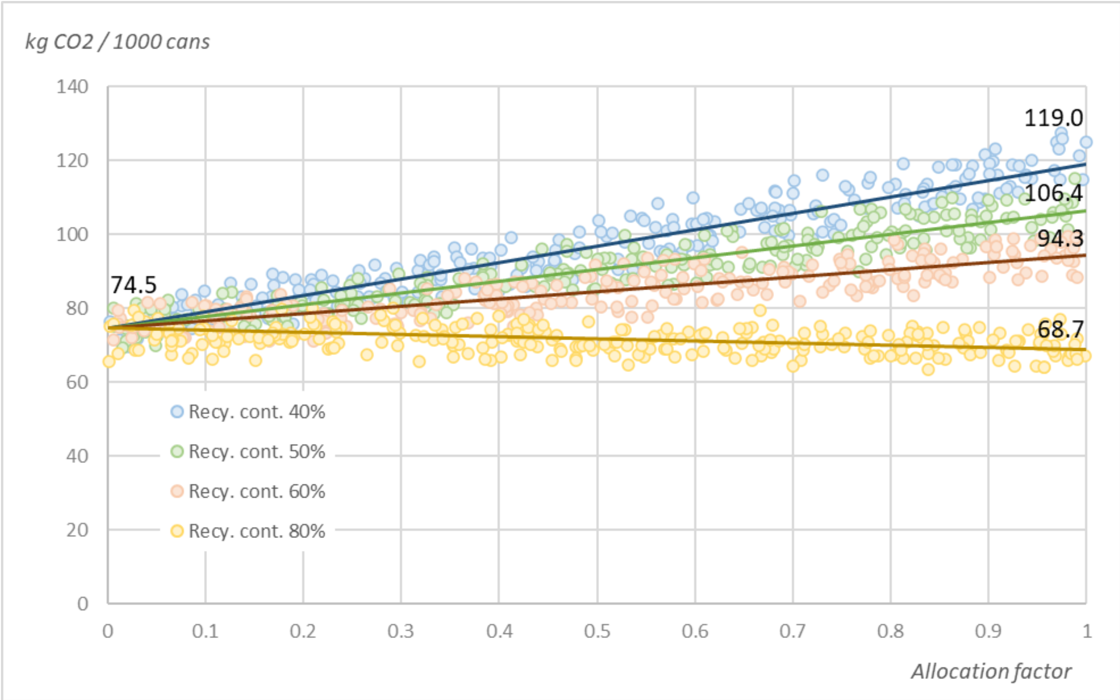



*Figure 20 - Influence of allocation factor and recycled content on climate change indicator for aluminium food cans (125 ml)*

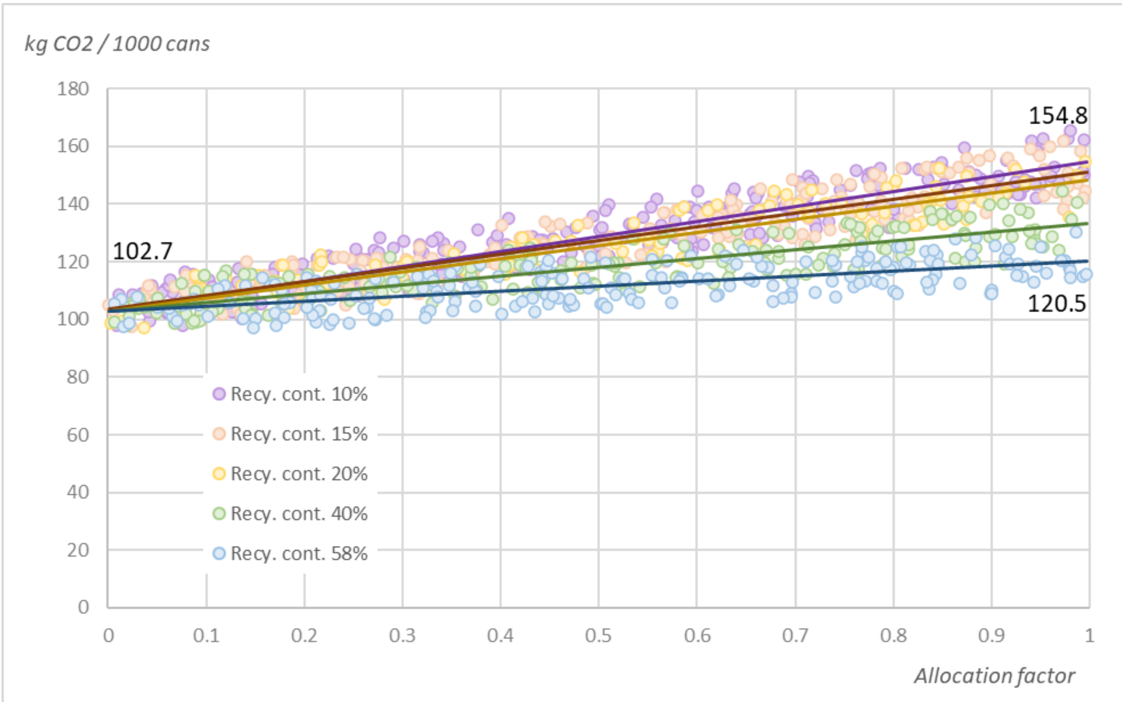



*Figure 21 - Influence of allocation factor and recycled content on climate change indicator for steel food cans (425 ml)*

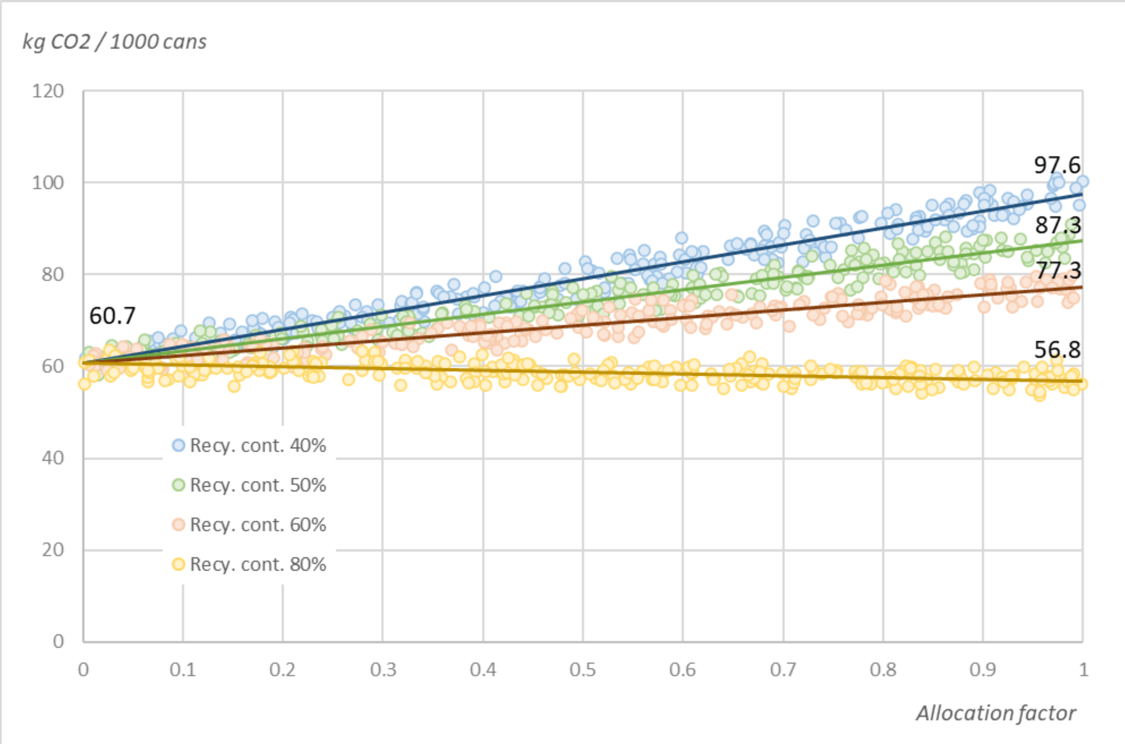



*Figure 22 - Influence of allocation factor and recycled content on climate change indicator for aluminium beverage cans (330 ml)*

### V.3.4. Sensitivity analysis: evolution of can-manufacturing over time

The purpose of this section is to analyse the evolution of can manufacturing over time compared to previous MPE's LCA studies. The following parameters are analysed:

- Representativeness of can makers in term of data collection
- Comparison on key data:
  - Packaging weight
- Impact on climate change

*Context and limitations*

Two studies are considered to analyse the **evolution of steel packaging over time**:

- **RDC study**, published in 2016[35]: the study "Life Cycle Assessment of metal packaging in Europe" realised for EMPAC by RDC environment covers the **production year 2013**. This study provides comparative data for the following packaging: steel food can (425 ml), steel aerosol (520 ml), steel general line (2500 ml), steel closure and steel speciality.
  This study is used to compare the representativeness in term of data collection and key data.
- **TNO study**, published in 2012: the study "LCA model for metal packaging" realised for Empac by TNO in 2012 showed the evolution of results from 2000 to 2008 by covering three **years of production: 2000, 2006 and 2008**. This study provides comparative data for the following packaging: steel food can (425 ml), steel aerosol (520 ml), steel general line (2500 ml), steel closure and steel speciality.

It must be noticed that the comparison of results must be interpreted with caution as the results for 2000, 2006 and 2008 (produced by TNO) are not based on the same model than the ones for 2013 and 2018 (produced by RDC Environment). Although RDC tried to follow a similar methodology as the one presented in the TNO report, several differences between the two studies may occur. Amongst them, the following can be identified:

- The precise list of LCI's used to model the life cycle is not available in the TNO study. The choice made by RDC Environment of some processes may therefore be different than the ones made by TNO.
- The judgement of LCA experts may be different regarding the best source for some parts of the model (e.g. Copert is preferred by RDC Environment instead of Ecoinvent for transport model).

Two studies are considered to analyse the **evolution of aluminium packaging over time**:

- **RDC study**, published in 2019[36]: the study "Life Cycle Assessment of Aluminium Beverage Cans in Europe" realised for MPE by RDC environment covers the

[35] Life Cycle Assessment of metal packaging in Europe, European Metal Packaging (Empac) (published in 2016)

[36] Life Cycle Assessment of Aluminium Beverage Cans in Europe, Metal Packaging Europe (published in 2019)

**production year 2016**. This study provides comparative data for the following packaging: aluminium beverage can 250 ml, can 330 ml and can 500 ml.
This study is used to compare the representativeness in term of data collection and key data.

- **PE study**, published in 2009: the LCA study on aluminium beverage cans, carried out by Sphera (former PE International) in 2009 for BCME/European Aluminium/APEAL[37] covers the **production year 2006**. This study provides comparative data for the following packaging: aluminium beverage can 250 ml, can 330 ml and can 500 ml.

The PE study (published in 2009, production year 2006) cannot be compared with the current one due to methodological differences such as the impact categories and the inclusion of beer in the system boundary of Sphera study. However, in the RDC study published in 2019, an analysis was done to evaluate the environmental impact based on data collected by PE and provided by the can makers for the production year 2006. It is the results of this analysis that are used here.

### *Representativeness in term of data collection*

Table 33 and

[37] BCME, EAA, APEAL, PE International, Life Cycle Inventory and impact Analysis for Beverage Cans, 2009

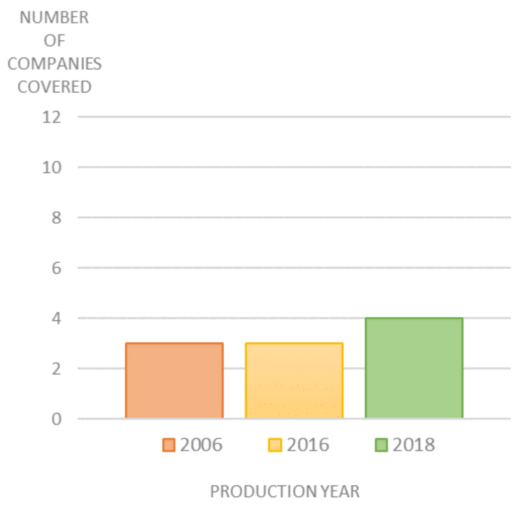
Table 34 list the companies involved in the data collection according to the type of packaging. It must be noted that the companies involved in the data collection for the previous studies are not the same ones that participated in the present study.

*Table 33 - Companies involved in the data collection for aluminium beverage cans*

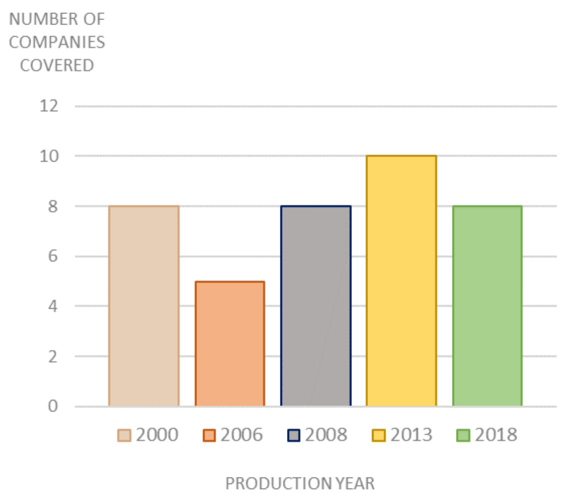
| Companies | **Production year 2006** (study published in 2009) | **Production year 2016** (study published in 2019) | **Production year 2018** (this study) |
|---|---|---|---|
| Ardagh | | *X* | *X* |
| Ball Packaging Europe | *X* | *X* | *X* |
| Crown | *X* | *X* | *X* |
| Rexam | *X* | | |
| Silgan | | | *X* |

*Table 34 - Companies involved in the data collection for other metal packaging*

| Companies | **Production year 2000** (study published in 2012) | **Production year 2006** (study published in 2012) | **Production year 2008** (study published in 2012) | **Production year 2013** (study published in 2016) | **Production year 2018** (this study) |
|---|---|---|---|---|---|
| Ardagh | X | X | X | X | |
| Blechwaren Limburg | X | | X | X | |
| Colep | X | | X | X | X |
| Crown | X | X | X | X | X |
| Envases | | | | | X |
| Glud & Marstrand | X | | X | X | |
| Huber | X | X | X | | |
| Massilly | X | X | X | X | X |
| Mivisa | | X | | | |
| Newbox | | | | X | |
| Pack2Pack | | | | X | |
| Pelliconi | | | | | X |
| Sarten | | | | X | X |
| Silgan | X | | X | X | X |
| Trivium | | | | | X |




*Beverage can*




*Other packaging*

*Figure 23 - Evolution of the number of companies involved in data collection.*

## *Comparison on key data*

The 2018 data (this study) is compared to:

- 2013 data for steel food can (425 ml), steel aerosol (520 ml), steel general line (2500 ml), steel closure and steel speciality (study published in 2016)

- 2006 and 2016 data for aluminium beverage can 250 ml, can 330 ml and can 500 ml (studies published in 2009 and 2019 respectively)

- **Packaging weight**

The weight of packaging is a key factor as all impact results are expressed by 1000 units. This is also a key issue for the manufacturers: as it can be seen in the next table, the average weights of the standard packaging are slightly reduced over time, except for the steel general line.

Note: the lid was not taken into account in the previous study for the steel general line, so it is excluded from this comparison (the table below does not consider the lid for 2018 data).

Steel specialities are customised packaging used for promotion, therefore the variation of results depends on the specific application and use of the packaging. There is no standardised size or form for specialities. In the absence of a standardised size, the evolution of the weight reflects the differences in terms of products covered between the previous study and the current study.

The light weighting is the results of the compromise between reducing the amount of used material and ensuring the same performance of the products. The can manufacturers would use several ways to reduce the weight of their packaging and this is kept as confidential information. The reasons explaining this willingness to produce more lightweight packaging are multiple:

- Ensuring a better resource efficiency;
- Preventing waste production;
- Reducing the costs throughout the supply chain (e.g transportation costs);
- Improving product competitiveness;
- Reducing the environmental footprint.

### *Impact on climate change*

In order to follow the evolution of environmental performances of can manufacturing, these four studies are considered in this paragraph to produce graphical representations of the **evolution of climate change impact**.

Thus, the following years are considered to analyse the evolution of the impact on climate change:

- 2006, 2016 and 2018 are compared for beverage cans
- 2000, 2006, 2008, 2013 and 2018 are compared for steel packaging

Note:

- In the previous studies, the impact on climate change was assessed using the IPCC 2013 method (not the latest one). To enable comparison of results, the impacts associated with the 2018 data were also calculated using this method.
- The steel production has been modelled with the same database (APEAL 2015), therefore no variation is visible over time. For this reason, a separate comparison using Worldsteel database is made in order to provide an estimation of the evolution of the impact of steel production over time.
- No comparison is available for aluminium food cans (as the reference volume has changed from 425 ml in previous studies to 125 ml in the current study) and steel aerosol can 420 ml (as this packaging has not been studied previously)
- No data is available for the steel aerosol can 520 ml for the year 2000
- The lid was not taken into account in the previous studies for the steel general line, so it is excluded from this comparison (the 2018 data does not take the lid into account).

### *V.3.5. Sensitivity analysis: comparison of steel tinplated production with Worldsteel datasets*

Given that the steel production has been modelled with the same database (APEAL 2015) in the previous and current studies, no variation is visible over time. Therefore, in order to provide an estimation, a separate analysis is made specifically on steel tinplated production by using Worldsteel database.

APEAL and Worldsteel databases are methodologically different in terms of representativity, population, technological coverage, therefore the results cannot be compared.

The Table 35 shows the impacts associated with steel tinplated production in Europe for 2018 and 2020 based on Worldsteel datasets (impacts for the production of 1 kg of steel). The impacts are calculated with EF method.

The Figure 24 presents the evolution of the impacts associated with steel tinplated production. The impacts are presented as a percentage based on the year 2018.

The Figure 24 shows a reduction in impacts for all indicators (-2% to -44% depending on the indicator), except for the indicator resource use, minerals and metals (+48%).

*Table 35 - Impacts associated with steel tinplated production in Europe between 2018 and 2020 based on Worldsteel datasets (impacts per 1 kg of steel)*

| Impact categories | 2018 | 2020 | Difference |
|---|---|---|---|
| Climate change | 3.03E+00 | 2.79E+00 | -8% |
| Resource use, fossils | 3.05E+01 | 2.98E+01 | -2% |
| Resource use, minerals and metals | 4.93E-07 | 7.29E-07 | 48% |
| Eutrophication, freshwater | 1.65E-06 | 1.16E-06 | -30% |
| Particulate Matter | 9.75E-08 | 8.99E-08 | -8% |
| Photochemical ozone formation | 6.08E-03 | 5.73E-03 | -6% |
| Acidification | 8.12E-03 | 7.52E-03 | -7% |
| Eutrophication, terrestrial | 1.95E-02 | 1.83E-02 | -6% |
| Eutrophication marine | 1.88E-03 | 1.73E-03 | -8% |
| Human toxicity, cancer | 4.43E-09 | 2.62E-09 | -41% |
| Ecotoxicity, freshwater | 1.83E-01 | 1.14E-01 | -38% |
| Ozone depletion | 3.04E-15 | 1.70E-15 | -44% |
| Ionising radiation, human health | 7.32E-02 | 4.41E-02 | -40% |
| Human toxicity, non-cancer | 1.05E-07 | 6.61E-08 | -37% |

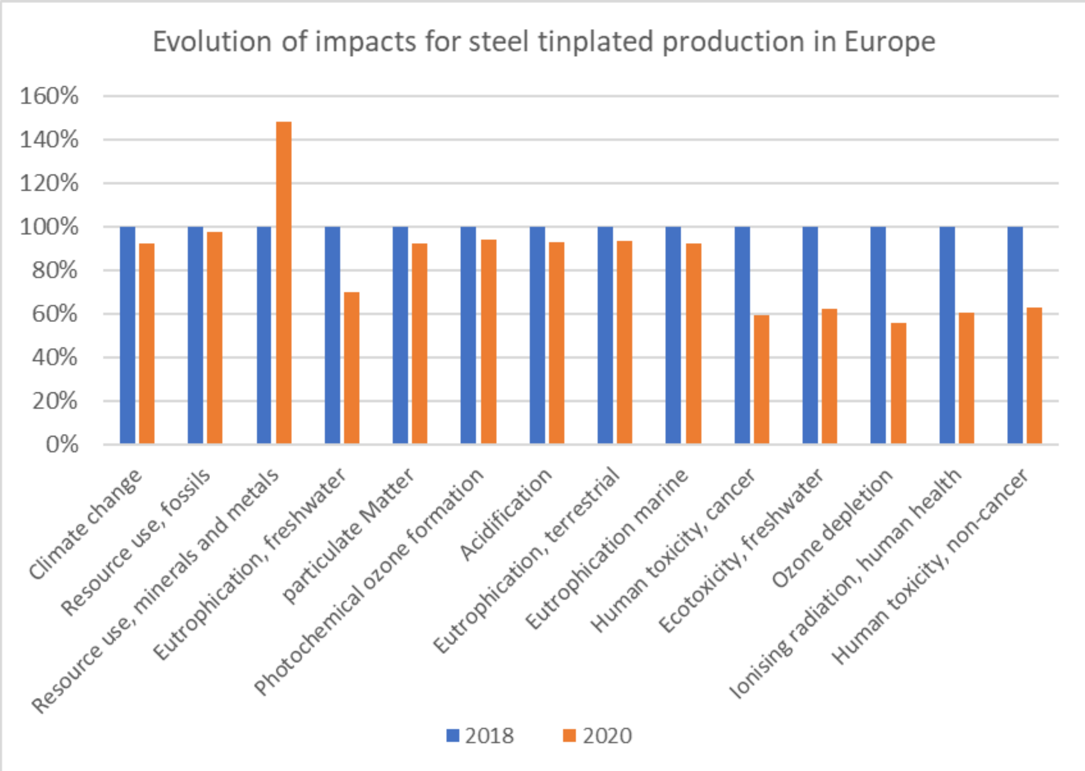



*Figure 24 - Evolution of impacts for steel tinplated production in Europe between 2018 and 2020*

The increase in the impact on the "Resource use, minerals and metals" indicator is explained by two factors[38]:

- different population between 2018 and 2020 data: different grades of steel are manufactured on the sites which affects the results. This factor has some small influence.
- change in upstream processes: the upstream processes have been updated between the two versions of the results. The tin process coming from GaBi database shows a significant change to the input flow (non-renewable element) by two orders of magnitude between the 2018 version and the 2020 version, while the tin ore input remains the same. Also, the molybdenum upstream process was changed from a generic GaBi dataset to one generated by IMOA. This increased the resource impact.

[38] Information provided by Worldsteel

# VI. Conclusions

Life Cycle Inventories (LCIs) have been calculated for the following packaging:

- aluminium beverage can 250 ml
- aluminium beverage can 330 ml
- aluminium beverage can 500 ml
- aluminium food can 125 ml
- steel food can 425 ml
- steel aerosol 420 ml
- steel aerosol 520 ml
- steel general line 2500 ml
- steel closure
- steel speciality

Those LCIs must be used for LCA studies analysing the European metal packaging.

The average results, three sensitivity analyses for different End-of-Life parameters, and an assessment of the improvements made by the metal packaging industry over almost 20 years have been calculated.

The system boundaries described in this study corresponds to: "cradle-to-gate + transport to filling sites + End-of-Life".

## VI.1. Completeness and consistency check

### VI.1.1. Completeness

Completeness checks were carried out at gate-to-gate system boundaries, analysing:

- The completeness of process steps as regards primary data provided by the metal packaging manufacturers
- The energy, input materials as well as emissions from metal packaging manufacturers. Note that in case where no data were available, average from other plants or data from literature (as for the wastewater treatment) were used.

For more details, see section IV.

### VI.1.2. Consistency

Several checks were made in order to validate the data received from the metal packaging manufacturing plants.

When questionable data were identified, an email was sent to the manufacturing plant to validate the data. Three types of data quality tests were performed as part of the data validation process. These tests are presented in the section II.2.6.

As regards the results, plausibility of the results and main source of impacts were assessed having a critical view on data quality.

## VI.2. Limitations

It is important to remind the future users of the results of the study that the recycling credits are already included in the LCI, hence they should *not* be accounted additionally.

In this study the main limitations are related to the quality of the background datasets and the approach to average the information collected from the involved members. The list of limitations is detailed in paragraph III; the main limitations are listed below:

- Limitation due to potential methodological inconsistencies between background databases
- Limitation due to the approach to average the information collected from the different members.
- Limitation due to filling missing data
- Limitation due to simplified modelling for some minor raw materials
- Limitations due to the use of average recycling rate and recycling content
- Limitations due to the geographical scope
- Limitations due to non-regionalized water consumption

## VI.3. Identification of significant issues

Depending on the impact category, the environmental impacts of the metal packaging are mainly shared between the metal production and the packaging manufacturing.

At the raw materials production, impacts is mainly related to the emissions from melting furnace for steel or aluminium production. Melting furnaces emit significant amounts of $CO_2$, $NO_x$ and $SO_x$:

- $CO_2$ emissions reflect emissions from fossil fuel combustion, especially natural gas and heavy fuel oil.
- $NO_X$ emissions are mostly thermal $NO_X$.
- $SO_X$ emissions are mostly driven by sulphur coming from heavy fuel oil.

Those interpretations are analysed from the APEAL LCI's.

At the manufacturing stage, the key issues are related to the energy consumption and the infrastructure:

- The emissions linked to the consumption and extraction of natural gas.
- The emissions linked to the production of electricity.
- The direct emissions of NOX, SOX and VOC

- For the resources consumption, main of the impact of the manufacturing stage is related to the consumption of cadmium and lead when building the infrastructures of the plants. This seems overestimated and may be due to assumptions on the use of rare elements for buildings

## VI.4. Recommendations

This assessment reflects the existing technical situation for the year 2018 and, compared to the European metal production in 2017, represents 42% of the European production volume of steel packaging and 82% of the European production volume of aluminium packaging.

The conditions of packaging manufacturing industry will change over time affecting the energy and material inputs and subsequent emissions.

Therefore, it is recommended to perform frequent update of the LCIs (at least every 5 years).

In the next update of the study, it is recommended to use the Worldsteel datasets or the updated APEAL dataset for the modelling.

# VII. Annex

## VII.1. Electricity mix modelling

For each country, IEA provides data on the quantity of electricity that is produced, exported and imported. Based on these three types of information, it is possible to determine the electricity consumption mix. Electricity consumed is determined based on the following formula:

*elec produced + elec imported - elec exported.*

The consumption mix is obtained from the combination of two production mixes:

- For the share that is imported (% imports), the mix to be assigned is approximated by the continental production mix, assuming importations from the corresponding continental market, on average.
- For the part of electricity that is consumed locally, i.e. that is not imported (1 - % imports), the mix is taken equal to the production mix of the considered country. The calculation is hence made according to the following formula:

*Consumption mix = % imports * [continental mix] + (1 - % imports) * [country-specific production mix]*

In this study, the attributional approach is used to model the electricity mixes. In this approach, the allocation between the consumers is uniform. In other words, in order to answer the demand of a consumer, all power and heat plants in the country contribute proportionally to their share in the national electricity generation on a yearly basis.

Electricity supply occurs at different voltage levels (110 V, 220 V...). Figures on total losses come from IEA data sources (2009 data) and figures on the electricity losses for each of the voltage levels are based on ecoinvent modelling (7% of the total losses occur on high voltage, 13% on medium voltage and 80% in low voltage levels).

| Parameter | Data | Secondary datasets used in the LCA model |
|---|---|---|
| Electricity mix used to model the metal packaging production by MPE members | | |
| Coal | 29% | 64% electricity production, hard coal, high voltage, DE, EI v3.5<br>36% electricity production, lignite, high voltage, DE, EI v3.5 |
| Hydro | 13% | 5% electricity production, hydro, pumped storage high voltage, DE, EI v3.5<br>43% electricity production, hydro, reservoir, alpine region, high voltage, NO, EI v3.5<br>8% electricity production, hydro, reservoir, non-alpine region, high voltage, SE, EI v3.5<br>43% electricity production, hydro, run-of-river, high voltage, PL, EI v3.5 |
| Gaz | 22% | 44% electricity production, natural gas, combined cycle power plant, high voltage, IT; EI v3.5<br>36% electricity production, natural gas, conventional power plant, high voltage, IT; EI v3.5<br>20% heat and power co-generation, biogas, gas engine; high voltage, IT ; EI v3.5 |
| Nuclear | 22% | 93% electricity production, nuclear, pressure water reactor, high voltage, FR, EI v3.5<br>7% electricity production, nuclear, boiling water reactor, high voltage, DE, EI v3.5 |
| Oil | 2% | electricity production, oil, high voltage, GR, EI v3.5 |
| Wind | 12% | 26% electricity production, wind, 1-3MW turbine, offshore, high voltage, DK, EI v3.5<br>74% electricity production, wind, 1-3MW turbine, onshore, high voltage, DK, EI v3.5 |

## VII.2. Datasets used

| Product/process | Type of activity | Secondary dataset |
|---|---|---|
| Aluminium | Aluminium ingot production | Aluminium ingot - EU-27: Aluminium ingot mix EAA update 2015 (consumption mix) |
| Aluminium | Aluminium sheet production | Aluminium sheet - EU-27: Aluminium sheet [p-agg] EAA update 2015 |
| Aluminium | Aluminium remelting | Aluminium rolling ingot - EU-27: Remelting & Casting of rolling scrap [p-agg] EAA update 2015 |
| Aluminium | Aluminium landfill | waste aluminium - treatment of waste aluminium, sanitary landfill - CH |
| Aluminium | Aluminium incineration | scrap aluminium - treatment of scrap aluminium, municipal incineration - Europe without Switzerland |
| Steel | Steel tinplate production | Tin plate - Steel tinplate without EoL recycling - 1 kg (typical thickness between 0.13 - 0.49 mm) at plant - APEAL 2015 - RER |
| Steel | Steel recycling | Steel recycled - Recycling Steel APEAL 2012 - RER |
| Steel | Steel landfill | scrap steel - treatment of scrap steel, inert material landfill - Europe without Switzerland |
| Steel | Steel incineration | scrap steel - treatment of scrap steel, municipal incineration - Europe without Switzerland |
| Other raw materials | Inks, coatings and sealings | 1-butanol - hydroformylation of propylene - RER |
| Other raw materials | Inks, coatings and sealings | acetone, liquid - acetone production, liquid - RER |
| Other raw materials | Inks, coatings and sealings | acrylic varnish, without water, in 87.5% solution state - acrylic varnish production, product in 87.5% solution state - RER |
| Other raw materials | Inks, coatings and sealings | butadiene - butadiene production - RER |
| Other raw materials | Inks, coatings and sealings | carbon black - carbon black production - GLO |
| Other raw materials | Inks, coatings and sealings | dimethylamine - dimethylamine production - RER |
| Other raw materials | Inks, coatings and sealings | epoxy resin, liquid - epoxy resin production, liquid - RER |
| Other raw materials | Inks, coatings and sealings | ethylene glycol monoethyl ether - ethylene glycol monoethyl ether production - RER |
| Other raw materials | Inks, coatings and sealings | limestone, crushed, washed - limestone production, crushed, washed - CH |
| Other raw materials | Inks, coatings and sealings | paraffin - paraffin production - RER |
| Other raw materials | Inks, coatings and sealings | polyester resin, unsaturated - polyester resin production, unsaturated - RER |
| Other raw materials | Inks, coatings and sealings | polyvinylchloride, bulk polymerised - polyvinylchloride production, bulk polymerisation - RER |
| Other raw materials | Inks, coatings and sealings | polyvinylchloride, emulsion polymerised - polyvinylchloride production, emulsion polymerisation - RER |
| Other raw materials | Inks, coatings and sealings | polyvinylchloride, suspension polymerised - polyvinylchloride production, suspension polymerisation - RER |
| Other raw materials | Inks, coatings and sealings | solvent, organic - solvent production, organic - GLO |

| | | |
|---|---|---|
| Other raw materials | Inks, coatings and sealings | styrene - styrene production - RER |
| Other raw materials | Inks, coatings and sealings | triethanolamine - ethanolamine production - RER |
| Heat production | Heat production | heat, central or small-scale, natural gas - propane extraction, from liquefied petroleum gas - GLO |
| Heat production | Heat production | heat, central or small-scale, other than natural gas - heat production, light fuel oil, at boiler 100kW, non-modulating - Europe without Switzerland |
| Heat production | Heat production | heat, central or small-scale, other than natural gas - heat production, lignite briquette, at stove 5-15kW - Europe without Switzerland |
| Heat production | Heat production | heat, district or industrial, natural gas - heat production, natural gas, at industrial furnace low-NOx >100kW - Europe without Switzerland |
| Heat production | Heat production | heat, district or industrial, other than natural gas - heat production, at hard coal industrial furnace 1-10MW - Europe without Switzerland |
| Heat production | Heat production | heat, district or industrial, other than natural gas - heat production, heavy fuel oil, at industrial furnace 1MW - Europe without Switzerland |
| Heat production | Heat production | heat, district or industrial, other than natural gas - heat production, propane, at industrial furnace >100kW - RoW |
| Electricity | Electricity | electricity, high voltage - electricity production, hard coal - DE |
| Electricity | Electricity | electricity, high voltage - electricity production, hydro, pumped storage - DE |
| Electricity | Electricity | electricity, high voltage - electricity production, hydro, reservoir, alpine region - NO |
| Electricity | Electricity | electricity, high voltage - electricity production, hydro, reservoir, non-alpine region - SE |
| Electricity | Electricity | electricity, high voltage - electricity production, hydro, run-of-river - PL |
| Electricity | Electricity | electricity, high voltage - electricity production, lignite - DE |
| Electricity | Electricity | electricity, high voltage - electricity production, natural gas, combined cycle power plant - IT |
| Electricity | Electricity | electricity, high voltage - electricity production, natural gas, conventional power plant - IT |
| Electricity | Electricity | electricity, high voltage - electricity production, nuclear, boiling water reactor - DE |
| Electricity | Electricity | electricity, high voltage - electricity production, nuclear, pressure water reactor - FR |
| Electricity | Electricity | electricity, high voltage - electricity production, oil - GR |
| Electricity | Electricity | electricity, high voltage - electricity production, wind, 1-3MW turbine, offshore - DK |
| Electricity | Electricity | electricity, high voltage - electricity production, wind, 1-3MW turbine, onshore - DK |
| Electricity | Electricity | electricity, high voltage - heat and power co-generation, biogas, gas engine - IT |
| Electricity | Electricity | electricity, high voltage - market group for electricity, high voltage - Europe without Switzerland |
| Metal working factory | Factory production | metal working factory - metal working factory construction - RER |
| Metal working factory | Machine production | metal working machine, unspecified - metal working machine production, unspecified - RER |
| Manufacturing | Water | tap water - market group for tap water - RER |
| Manufacturing | Waste | hazardous waste, for incineration - treatment of hazardous waste, hazardous waste incineration - Europe without Switzerland |
| Manufacturing | Waste | municipal solid waste - treatment of municipal solid waste, incineration - CH |
| Manufacturing | Waste | municipal solid waste - treatment of municipal solid waste, sanitary landfill - CH |

| | | |
|---|---|---|
| Transport | Truck | decommissioned road - market for decommissioned road - GLO |
| Transport | Truck | diesel, low-sulfur - market for diesel, low-sulfur - Europe without Switzerland |
| Transport | Truck | lorry, 40 metric ton - market for lorry, 40 metric ton - GLO |
| Transport | Truck | maintenance, lorry 40 metric ton - market for maintenance, lorry 40 metric ton - GLO |
| Transport | Truck | road - market for road - GLO |
| Transport | Truck | road maintenance - market for road maintenance - GLO |
| Transport | Truck | Transport - Heavy Duty Trucks Articulated 34 - 40 t - Diesel - Euro V - Highway - RER |
| Transport | Truck | Transport - Heavy Duty Trucks Articulated 34 - 40 t - Diesel - Euro V - Rural - RER |
| Transport | Truck | Transport - Heavy Duty Trucks Articulated 34 - 40 t - Diesel - Euro V - Urban - RER |
| Transport | Truck | Transport - Heavy Duty Trucks Articulated 34 - 40 t - Diesel - Euro VI - Highway - RER |
| Transport | Truck | Transport - Heavy Duty Trucks Articulated 34 - 40 t - Diesel - Euro VI - Rural - RER |
| Transport | Truck | Transport - Heavy Duty Trucks Articulated 34 - 40 t - Diesel - Euro VI - Urban - RER |
| Transport | Truck | used lorry, 40 metric ton - market for used lorry, 40 metric ton - GLO |
| Transport | Train | transport, freight train - transport, freight train, diesel - Europe without Switzerland |
| Transport | Train | transport, freight train - transport, freight train, electricity - Europe without Switzerland |
| Transport | Ship | maintenance, freight ship, transoceanic - maintenance, freight ship, transoceanic - RER |
| Transport | Ship | port facilities - port facilities construction - RER |
| Transport | Ship | transport, freight, sea, transoceanic ship - transport, freight, sea, transoceanic ship - GLO |
| Secondary and tertiary packaging | - | containerboard, linerboard - containerboard production, linerboard, kraftliner - RER |
| Secondary and tertiary packaging | - | containerboard, linerboard - containerboard production, linerboard, testliner - RER |
| Secondary and tertiary packaging | - | EUR-flat pallet - EUR-flat pallet production - RER |
| Secondary and tertiary packaging | - | municipal waste collection service by 21 metric ton lorry - municipal waste collection service by 21 metric ton lorry - CH |
| Secondary and tertiary packaging | - | polyethylene, high density, granulate - polyethylene production, high density, granulate - RER |
| Secondary and tertiary packaging | - | polyethylene, high density, granulate, recycled - polyethylene production, high density, granulate, recycled - Europe without Switzerland |
| Secondary and tertiary packaging | - | polyethylene, low density, granulate - polyethylene production, low density, granulate - RER |
| Secondary and tertiary packaging | - | polypropylene, granulate - polypropylene production, granulate - RER |
| Secondary and tertiary packaging | - | treatment of waste paperboard, municipal incineration - CH |
| Secondary and tertiary packaging | - | treatment of waste paperboard, sanitary landfill - CH |
| Secondary and tertiary packaging | - | treatment of waste wood, untreated, municipal incineration - CH |

| | | |
|---|---|---|
| Secondary and tertiary packaging | - | treatment of waste wood, untreated, sanitary landfill - CH |
| Secondary and tertiary packaging | - | waste paperboard - treatment of waste paperboard, sanitary landfill - CH |
| Secondary and tertiary packaging | - | waste polyethylene - treatment of waste polyethylene, municipal incineration - CH |
| Secondary and tertiary packaging | - | waste polyethylene - treatment of waste polyethylene, sanitary landfill - CH |
| Secondary and tertiary packaging | - | waste polypropylene - treatment of waste polypropylene, municipal incineration - RoW |
| Secondary and tertiary packaging | - | waste polypropylene - treatment of waste polypropylene, sanitary landfill - CH |
| Secondary and tertiary packaging | - | wood chips, wet, measured as dry mass - wood chips production, softwood, at sawmill - CH |

## VII.3. Sensitivity analysis: transport of pre-consumer scrap

The results **without the transport of pre-consumer scrap** are presented in Table 24 and Table 25 of the report and reported here below for convenience.

*Table 24 - Impact results based on the closed-loop scenario for* ***aluminium packaging*** *– Results are* ***expressed by 1000 units of packaging***

| Impact categories | Unit | Aluminium beverage can 250 ml | Aluminium beverage can 330 ml | Aluminium beverage can 500 ml | Aluminium food can 125 ml |
|---|---|---|---|---|---|
| Climate Change | kg CO2-Eq. | 5.06E+01 | 6.07E+01 | 7.77E+01 | 7.45E+01 |
| Resource use, fossils | Energy, MJ | 7.55E+02 | 9.07E+02 | 1.17E+03 | 1.09E+03 |
| Particulate Matter | disease incidence | 2.58E-06 | 3.08E-06 | 3.87E-06 | 3.69E-06 |
| Acidification | Moles H+-eq. | 2.71E-01 | 3.24E-01 | 4.09E-01 | 3.76E-01 |
| Photochemical ozone formation - human health | kg NMVOC-eq. | 1.56E-01 | 1.86E-01 | 2.36E-01 | 2.43E-01 |
| Eutrophication terrestrial | Moles N-eq. | 7.04E-01 | 8.44E-01 | 1.07E+00 | 9.37E-01 |
| Resource use, minerals and metals | kg Antimony eq. | 7.64E-05 | 9.21E-05 | 1.24E-04 | 1.29E-04 |
| Eutrophication freshwater | kg P-eq. | 8.18E-03 | 9.91E-03 | 1.27E-02 | 7.31E-03 |
| Water use | Volume m3-world eq. | 1.20E+01 | 1.45E+01 | 1.86E+01 | 1.27E+01 |
| Land Use | dimensionless (pt) | 3.33E+02 | 4.03E+02 | 5.49E+02 | 5.88E+02 |
| Eutrophication marine | kg N-eq. | 5.05E-02 | 6.03E-02 | 7.63E-02 | 7.53E-02 |
| Ozone depletion | kg CFC11-eq. | 2.89E-06 | 3.53E-06 | 5.00E-06 | 5.29E-06 |
| Ionising radiation - human health | kBq Uranium-235 eq. | 7.42E+00 | 8.89E+00 | 1.12E+01 | 9.49E+00 |
| Cancer human health effects | CTUh | 2.05E-07 | 2.47E-07 | 3.34E-07 | 3.31E-07 |
| Non-cancer human health effects | CTUh | 2.40E-06 | 2.89E-06 | 3.73E-06 | 3.17E-06 |
| Ecotoxicity freshwater | CTUe | 7.84E+00 | 9.46E+00 | 1.28E+01 | 1.21E+01 |

*Table 25 - Impact results based on the closed-loop scenario for **steel packaging** – Results are **expressed by 1000 units of packaging***

| Impact categories | Unit | Steel food can 425 ml | Steel aerosol can 420 ml | Steel aerosol can 520 ml | Steel general line 2500 ml | Steel closure | Steel speciality |
|---|---|---|---|---|---|---|---|
| Climate Change | kg CO2-Eq. | 1.03E+02 | 1.57E+02 | 1.78E+02 | 6.06E+02 | 1.87E+01 | 3.63E+02 |
| Resource use, minerals and metals | kg Antimony eq. | 2.08E-03 | 3.02E-03 | 3.42E-03 | 1.31E-02 | 3.24E-04 | 7.11E-03 |
| Resource use, fossils | Energy, MJ | 1.56E+03 | 2.39E+03 | 2.71E+03 | 9.06E+03 | 3.17E+02 | 5.52E+03 |
| Particulate Matter | disease incidence | 6.38E-06 | 9.47E-06 | 1.07E-05 | 3.90E-05 | 1.07E-06 | 2.27E-05 |
| Acidification | Moles H+-eq. | 5.35E-01 | 8.07E-01 | 9.14E-01 | 3.22E+00 | 9.37E-02 | 1.89E+00 |
| Photochemical ozone formation - human health | kg NMVOC-eq. | 4.09E-01 | 6.00E-01 | 6.80E-01 | 2.51E+00 | 7.85E-02 | 1.43E+00 |
| Eutrophication terrestrial | Moles N-eq. | 1.58E+00 | 2.39E+00 | 2.71E+00 | 9.43E+00 | 2.70E-01 | 5.44E+00 |
| Water use | Volume m3-world eq. | 5.28E+01 | 7.56E+01 | 8.54E+01 | 3.17E+02 | 8.95E+00 | 1.86E+02 |
| Eutrophication marine | kg N-eq. | 1.32E-01 | 1.96E-01 | 2.22E-01 | 8.10E-01 | 2.22E-02 | 4.60E-01 |
| Eutrophication freshwater | kg P-eq. | 1.19E-02 | 2.03E-02 | 2.30E-02 | 6.03E-02 | 2.66E-03 | 4.30E-02 |
| Ozone depletion | kg CFC11-eq. | 1.04E-05 | 1.60E-05 | 1.82E-05 | 5.89E-05 | 1.94E-06 | 3.85E-05 |
| Land Use | dimensionless (pt) | 7.52E+02 | 1.11E+03 | 1.27E+03 | 4.63E+03 | 1.20E+02 | 2.68E+03 |
| Ionising radiation - human health | kBq Uranium-235 eq. | 1.16E+01 | 1.83E+01 | 2.08E+01 | 6.71E+01 | 2.03E+00 | 4.14E+01 |
| Cancer human health effects | CTUh | 8.00E-07 | 1.21E-06 | 1.37E-06 | 4.98E-06 | 1.40E-07 | 3.08E-06 |
| Non-cancer human health effects | CTUh | 3.10E-05 | 4.56E-05 | 5.16E-05 | 1.92E-04 | 4.82E-06 | 1.09E-04 |
| Ecotoxicity freshwater | CTUe | 4.45E+01 | 6.52E+01 | 7.39E+01 | 2.78E+02 | 7.20E+00 | 1.64E+02 |

Table 36 and Table 37 show the results **including the transport of pre-consumer scrap**. A distance of 500 km per truck is taken into account.

*Table 36 - Impact results based on the closed-loop scenario for* ***aluminium packaging including the transport of pre-consumer scrap*** *– Results are* ***expressed by 1000 units of packaging***

| Impact categories | Unit | Aluminium beverage can 250 ml | Aluminium beverage can 330 ml | Aluminium beverage can 500 ml | Aluminium food can 125 ml |
|---|---|---|---|---|---|
| Climate Change | kg CO2-Eq. | 5.07E+01 | 6.08E+01 | 7.79E+01 | 7.48E+01 |
| Resource use, fossils | Energy, MJ | 7.57E+02 | 9.09E+02 | 1.17E+03 | 1.09E+03 |
| Particulate Matter | disease incidence | 2.59E-06 | 3.08E-06 | 3.88E-06 | 3.70E-06 |
| Acidification | Moles H+-eq. | 2.72E-01 | 3.25E-01 | 4.10E-01 | 3.77E-01 |
| Photochemical ozone formation - human health | kg NMVOC-eq. | 1.56E-01 | 1.86E-01 | 2.37E-01 | 2.44E-01 |
| Eutrophication terrestrial | Moles N-eq. | 7.05E-01 | 8.45E-01 | 1.07E+00 | 9.39E-01 |
| Resource use, minerals and metals | kg Antimony eq. | 7.68E-05 | 9.26E-05 | 1.24E-04 | 1.30E-04 |
| Eutrophication freshwater | kg P-eq. | 8.19E-03 | 9.92E-03 | 1.28E-02 | 7.34E-03 |
| Water use | Volume m3-world eq. | 1.20E+01 | 1.45E+01 | 1.86E+01 | 1.27E+01 |
| Land Use | dimensionless (pt) | 3.35E+02 | 4.05E+02 | 5.51E+02 | 5.92E+02 |
| Eutrophication marine | kg N-eq. | 5.05E-02 | 6.04E-02 | 7.65E-02 | 7.55E-02 |
| Ozone depletion | kg CFC11-eq. | 2.91E-06 | 3.56E-06 | 5.04E-06 | 5.34E-06 |
| Ionising radiation - human health | kBq Uranium-235 eq. | 7.43E+00 | 8.90E+00 | 1.12E+01 | 9.50E+00 |
| Cancer human health effects | CTUh | 2.06E-07 | 2.48E-07 | 3.36E-07 | 3.34E-07 |
| Non-cancer human health effects | CTUh | 2.41E-06 | 2.90E-06 | 3.74E-06 | 3.18E-06 |
| Ecotoxicity freshwater | CTUe | 7.88E+00 | 9.50E+00 | 1.28E+01 | 1.22E+01 |

*Table 37 - Impact results based on the closed-loop scenario for* ***steel packaging including the transport of pre-consumer scrap*** *– Results* ***are expressed by 1000 units of packaging***

| Impact categories | Unit | Steel food can 425 ml | Steel aerosol can 420 ml | Steel aerosol can 520 ml | Steel general line 2500 ml | Steel closure | Steel speciality |
|---|---|---|---|---|---|---|---|
| Climate Change | kg CO2-Eq. | 1.03E+02 | 1.58E+02 | 1.79E+02 | 6.07E+02 | 1.88E+01 | 3.64E+02 |
| Resource use, minerals and metals | kg Antimony eq. | 2.08E-03 | 3.02E-03 | 3.42E-03 | 1.31E-02 | 3.24E-04 | 7.12E-03 |
| Resource use, fossils | Energy, MJ | 1.56E+03 | 2.40E+03 | 2.72E+03 | 9.09E+03 | 3.17E+02 | 5.54E+03 |
| Particulate Matter | disease incidence | 6.39E-06 | 9.49E-06 | 1.07E-05 | 3.90E-05 | 1.07E-06 | 2.27E-05 |
| Acidification | Moles H+-eq. | 5.36E-01 | 8.09E-01 | 9.16E-01 | 3.22E+00 | 9.38E-02 | 1.89E+00 |
| Photochemical ozone formation - human health | kg NMVOC-eq. | 4.10E-01 | 6.02E-01 | 6.82E-01 | 2.52E+00 | 7.86E-02 | 1.43E+00 |
| Eutrophication terrestrial | Moles N-eq. | 1.58E+00 | 2.40E+00 | 2.72E+00 | 9.45E+00 | 2.71E-01 | 5.45E+00 |
| Water use | Volume m3-world eq. | 5.28E+01 | 7.56E+01 | 8.55E+01 | 3.17E+02 | 8.95E+00 | 1.86E+02 |
| Eutrophication marine | kg N-eq. | 1.32E-01 | 1.96E-01 | 2.22E-01 | 8.11E-01 | 2.23E-02 | 4.62E-01 |
| Eutrophication freshwater | kg P-eq. | 1.19E-02 | 2.04E-02 | 2.31E-02 | 6.05E-02 | 2.67E-03 | 4.32E-02 |
| Ozone depletion | kg CFC11-eq. | 1.04E-05 | 1.61E-05 | 1.83E-05 | 5.93E-05 | 1.95E-06 | 3.89E-05 |
| Land Use | dimensionless (pt) | 7.56E+02 | 1.12E+03 | 1.27E+03 | 4.65E+03 | 1.21E+02 | 2.70E+03 |
| Ionising radiation - human health | kBq Uranium-235 eq. | 1.17E+01 | 1.84E+01 | 2.08E+01 | 6.72E+01 | 2.03E+00 | 4.15E+01 |
| Cancer human health effects | CTUh | 8.03E-07 | 1.22E-06 | 1.38E-06 | 4.99E-06 | 1.40E-07 | 3.09E-06 |
| Non-cancer human health effects | CTUh | 3.10E-05 | 4.57E-05 | 5.16E-05 | 1.92E-04 | 4.83E-06 | 1.09E-04 |
| Ecotoxicity freshwater | CTUe | 4.46E+01 | 6.54E+01 | 7.41E+01 | 2.79E+02 | 7.21E+00 | 1.65E+02 |

The percentages of change are presented in Table 38 and Table 39.

*Table 38 – Percentage change for **aluminium packaging due to the inclusion of the transport of pre-consumer scrap** (impact results based on the closed-loop scenario)*

| Impact categories | Aluminium beverage can 250 ml | Aluminium beverage can 330 ml | Aluminium beverage can 500 ml | Aluminium food can 125 ml |
|---|---|---|---|---|
| Climate Change | 0.2% | 0.2% | 0.2% | 0.3% |
| Resource use, fossils | 0.2% | 0.2% | 0.2% | 0.4% |
| Particulate Matter | 0.1% | 0.1% | 0.1% | 0.2% |
| Acidification | 0.1% | 0.1% | 0.1% | 0.2% |
| Photochemical ozone formation - human health | 0.2% | 0.2% | 0.2% | 0.3% |
| Eutrophication terrestrial | 0.1% | 0.1% | 0.1% | 0.2% |
| Resource use, minerals and metals | 0.5% | 0.5% | 0.5% | 0.8% |
| Eutrophication freshwater | 0.1% | 0.1% | 0.1% | 0.4% |
| Water use | 0.1% | 0.1% | 0.1% | 0.3% |
| Land Use | 0.5% | 0.5% | 0.5% | 0.7% |
| Eutrophication marine | 0.2% | 0.2% | 0.2% | 0.3% |
| Ozone depletion | 0.9% | 0.8% | 0.7% | 1.1% |
| Ionising radiation - human health | 0.1% | 0.1% | 0.1% | 0.2% |
| Cancer human health effects | 0.5% | 0.5% | 0.5% | 0.8% |
| Non-cancer human health effects | 0.3% | 0.3% | 0.2% | 0.5% |
| Ecotoxicity freshwater | 0.5% | 0.5% | 0.4% | 0.7% |

*Table 39 – Percentage change for **steel packaging due to the inclusion of the transport of pre-consumer scrap** (impact results based on the closed-loop scenario)*

| Impact categories | Steel food can 425 ml | Steel aerosol can 420 ml | Steel aerosol can 520 ml | Steel general line 2500 ml | Steel closure | Steel speciality |
|---|---|---|---|---|---|---|
| Climate Change | 0.3% | 0.3% | 0.3% | 0.3% | 0.2% | 0.4% |
| Resource use, minerals and metals | 0.1% | 0.1% | 0.1% | 0.0% | 0.0% | 0.1% |
| Resource use, fossils | 0.3% | 0.3% | 0.3% | 0.3% | 0.2% | 0.4% |
| Particulate Matter | 0.1% | 0.2% | 0.2% | 0.1% | 0.1% | 0.2% |
| Acidification | 0.2% | 0.2% | 0.2% | 0.2% | 0.1% | 0.3% |
| Photochemical ozone formation - human health | 0.2% | 0.3% | 0.3% | 0.2% | 0.2% | 0.3% |
| Eutrophication terrestrial | 0.2% | 0.2% | 0.2% | 0.1% | 0.1% | 0.2% |
| Water use | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% |
| Eutrophication marine | 0.2% | 0.2% | 0.2% | 0.2% | 0.1% | 0.3% |
| Eutrophication freshwater | 0.3% | 0.3% | 0.3% | 0.3% | 0.2% | 0.4% |
| Ozone depletion | 0.6% | 0.7% | 0.7% | 0.6% | 0.5% | 0.8% |
| Land Use | 0.6% | 0.7% | 0.7% | 0.5% | 0.5% | 0.8% |
| Ionising radiation - human health | 0.2% | 0.2% | 0.2% | 0.2% | 0.1% | 0.3% |
| Cancer human health effects | 0.4% | 0.4% | 0.4% | 0.3% | 0.3% | 0.5% |
| Non-cancer human health effects | 0.1% | 0.1% | 0.1% | 0.0% | 0.0% | 0.1% |
| Ecotoxicity freshwater | 0.2% | 0.3% | 0.3% | 0.2% | 0.2% | 0.3% |

## VII.4. Critical review report

*Critical Review*
*of*

*"Life Cycle Assessment of metal packaging in Europe - update*
*February 2022"*

according to
ISO 14040, ISO 14044 and ISO/TS 14071

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SOL 21-008.1

29 March 2022

for

**Metal Packaging Europe**

# 1 Introduction

RDC Environment has performed a LCA study for Metal Packaging Europe (MPE). The report of this study is entitled "**Life Cycle Assessment of metal packaging in Europe - update**" and is dated **February** 2022.

The goals of the study were the following:

- "To determine the environmental impacts and credits (i.e. avoided impacts) along the life cycle of metal packaging produced in Europe". This will be done by generating a LCA of the following packaging [...]" (the detailed list is displayed on page 15 of the LCA report).
- "To track performance of the metal packaging production in Europe by comparing the impacts of the 2018 production year with those ones of the previous MPE's LCA studies: [...]" (the list of previous studies is provided on page 15 of the LCA report)
- "To generate Life Cycle Inventories (LCIs) of the production phase and some selected further life cycle phases of the metal packaging produced in Europe according to the following boundaries: Cradle to gate + transport to filling site + end-of-life."

This study has been done applying ISO 14040:2006 and ISO 14044:2006 recommendations and may be published. It is not a comparative LCA study. Therefore, Metal Packaging Europe & RDC Environment have requested one expert to make a critical review (CR) of this study.

The present report is the "Final CR report" prepared by Solinnen. This CR report, including appendices, is dedicated to be integrated as a whole within the final report of RDC Environment.

# 2 Presentation of the experts of Solinnen

Dipl. Eng. Delphine Bauchot, Director at Solinnen has more than 20 years of experience of the LCA practice, including CR practice. Ms. Bauchot has applied the LCA practice to different packaging systems and metal products systems. She was involved in the review of some previous studies performed by RDC Environment for MPE.

The choice of the expert has been made to make available competencies which cover the studied topics, i.e. sector specific expertise (steel/aluminum & packaging/distribution) and the LCA expertise.

## 3 Nature of the CR work, CR process and limitations

The expert has worked according to the requirements of ISO 14040:2006 and 14044:2006 concerning CR, and according to the requirements of ISO/TS 14071. According to ISO 14044, the CR process has worked in order to check if:

- the methods used to carry out the LCA are consistent with ISO 14044 requirements,
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study,
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

The first goal of the CR was to provide RDC Environment with detailed comments in order for RDC Environment to improve its work. These comments have covered methodology choices and reporting. The expert has checked the plausibility of the data used in the report, through sample tests, including a review of the model and database within the software used by RDC Environment. Additionally, the present final CR report provides the future reader of the report with information that will help understanding the report.

The CR work has started after the generation of a first full LCA report by RDC Environment. The work has started in November 2021 and ended up in March 2022. During this period, different oral and written exchanges have been held between the expert and RDC Environment, including clarification exchanges regarding the CR comments, and the production of one new final version of the report by RDC Environment. RDC Environment has taken into account most of the comments and significantly modified and improved its report.

The present final CR report is the synthesis of the final comments by the expert. Some detailed comments are provided within this final CR report, together with the full detailed exchanges as appendix (this appendix is made according to Annex A of ISO/TS 14071).

The present CR report is delivered to Metal Packaging Europe and RDC Environment. The expert cannot be held responsible of the use of its work by any third party. The conclusions of the expert cover the **full report** from RDC Environment "Life Cycle Assessment of metal packaging in Europe -update- February 2022" and no other report, extract or publication which may eventually been done. The expert conclusions have been set given the current state of the art and the information which has been received. These expert conclusions could have been different in a different context.

## 4 Conclusions of the review

The CR first set of 95 comments covered the following points:

- Deviation (9 comments),
- Recommendation (69 comments),
- Editorial comments and other miscellaneous comments (17 comments).

Out of these comments, 40 covered methodological issues, 19 about Data and technical issues, 14 about Analysis and Interpretation, 22 covered other and miscellaneous issues.

An exhaustive work has been done by RDC Environment and Romeo Pavanello from Metal Packaging Europe to provide a final report integrating answers to all the CR points, and the final result has improved as compared to the first one.

As a whole, the expert considers that the final report answers to the goals which have been set up, within the scope of the limitations that are mentioned in the report.

# 5 Detailed comments

The following lines bring some highlights that a reader of the final LCA report may use to assist his reading and understanding of the report. They mainly recap some critical comments which were not addressed, or which were addressed in a way which is different from what the expert expected. The reading of the detailed comments and answers (see appendices) is recommended.

## *5.1 Consistency of methods used with ISO 14040 and ISO 14044 requirements*

The final structure of the report reflects the ISO 14040 and ISO 14044 standard requirements. The methods that have been selected for reference calculations are clearly presented.

The critical review of the previous study on aluminium beverage cans in 2019 advised Metal Packaging Europe to consider applying the PEF approach in its next study in order to be prepared to future requests of stakeholders and provide LCA practitioners with representative LCIs of beverage cans that will comply with PEF requirements. Such recommendation has been followed and this is an improvement.

Similarly to critical review performed by Solinnen on previous MPE studies, no assessment of the consistency of the methodology applied for the metal production has been done, since these choices have been done by the data providers (European Aluminium and APEAL).

## *5.2 Scientific and technical validity*

The scientific and technical validity of the work is high due to the exhaustive approach which has been followed.

As recommended in critical review of the previous study "LCA of Aluminium Beverage Cans in Europe, March 2019", MPE has used specific data for the quantities of coatings, inks and sealings for all metal packaging as well as for the coating composition for aluminium cans.

Also, this study has highlighted the limit of the mass allocation used for electricity consumption allocation and the need to collect specific data for each type of packaging or, if needed, to consider different kinds of allocation and select the most appropriate one. This is a recommendation for future MPE studies.

### 5.3 Appropriateness of data used in relation to the goal of the study

The overall data used and the calculations done are adapted to provide the final results in the scope of the goal of the study.

Like in previous studies made by MPE, one can also regret that there were no statistics about the share of the different end-of-life scenarios (close-loop recycling, open-loop recycling and others) that would allow to give an average European scenario.

As clearly explained in the report, APEAL dataset have been used for steel modeling whereas Worldsteel datasets are more up-to-date regarding the produced steel in Europe. This choice allows comparison with previous studies and such approach is quite understandable. Nevertheless the reader needs to keep this limitation in mind when considering the results and MPE shall update its study as soon as APEAL provide new datasets.

### 5.4 Validity of interpretations in the scope of the limitations of the study

The conclusions (VI.) are adapted to the goal of the study, taking into account the limitations of the study (chapter III and VI.2) which are adapted and clearly stated: the reader shall take it into account when reading the conclusions.

### 5.5 Transparency and consistency

The overall level transparency and consistency of the report is high, and in line with the ISO 14044:2006 expectations. One can expect that this LCA report will be accompanied by the detailed LCI of the studied products since it is one of the goal of the study.

## 6 Appendices

The detailed CR tables exchanged during the work are the appendices of the present CR report. They recap the detailed exchanges between the expert and RDC Environment.