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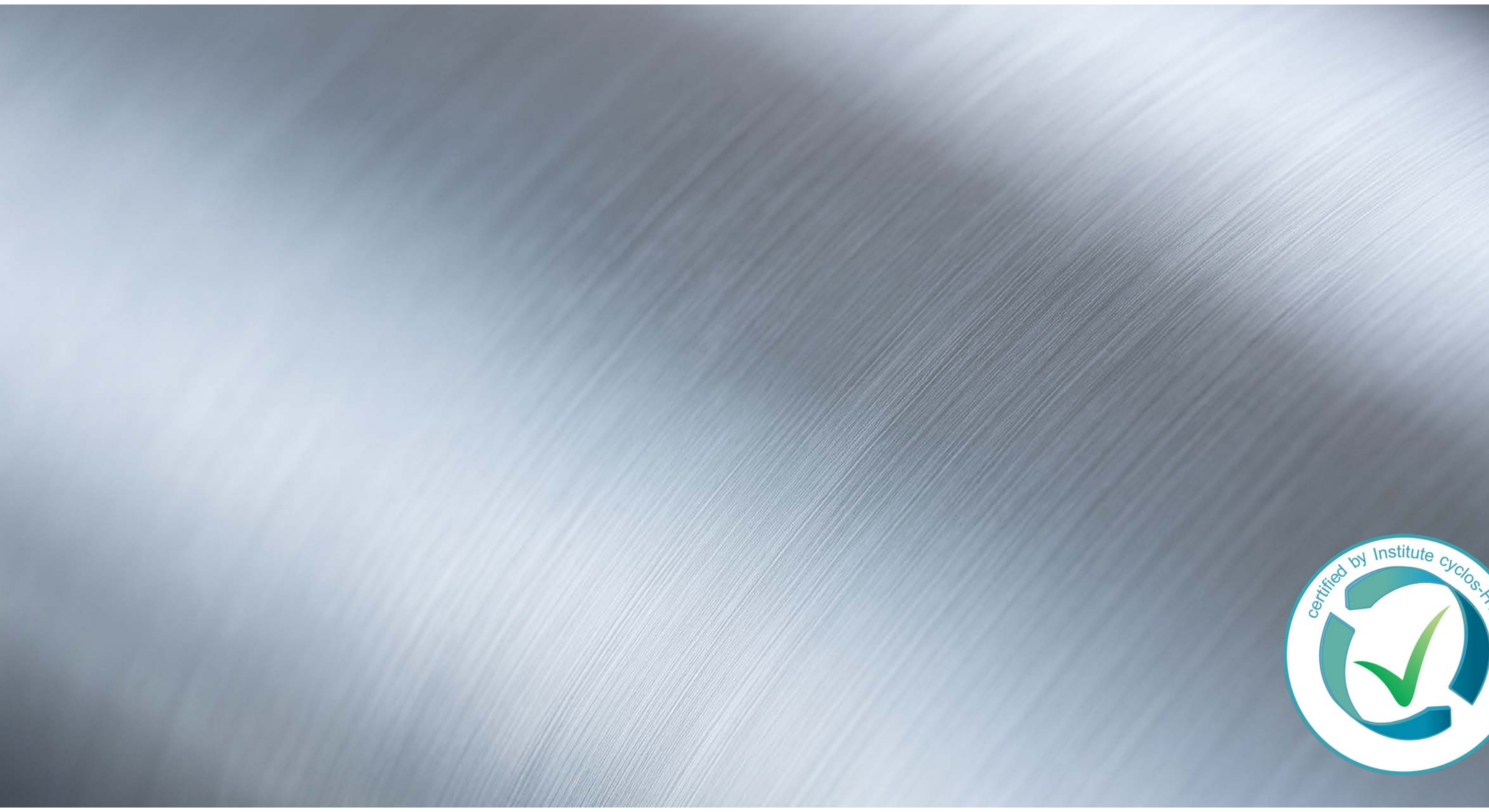
Design for **Recyclability Guidelines** and **Recyclability Assessment** for Packaging containing Aluminium



Project number: 2671-001-2023 | Published: 09.2025 | V1.0

Commissioners:

alufoil European Aluminium Foil Association · European Aluminium · Aluminium Closures · Metal Packaging Europe · etma european tube manufacturers association · AEROBAL

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alufoil
European Aluminium
Foil Association

The European Aluminium Foil Association (EAFA) is the main trade association, specifically representing companies engaged in the rolling and rewinding of aluminium foil and the manufacturing of semi-rigid alufoil containers and household foil in Europe. With its more than 40 members, the organisation represents the total aluminium foil rolling market in Europe. Founded in 1974 it has its roots in associations dating back to the 1920s.

European
Aluminium

European Aluminium, founded in 1981 and based in Brussels, is a member-based industry association representing Europe's most complete and thriving metals value chain. The association's 100+ members include primary aluminium producers; downstream manufacturers of extruded, rolled and cast aluminium; producers of recycled aluminium and national aluminium associations, representing more than 600 plants in 30 European countries.

ALUMINIUM
CLOSURES

The Aluminium Closures Group (ACG) consists of the leading manufacturers of closures, aluminium strips and sheets for closures. It was founded in 2012 and consists of 14 members, which represent about 90% of the European production.

Metal
Packaging
Europe

Metal Packaging Europe (MPE) gives Europe's rigid metal packaging industry a unified voice, by bringing together manufacturers, suppliers, and national associations. It consists of 13 corporate members and is connected to a considerable number of associations and producers of aluminium and steel.

european tube
manufacturers association
etma

The European Tube Manufacturers Association (etma), founded in 1959, is an association of producers of flexible aluminium, plastic and laminate tubes for packaging purposes. Etma currently represents the interests of 46 members from 19 European countries. Etma members currently produce about 12 billion tubes and thus account for about 75 per cent of the entire European production.

AEROBAL

After its foundation in 1976, AEROBAL, the former European Association of Aluminium Aerosol Container Manufacturers, was transformed into the International Organisation of Aluminium Aerosol Container Manufactures as of 1st January 2006. It represents 26 international aluminium aerosol can producers running production plants in Europe, North America, South America, Asia, Australia and Africa. Thanks to this enlargement, AEROBAL covers the main aluminium aerosol can markets worldwide and represents about 73 percent of the overall aluminium aerosol can production.

Initiation and task

As a packaging material, aluminium is characterised by several properties that enable it to be used in a wide range of packaging applications.

As a raw material, aluminium is generally considered to be highly recyclable. However, such high recyclability is not a given for all packaging containing aluminium, due to the product design or a lack of recycling infrastructure. In particular, the publication of the European Packaging and Packaging Waste Regulation (PPWR) in January 2025 and the resulting efforts to standardise procedures for assessing recyclability require an in-depth and differentiated examination of the topics of „recyclability“ and „Design for Recycling (D4R)“ for the various packaging applications.

EAFA (European Aluminium Foil Association) and the **Aluminium Closures Group**, **AEROBAL** (International Organisation of Aluminium Aerosol Container Manufacturers), **etma** (european tube manufacturers association), as well as **EA** (European Aluminium) and **MPE** (Metal Packaging Europe) have commissioned **cyclos-HTP Institute (CHI)** to discuss recyclability and to develop D4R guidelines, focusing on packaging applications involving aluminium, such as foil packaging, aluminium closures, aerosol cans, aluminium tubes and food and beverage cans.

When addressing recyclability and D4R guidelines for packaging containing aluminium, a fundamental distinction must be made between aluminium packaging and packaging made of other materials that contains aluminium:

Aluminium packaging is defined at this point in such a way that the whole packaging is mainly made of aluminium, as is the case with beverage cans, food cans, aerosol cans and tubes, (pet) food trays and containers, coffee capsules, alu/alu blisters or chocolate or cheese foil.

Thanks to its properties, aluminium (mainly in the form of foil) is also frequently used in combination with other packaging materials, and thus appears as a minor material that provides additional functional properties to the overall packaging in multilayered packaging solutions, such as pouches and liquid packaging cartons[1].

Today, the very strong focus on the recyclability and the simultaneous optimisation of recycling processes in line with economic requirements result in penalisations of plastic-based packaging containing aluminium in certain D4R guidelines, thus leading to the substitution of the aluminium material.

This is one of the reasons why this document not only develops guidelines and assessments for aluminium packaging, but also provides an in-depth discussion of aluminium used as a minor material.

The text was thoughtfully developed in consistency with the provisions of the PPWR, both in terms of the terminology and requirements in the field of recyclability.

[1] The term ‘liquid packaging carton’ (LPC) includes packaging made of cardboard composites consisting of card-board/PE or cardboard/aluminium/PE for the filling of liquid, pasty or flowable pieces (e.g., beverage cartons, sauce packaging, etc.)

The Packaging and Packaging Waste Regulation (PPWR) establishes requirements for the entire life-cycle of packaging […] to allow its placing on the market […]. This Regulation applies to all packaging, regardless of the material used, and to all packaging waste, whether such packaging is used in or such packaging waste originates from industry, other manufacturing, retail or distribution, offices, services or households. […] All packaging placed on the market shall be recyclable with some exceptions among others (see Articles 1, 2 and 6):

- contact-sensitive packaging of medical devices,
- outer packaging, where such packaging is necessary to comply with specific requirements to preserve the quality of the medicinal product,
- contact-sensitive packaging for infant formula and follow-on formula, processed cereal-based food and baby food, and food for special medical purposes.

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For this reason, the Design for Recycling Guidelines do not address in all points packaging covered by the exceptions.

1. Packaging functionalities - why is aluminium used?

As a packaging material, aluminium is characterised by several properties that justify its usage in a wide range of applications.

Aluminium has excellent barrier properties[2]. Even very thin aluminium foils (down to 5 microns) are impermeable to light, water vapour and air and thus protect the contents from external factors that impair quality; they protect and preserve products over long periods of time, even without refrigeration. Aluminium is neutral in taste and odour (no detectable impacts to foodstuff). Moreover, it is generally corrosion resistant, due to the naturally occurring surface oxide on all aluminium in the presence of atmospheric oxygen.

Aluminium in packaging is therefore used for sensitive foods and drinks, but also for cosmetics and pharmaceuticals. For the latter, aluminium foil used in blister packs, is characterised by the combination of push-through and very specific barrier properties.

© Alupro

Thanks to its good thermal conductivity, aluminium can withstand large temperature variations. Drinks in aluminium cans can be cooled energy-efficiently and food in aluminium trays can be heated easily. When heat-sealing flexible packaging containing aluminium foil, sealing times can be minimised and temperature differences can be better compensated during the hot filling process.

Aluminium is easy to fold and form while retaining its shape (the so-called deadfold property) and has very good machinability. In the case of aluminium tubes, the so-called suck-back effect is avoided which prevents a possible contamination of the filling, and the efficient emptying of the tube is ensured. Aluminium packaging is also characterised by good printability.

[2] FABES (2004)

2. Environmental benefits of aluminium in packaging

2.1 Saving resources through material minimisation

Material minimisation has been achieved across the board of aluminium packaging which leads to lighter packaging and results in direct energy and CO_2 savings throughout the life cycle including during transport. Thanks to improved technologies, it is now possible to produce very thin aluminium sheets and foils with a consistent barrier effect. In the last 50 years, the weight of the average aluminium beverage can has been reduced by 38%, whereas foils for coffee bags and confectionery foils have become 30% thinner; aluminium yogurt lids have become 15% thinner. Within only the last decade, the weight of a typical 150 ml aluminium aerosol can has been reduced by approximately 13%. Despite the lower material usage, the high functionality is still given. The use of aluminium as a barrier in other packaging structures also helps to reduce the consumption of primary raw materials from other materials such as paper or plastics.

2.2 Easy separation of aluminium scrap, and established recycling infrastructures

Aluminium is a good electrical conductor allowing aluminium packaging to be reliably sorted by eddy current separators when mixed with other waste materials (for more details, see chapter 3.2).

2.3 Positive market value of aluminium scrap

Aluminium packaging is generally easy to recycle, and scrap has high value depending on its cleanliness and – if sorted by product – the high material value in turn provides the necessary incentives to achieve high recycling rates.

2.4 Constant quality of secondary materials

Secondary aluminium from packaging recycling is usually appropriate for a variety of applications, where it replaces the primary raw material. However, due to the mixing of different alloys in the mixed collection of recyclable materials, using recyclates only to produce the original product (e.g., in a closed product loop) is neither technically, economically nor ecologically sensible. Furthermore, it should be mentioned that alloy sorting techniques (LIBS, X-ray) have not (yet) reached an industrial scale for separation of aluminium packaging from different alloys. Those techniques are evolving very rapidly and have been implemented for other aluminium scrap items already (PreZero Pyral, HySort technology, TARC).

Exceptions are mono streams that are collected in sufficient volumes with homogeneous composition making it possible to sort and recycle the scraps separately, like aluminium beverage cans from incentive-based collection schemes such as deposit-return schemes. A used aluminium beverage can for example can be turned back into liquid metal to produce recycled material for new beverage cans.

Recycling processes for metals (considered to be “permanent materials”), can be repeated as often as required without changing the materials’ fundamental properties.

2.5 Low energy consumption in the production of secondary aluminium

Producing aluminium from scrap (secondary aluminium) requires up to 95% less energy than primary production from bauxite. This is mirrored in the Global Warming Potential (GWP) of the different production steps – which measures greenhouse gas emissions in terms of CO_2 equivalents (CO_2e).

In the 2024 Environmental Profile Report for the European aluminium industry[3] (published by European Aluminium), the respective GWP is set out for the production of primary aluminium produced in Europe and for the production of primary aluminium used in Europe (both cradle to gate), compared to the GWP for remelting and refining production (all gate to gate):

***Table 1:** Global Warming Potential of primary and secondary aluminium production*

LCI dataset	**GWP** (in CO_2e per kg of production)
Primary aluminium produced in Europe (cradle to gate)	6.6
Primary aluminium used in Europe (cradle to gate)	10.1
Remelting production (scrap processing into wrought alloy ingots) (gate to gate)	0.26
Refining production (scrap processing into casting alloy ingots) (gate to gate, without credit*)	0.41
Refining production (scrap processing into casting alloy ingots) (gate to gate, with credit*)	0.37

*with or without aluminium oxide valorisation

[3] European Aluminium (2025)

The recycling of aluminium after use and the utilization of recycled aluminium to replace virgin aluminium in new applications plays a key role due to its highly environmental relevance. In Europe, the supply of raw materials from secondary aluminium is becoming increasingly important (see 2.6). The share of secondary aluminium available to satisfy global aluminium demand is about 36%[4] and the global aluminium demand will increase by almost 40%[5] by 2030 as compared to 2020. To meet global climate goals and to decarbonize the aluminium industry sector by 2050 the International Aluminium Institute (IAI) has modelled a 1.5 Degree Scenario[6].

2.6 Strategic significance

Aluminium (including bauxite and alumina) is classified as a strategic raw material under the Critical Raw Materials Act (Regulation establishing a framework for ensuring a secure and sustainable supply of critical raw materials). This classification recognises Aluminium as among the most crucial materials for strategic technologies used across sectors.

According to the Regulation, by 2030 the strategic raw materials value chain must approach or reach several benchmarks adopted under the Critical Raw Materials Act. For example regarding processing, the EU must be capable of producing at least 40 % of the Union's annual consumption of strategic raw materials. With regard to recycling it must be capable of producing at least 25 % of the Union's annual consumption of strategic raw materials. The overarching objective of the Regulation is to ensure stable, reliable and secure supply chains for strategic and critical raw materials[7].

[4] IAI Global Cycle (2023)

[5] WEFORUM (2023)

[6] IAI (2023)

[7] European Commission (2023): European Critical Raw Materials Act

3. Overview of the recycling infrastructure in Europe for packaging containing aluminium

The following chapter describes the recycling paths for aluminium packaging and aluminium-containing packaging.

Annex 1 provides an overview of the most important aluminium packaging formats classified by packaging group and main material type, with established recycling infrastructures and those where country-specific requirements must be considered.

3.1 Collection

In the vast majority of EU countries, there is a nationwide collection of used aluminium packaging. The way it is organised varies and national particularities must be considered.

In some countries, used aluminium packaging is collected with packaging waste made of plastic, steel, liquid packaging cartons and, in some cases, paper and cardboard products. This currently applies, e.g. to Austria, Belgium, France, Germany, Netherlands and Portugal. But there are differences between the types of packaging authorised for collection within the countries: Whereas in Germany or France, the entire range of aluminium packaging (including flexible aluminium-based and flexible aluminium containing composite packaging) is permitted; Belgium strives to phase out the collection of plastic packaging consisting of a mixture of materials which cannot be separated (like plastic laminate with aluminium foil layer)[8]. In Switzerland, some used packaging and other items are collected in specially labelled collection containers, which are set up in almost all Swiss cantons. There are separate take-back systems via branch solutions and returns via commercial collection systems.

In addition, aluminium is recovered as a minor material from recycling paths of other material types and is also recycled here via established recycling infrastructures:

- Aluminium closures on single-use glass bottles are potentially included in the collection of used glass in depot containers. Non-ferrous metals recovery from waste glass processing is now state of the art and largely established.
- Aluminium closures on returnable bottles are also collected separately when the bottles are returned to the bottling plants. The return rate for aluminium closures on returnable bottles is estimated to be at least 95%[9], from which nearly 100% are being recycled.
- Aluminium foil in liquid packaging carton is recovered where the rejects from the fibre recovery of the liquid packaging carton are already made available and processed as by-products (PolyAl) for high quality recycling.

3.2 Sorting

The aluminium packaging is separated from the lightweight packaging collection mix in sorting plants. In most European countries, currently only packaging predominantly made of aluminium, such as cans, trays and foils is sorted out in the aluminium fraction. Germany is quite specific: here, multi-material packaging with aluminium as minor material is part of the aluminium sorting specification.

[8] https://www.fostplus.be/en/sorting/sorting-home

[9] Information from expert interview (2024).

The sorting fraction for items containing aluminium is standardised according to the state of the art using eddy current separators. The separation is based on the principle of electrical conductivity, which splits the sorting fraction at normal belt speeds from 2.2 to 2.5 m/s into a conductive and a non-conductive part. Aluminium is a good electrical conductor, so that sorting can be carried out with a high degree of efficiency (recovery[10, 11], up to 98%).

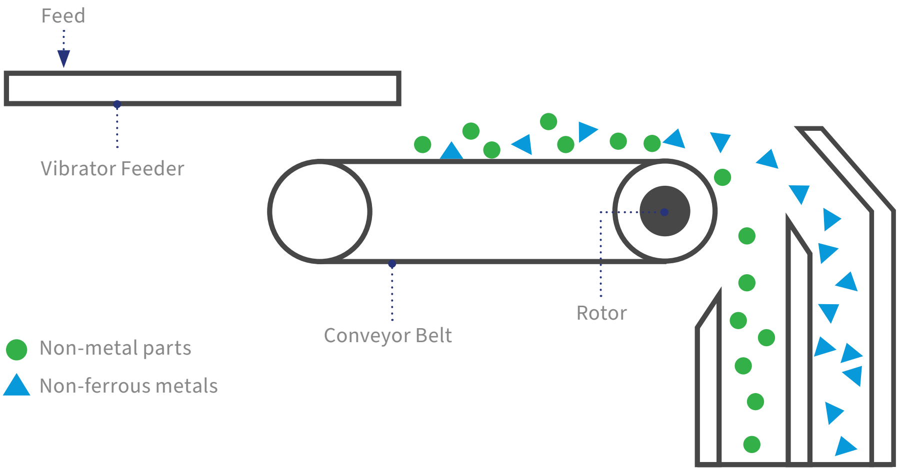


***Figure 1:** Process principle of an eddy current separator*

The process principle of eddy current separation is based on the induction of electrical currents in electrically conductive materials by a high frequency alternating magnetic field. To implement this in a machine, a pole wheel with strong-field permanent magnets in an alternating pole arrangement rotates at high speed (approx. 2,500 rpm) inside the deflection roller of a conveyor belt. When a non-magnetic metallic packaging, such as an aluminium tray, enters the alternating magnetic field, an electric current is induced in the packaging, the magnetic field of which is always directed in the opposite direction to the alternating field of the machine. The resulting repulsion leads to the electrical conductors being deflected out of the flow. However, the shape of the conductor also plays a decisive role and determines the ballistic trajectory at the head pulley.

A prerequisite for separation is that the induced current can flow in a directed manner. This is also the reason why, in some settings, an aluminium foil crumpled into a very small ball is subject to less magnetic repulsion, that leads to a lack of separability for small formats such as those occurring in glass reprocessing.

The sorting fraction in Germany (fraction no 420 aluminium) using eddy current separation has an aluminium share of 30 to 40% and is not directly suitable for use in secondary aluminium smelters.

However, not all aluminium-containing packaging from the lightweight packaging collection mix is sorted in the aluminium fraction; there are also other sorting fractions that contain aluminium as minor material (see Figure 2).

In particular, these are:

- the PP and PS fractions (e.g. yogurt cups with aluminium lids still attached), which do not lead to discharge into the aluminium fraction according to the operating principle of eddy current separation,
- the liquid packaging cartons that are separated before eddy-current separation,

[10] Taggart (1967)
[11] Richardson & Morrison (2003)

- marginal amounts of aluminium in the Paper/Paperboard/Cardboard (PPC) stream from packaging such as composite cans, spice wrappers, soup bags, butter wrappers, etc., which were not sorted into the aluminium stream because of the comparatively lower efficiency of the eddy current separation for these packaging types,
- plastic-based packaging containing aluminium is also found occasionally in the mixed plastic streams.

The figure below shows the simplified process flow chart of a state-of-the-art sorting plant for lightweight packaging. Highlighted in yellow are the eddy current separation for sorting the aluminium fraction (corresponds to the “non-ferrous-metals”); as well as other sorting fractions containing aluminium as by-material.

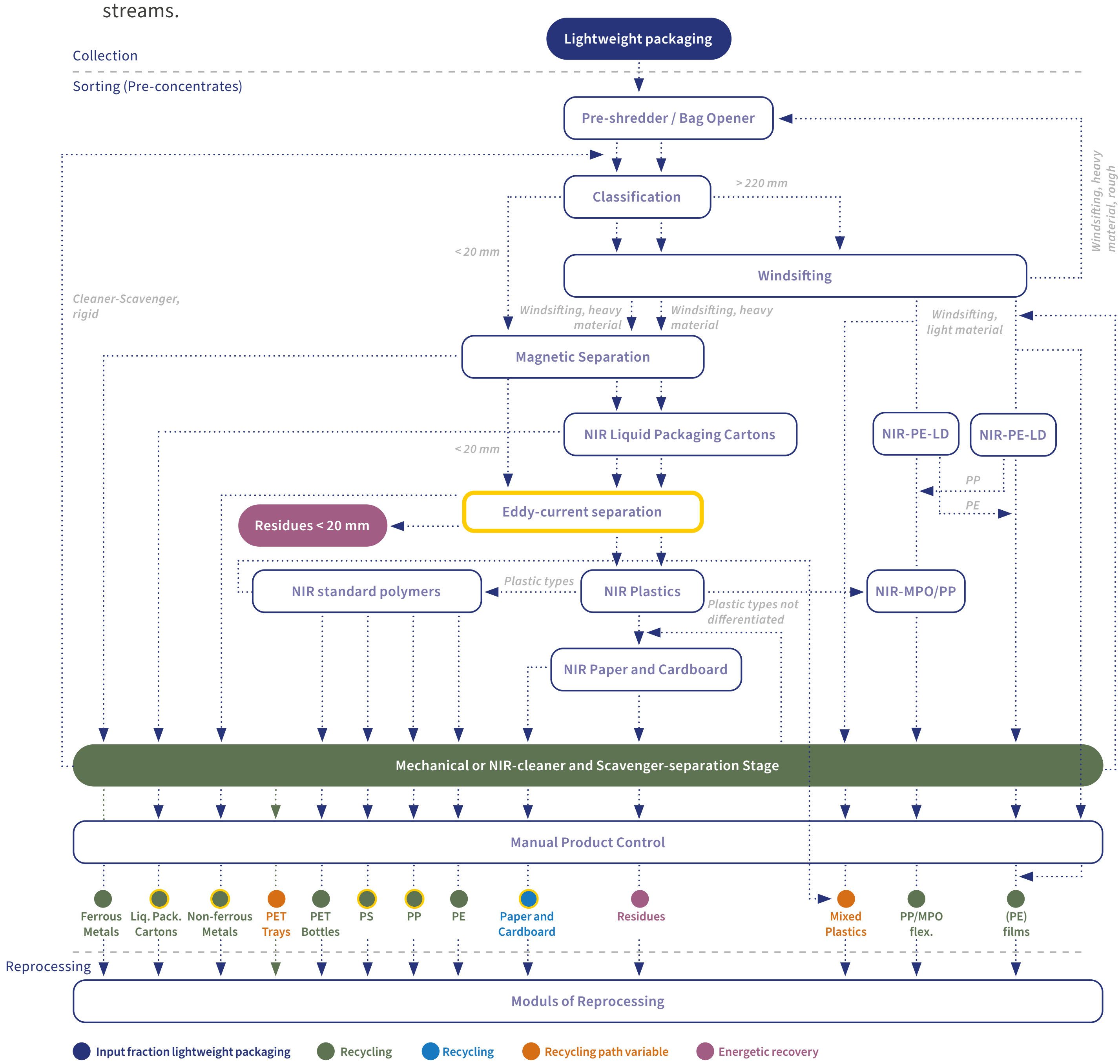


Figure 2: State-of-the-art sorting plant for lightweight packaging, simplified flow chart, ©CHI/HTP (2024)

Chapter 3.3 below describes the recycling routes of the sorting fractions (framed in yellow) that contain packaging with aluminium as a main or minor material:

- Non-ferrous metals including aluminium packaging (and potentially flexible packaging with aluminium as minor material); liquid packaging cartons
- Paper and cardboard
- PS and PP (e.g., yogurt cups with still attached aluminium lids)

Furthermore, the reprocessing of aluminium from different collection schemes (waste glass collection, deposit-return schemes for beverage cans) is considered.

The aluminium fractions (shown as non-ferrous metals in ***Figure 2***) resulting from the sorting process are pressed into bales and usually delivered to aluminium reprocessors (mechanical and/or pyrolysis).

It is important to note that the sortability of aluminium is not primarily dependent on the aluminium content or the size of the packaging. Existing rules in the sorting specifications which are applied by certain sorting centers and which consider aluminium content or size are mainly economically motivated to balance the costs for sorting and the proceeds from the sales of the sorted aluminium packaging. These sorting rules should not influence the fundamental recyclability of an aluminium packaging or packaging component. Even very small aluminium packaging items can be properly sorted and sent for recycling in state-of-the-art sorting centers.

3.3 Reprocessing

3.3.1 Reprocessing of aluminium and aluminium containing packaging

Reprocessing is carried out either mechanically or by means of pyrolysis or a combination of both processes.

The following illustration shows the simplified flow chart of state-of-the-art **mechanical reprocessing**.

1. The first process stage in the mechanical process is the disintegration comminution, which can be carried out using shredders or vertical hammer mills, the material is crushed to a grain size of < 50 mm.
2. This is followed by windsifting in order to remove non-metallic residues (which are currently used as refuse derived fuel (RDF) for energy recovery).
3. After that, a one or two-stage magnetic separation is applied to separate ferromagnetic materials.
4. The remaining material stream is divided into a heavy and light fraction by means of air separation.

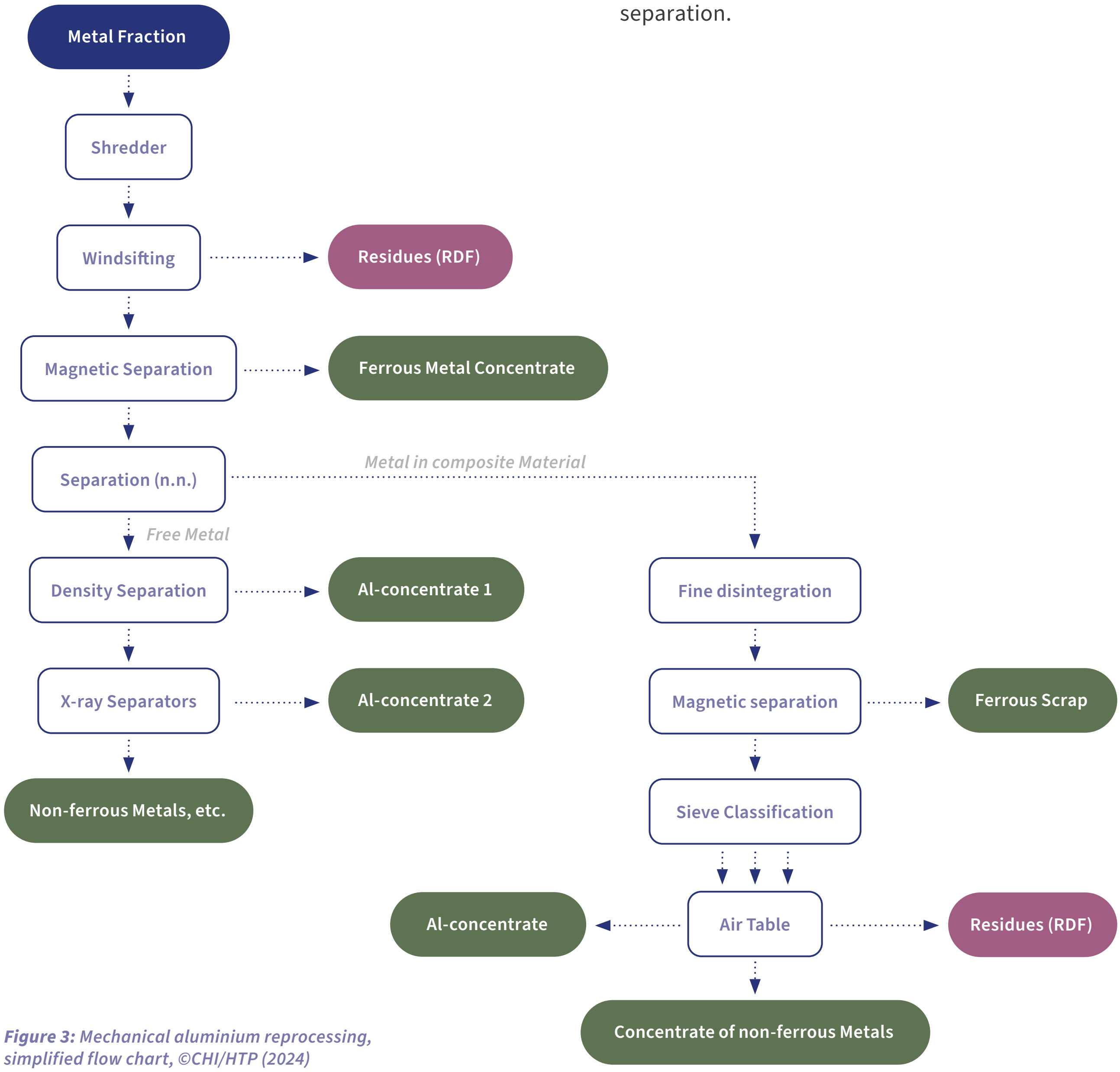


Figure 3: *Mechanical aluminium reprocessing, simplified flow chart, ©CHI/HTP (2024)*

5. The light fraction mainly contains aluminium composite packaging (shown on the right-hand side of the flow chart above), which is fed into a mechanical grinding followed by an additional magnetic separation and classification via sieves and air tables. Alternatively, the light fraction can be thermally treated by pyrolysis to recover the aluminium (see Figure 5).

6. The heavy fraction contains packaging with a high aluminium content, such as aerosol cans, meal trays, closures, coffee capsules and aluminium tubes. It is separated into several non-ferrous metal pre-concentrates via eddy current separation. Subsequent purification of the coarser-grained metal concentrates is usually carried out using X-ray separators.

Concentrates that are not sufficiently digested, such as light material extracted via air classifier (see above), are subjected to fine digestion using turbo mills. After the fine digestion, in which the plastic/aluminium blisters, plastic/aluminium laminates, etc. are disintegrated and the aluminium is spherified, screening stages follow to prepare for metal recovery and separation via air ovens. The plastic and paper materials separated from the aluminium composites are currently used as refuse derived fuel (RDF) for energy recovery.

***Figure 4:** Products from mechanical aluminium processing, ©TARC, Balen, Belgium*

The following illustration shows a simplified flow chart of the state-of-the-art **pyrolysis process**.

The process as such is carried out in a pyrolysis drum heated with flue gas at temperatures of 500 to 600°C in the absence of oxygen. Organic impurities (plastics, paper, inks, and adhesions) decompose in the absence of air (plastics are depolymerised and paper reduced to carbon dust) and are completely degassed, removed at the end of the rotary drum, and incinerated (with generation of energy). The energy released is used to heat the pyrolysis drum (autothermal process).

In the case of light fraction input, a shredding may be necessary before the pyrolysis operation, as well as a mechanical separation of aluminium and carbon dust in decoking mills after the pyrolysis operation.

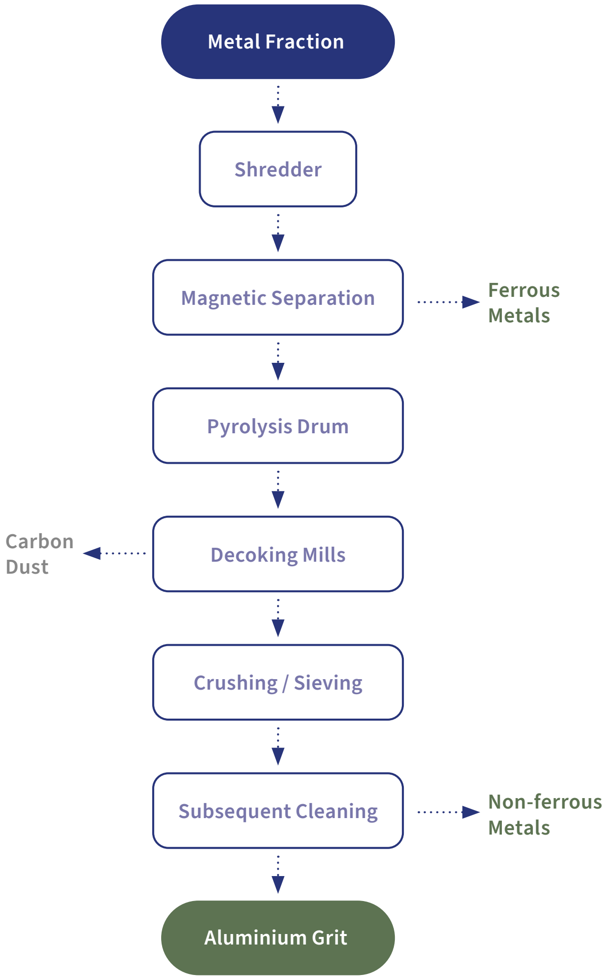


***Figure 5:** Pyrolysis process, simplified flow chart, ©CHI/HTP (2024)*

Depending on the input material, the pyrolysis output is then classified into various aluminium grain sizes and other non-ferrous metals are sorted out.

The pyrolysis process creates high-quality aluminium scrap.

Figure 6: Aluminium packaging scrap after pyrolysis, ©Pyral (2021)

The oxidization losses of metallic aluminium that occur during pyrolytic recovery have been sufficiently investigated. According to publications, the yield for the aluminium concentrate obtained is between 98 and 99%.

The case of chlorine-containing polymers:

For their specific barrier properties and high resistance to aggressive filled product, chlorine-containing polymers can be used as components or constituents of aluminium packaging (e.g., PVC layer for pharma applications, chlorine-containing lacquers for sensitive food applications). As for other plastics or lacquers, these chlorine-containing constituents or components are removed during the reprocessing in pyrolysis (and not sent for recycling) and do not impact the recycling of aluminium. Indeed, at the pyrolysis plant, chlorine-containing components or constituents are completely removed. However, an excessive level of chlorine in the material entering the pyrolysis process may cause equipment damage (corrosion), which requires a special attention from the operator when preparing the input batch (i.e. diluting the level of chlorine by mixing with other aluminium scraps). For these reasons, it is recommended to minimise the chlorine content in aluminium packaging when feasible.

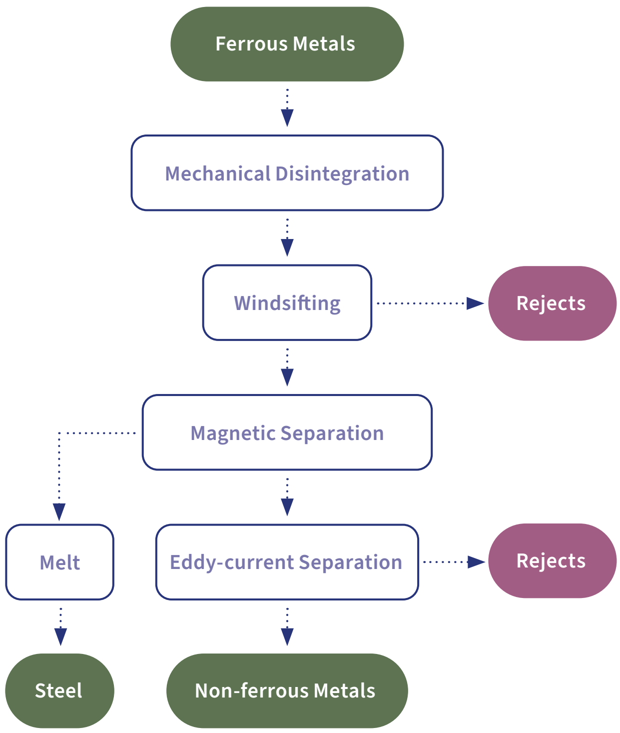


***Figure 7:** Mechanical reprocessing of the ferrous metal fraction, simplified flow chart, ©CHI/HTP (2024)*

3.3.2 Reprocessing of ferrous metal packaging (with aluminium as a possible material contained)

State-of-the-art reprocessing of ferrous metal packaging is carried out mechanically, as illustrated in the flow chart (see Figure 7). Aim of the mechanical disintegration ('shredding') process stage is the extensive separation of organic impurities (paper labels, plastics, residual contents) as rejects and the separation of non-ferrous metals (especially aluminium).

Process steps in the processing of the tinplate fraction include disintegration using special shredder designs (vertical hammer or chain mills), air sifting to remove labels separated by the disintegration process, magnetic separation to sort out ferrous metals and eddy current separation to recover non-ferrous metals. The sorted, cleaned ferrous metal scrap is made up into chargeable units that are used in steel production (in the converter stage).

3.3.3 Reprocessing of liquid packaging cartons / reprocessing of PolyAl

In some countries, liquid packaging cartons are not collected with other paper and cardboard packaging, but together with lightweight packaging (e.g., Belgium, Germany, Spain) and sorted out in sorting plants as a separate fraction (this is made possible by the fact that liquid packaging cartons have a specific spectrum in the NIR reflectance measurement). After sorting, the liquid packaging cartons are processed in recycling mills with specialized process. The secondary materials from the processing of the liquid packaging cartons are LDPE films, PP and PE closures as well as aluminium foils, which are separated as co-products (PolyAl) and in the past were usually used for energy recovery in cement plants.

To increase the recyclability of liquid packaging cartons, it is necessary to further process the PolyAl co-products and recycle them. There are already industrial-scale technologies available to separate and recover aluminium (and the polymers) from PolyAl.

PolyAl processing differs in how the laminate between aluminium and plastic is separated. At present, a purely mechanical composite separation (**Palurec**, **Hürth** in Germany) and delamination/debonding processes (**Saperatec**, **Dessau** in Germany and **Plastigram**, **Sokolov** in Czechia and **Szczuczyn** in Poland) are relevant to mention.

A | Mechanical process

Figure 8 shows a simplified flow chart of the mechanical recycling process for PolyAl.

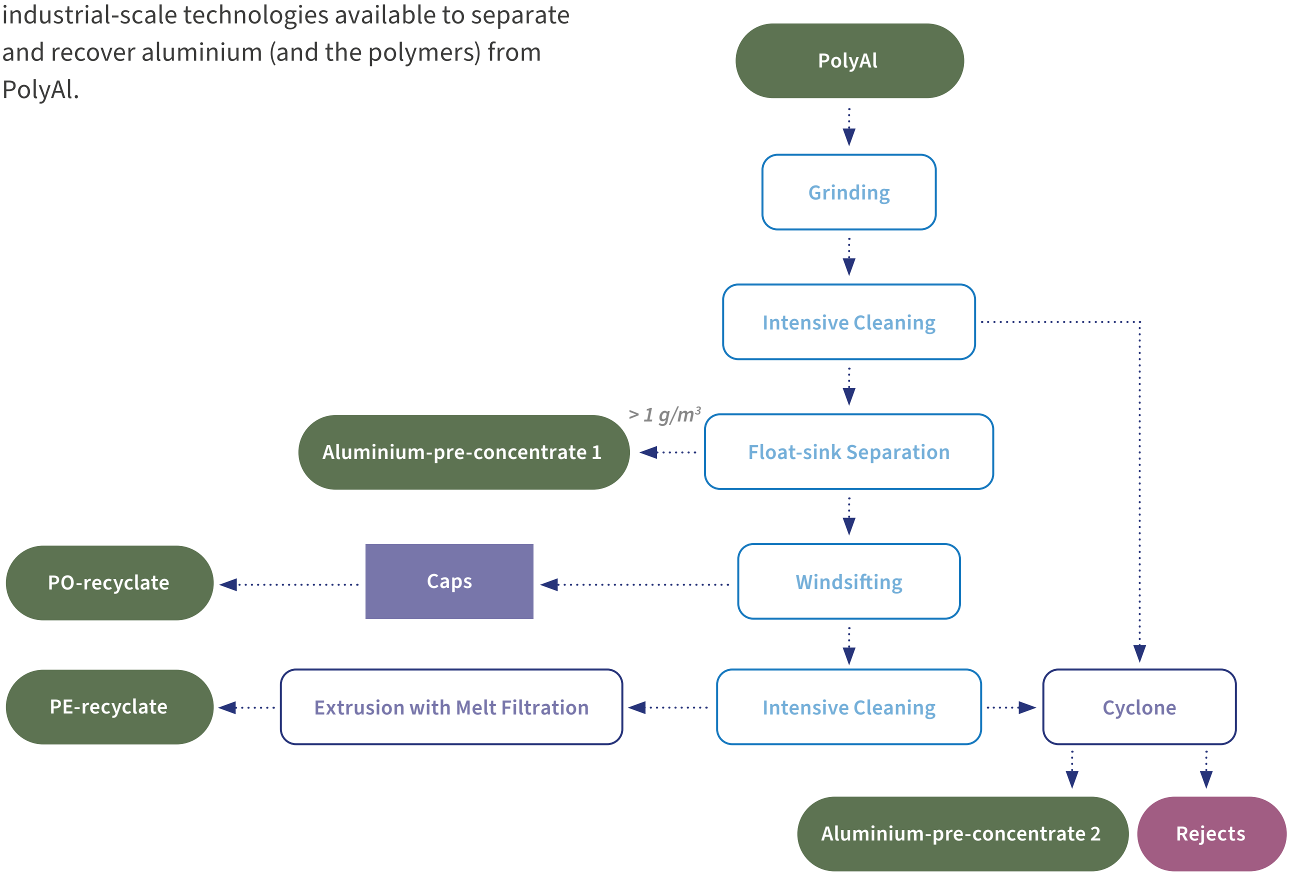


Figure 8: *Mechanical recycling process for PolyAl, simplified flow chart, ©CHI/HTP (2024)*

The PolyAl rejects are grinded and subjected to an intensive washing process. Fibre residues, aluminium and other adhesions are removed via friction washers ("intensive cleaning"). Larger pieces of aluminium foil are separated via density separation ("float-sink separation"); fine aluminium particles via hydrocyclone. The dried material stream of films and closures is separated from each other via wind sifting. The film material is granulated in an extruder with melt filtration. Palurec produces recyclates from LDPE and HDPE regrinds, as well as aluminium preconcentrates.

Plastigram produces LDPE regranulate, regrind from caps and aluminium powder (production volume of approx. 1,000 tons of aluminium powder annually). According to its own information the share of organic contaminants is about 40%, which are predominantely paper fibres[13].

Figure 9: *Aluminium pre-concentrates, ©Palurec*

B | Delamination/debonding processes

In May 2024, Saperatec officially opened its new plant for recycling composite packaging waste, after successfully testing the delamination technology for the recycling of multilayer laminates such as liquid packaging carton on an industrial scale.

Figure 10: *PolyAl (input material), aluminium pre-concentrates, ©Saperatec*

Its own information states that the recycling process uses special surfactant-based microemulsions that separate composite materials. This means that all raw materials from composites (plastic film, aluminium foil) can be recovered individually and made available for subsequent recycling steps. In addition to PolyAl, Saperatec also plans to recycle other aluminium-plastic packaging waste.

According to an article published by the Alliance for the Beverage Cartons and the Environment ACE in January 2024, EXTR:ACT planned to have a third of the collected PolyAl rejects from the processing of liquid cartons already be able to be recycled by the end of 2023; recycling capacities for 115,000 tonnes of PolyAl should be available by 2025 in Europe. This corresponds to a share of approx. 43% of PolyAl in LPC put on the market[14].

As the market significance of newly developed technologies increases, other composite fractions (aluminium-based composites, plastic-based composites) will gradually become more recyclable in the future.

[13] https://plastigram.eu/ (Retrieval on 10 July 2024).
[14] https://fbcaglobal.com/storage/files/jan2024-ace-recycling-brochure-copy.pdf

3.3.4 Reprocessing of paper and cardboard packaging – excl. liquid packaging cartons - (with aluminium as a possible minor material)

In general, paper and cardboard are collected separately from other recyclable materials in the mono paper stream. In addition, wastepaper grades are delivered via paper sorting plants and sorting plants for lightweight packaging (e.g., Austria, Germany). An exception to this is France, where packaging paper is often collected in a mixed PMD stream (with metal and plastic packaging).

All types of wastepaper are processed by means of wet mechanical treatment via pulpers or fibre drums. However, the degree of pulping is determined by the dwell time, which can be estimated between 4 and 7 minutes for recovered paper grades from paper and cardboard collection and 15 to 20 minutes for fibre-based composites.

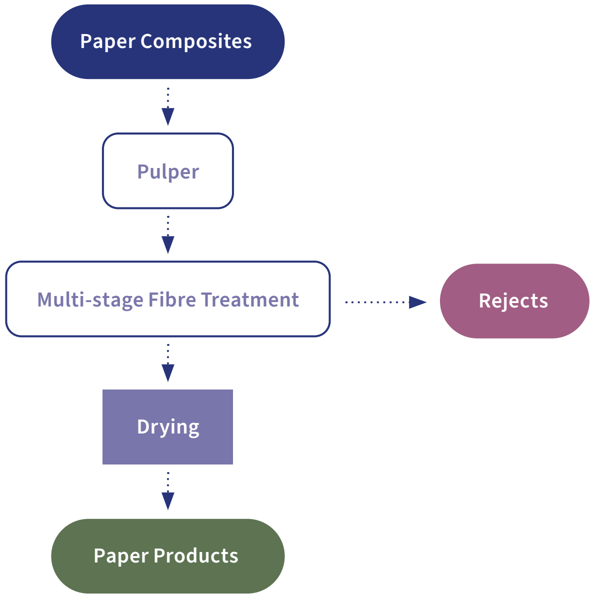


Figure 11: Recycling of fibre-based packaging, simplified flow chart, ©CHI/HTP (2024)

As a rule, the pulping is designed as a single-stage disintegration process; however, so-called secondary pulpers are also used, with which the reaction time can be extended for papers that are difficult to pulp.

After disintegration, the pulp is subjected to a multi-stage cleaning process (“fibre treatment”). Hydrocyclones are used to separate small, heavy impurities, such as sand, stones, staples, broken glass; screening machines with adopted mesh geometry are used **to separate foreign particles, such as** plastic films, **aluminium foil**, but also non-disintegrated fibres (specks) and larger adhesive residues (macro stickies) **as rejects**, which are generally used for energy recovery (for exception see 3.3.3 Reprocessing of liquid packaging cartons / reprocessing of PolyAl).

3.3.5 Reprocessing of plastic packaging, such as PS and PP (with aluminium as a possible minor material)

The actual processing of the PS sorting fraction begins with the pre-shredding (optional) of the large bales with downstream magnetic separation to separate the binding wire. This is followed by fine shredding using granulators (regrind < 10 mm) as a prerequisite for the functionality of the subsequent separation and transport processes. The subsequent washing process is designed as a cold wash and takes place without the addition of surfactants. The separation of foreign plastic particles and metals (e.g., aluminium lids remained attached to yogurt cups) is carried out by means of a two-stage float-sink separation (gravimetric sorting).

In the first stage, polyolefins (PE and PP) and EPS are separated at a separation density of 1 g/cm^3 in the floating material. In the second stage, PET, PVC, PLA etc. and aluminium particles are separated in the sinking material at a separation density of approx. 1.08 g/cm^3; PS regrind is separated as the floating material in this so-called salt stage (separation density is adjusted with an aqueous salt solution).

The sinking material from the salt stage is discharged as „reject“. The polystyrene enriched in the floating material of the salt stage is rinsed, dewatered, dried and finally remelted using an extruder. After extrusion with melt filtration and, if necessary, homogenisation of the regranulate produced, the sales units are made available in big bags, octabins or silos.

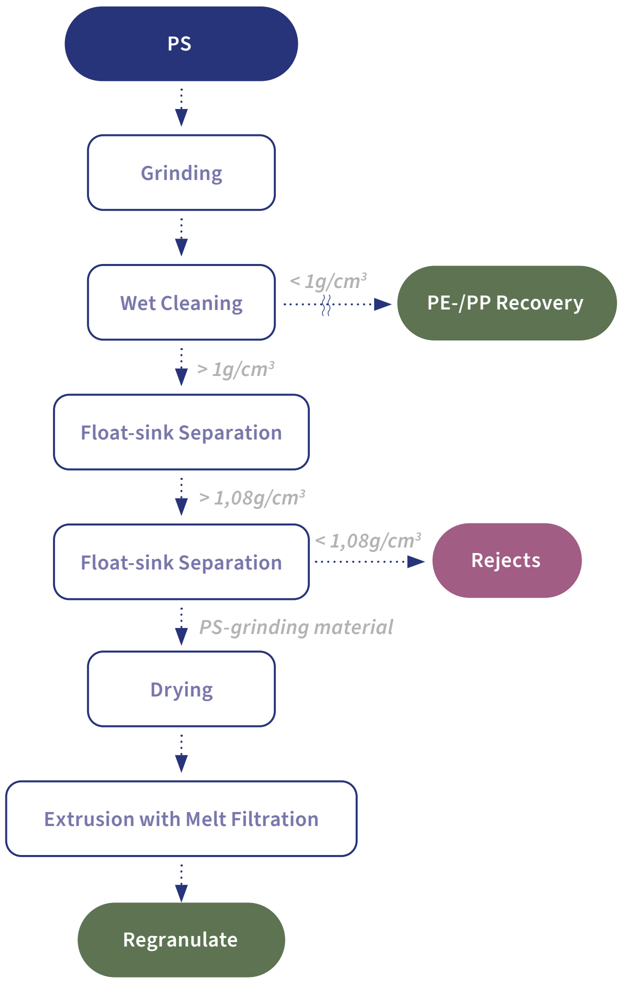


Figure 12: *PS recycling, simplified flow chart, ©CHI/HTP (2024)*

In contrast to PS, polyolefins (PP and PE) are only recycled in a sink-float separation process (without a salt stage).

3.3.6 Reprocessing of aluminium (as by-material) in glass recycling

The **aluminium closures from the separate waste glass collection** are also separated using eddy current, as well as induction sensor-supported sorting units, which recognise metal objects in the material flow from a particle size of 1 mm and separate them from the material flow using compressed air (see Figure 13).

Other aluminium-containing items, such as aluminium capsules and sleeves from champagne and wine bottles, are also partially sorted into the aluminium concentrate; however, aluminium foils (e.g. beer bottle neck foil) thinner than 20 microns are often spherified ("crumbled into a very small ball") due to the stress in the glass treatment process and may not be separated with a high degree of efficiency using eddy current separation.

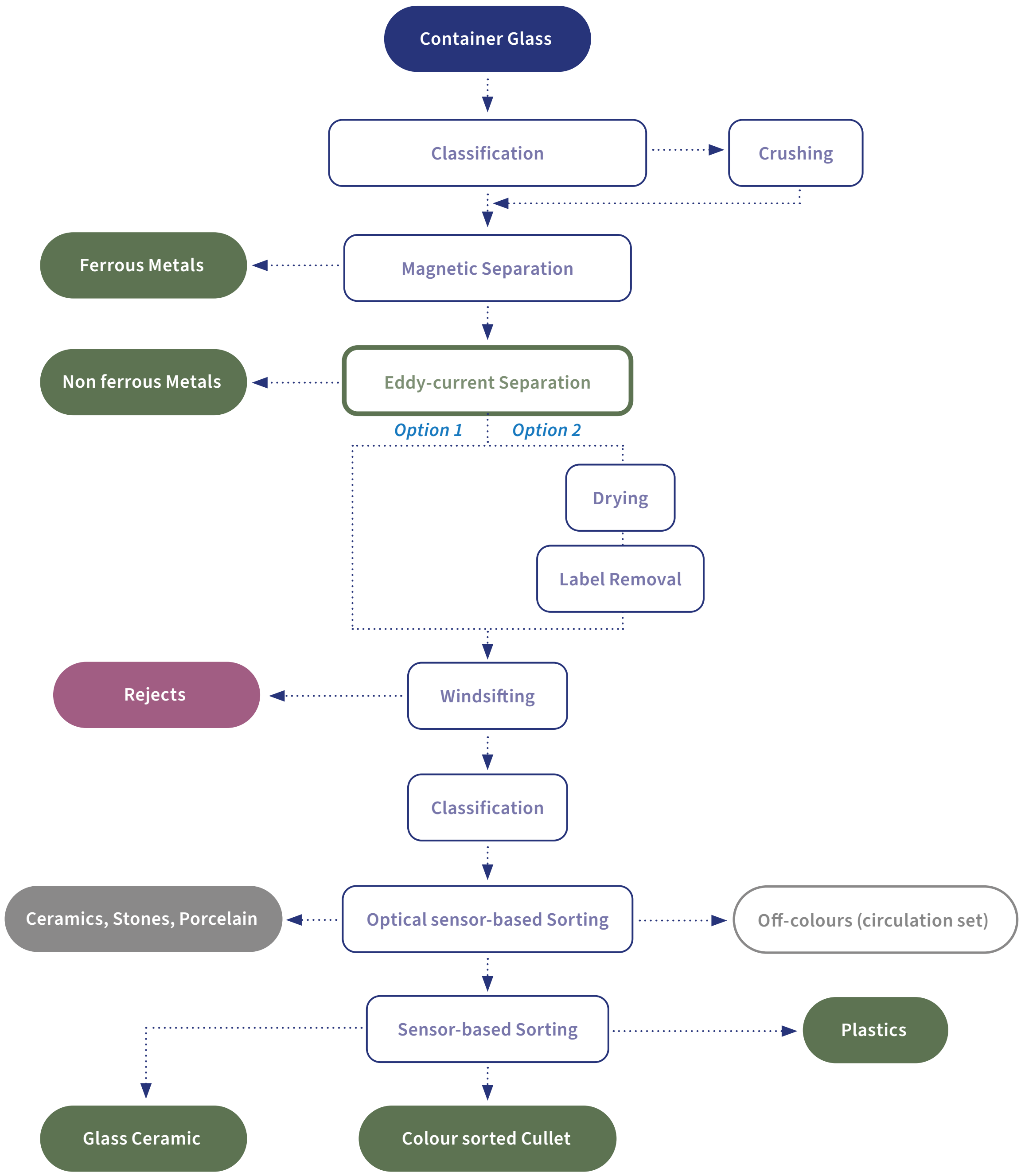


***Figure 13:** Container glass recycling, simplified flow chart, ©CHI/HTP (2024)*

Depending on its quality and homogeneity, the sorted non-ferrous fraction (from the glass recycling route) undergoes mechanical and/or pyrolytic reprocessing. The sealing compounds of the aluminium closures can be separated mechanically, then the closures can be pressed into bales and potentially delivered to remelting plants. Pyrolysis can also be used to remove sealing compounds but also varnish and foreign matter from the closures.

3.3.7 Reprocessing of aluminium from reusable glass bottle schemes

In case being collected separately (when the bottles are returned to the bottling plants), aluminium closures undergo mechanical reprocessing. After separation of sealing compounds and the plastic circlip (if any), the closures are shredded and sent to remelting. Aluminium powder, which is generated as a by-product of the shredding process, can be reused by the pigment industry. Design-related losses: Inks/lacquers, remaining parts of the paper seal (if any).

3.3.8 Reprocessing of aluminium from incentive-based collection schemes

Several European countries have already implemented or are about to implement deposit-return schemes (DRS), usually covering aluminium (metal) beverage cans and plastic (PET) bottles, sometimes combined with returnable and refillable glass containers.

As from the 1st of January 2029 all EU Member States should have a DRS in place, unless they can prove that they can achieve an 80% collection rate of the targeted packaging types without a deposit-return scheme in 2026 by other means (e.g. a classic EPR system). Most if not all DRS in place reach after a short start-up phase of 1-2 years a collection rate of 90% or more (the DRS of Finland and Germany even reach a 99% collection rate).[15]

DRS allows for a closed can-to-can recycling process as the quality of the collected cans via reverse vending machines (RVM's) has a very high aluminium purity, consisting of only the can sheet alloys of which the cans are made of.

The aluminium industry recently embarked on a standardisation project to further increase the circularity of the aluminium beverage can by using the same or very similar alloys for both the can body as well as the can end. This will increase the take up of used aluminium to produce can ends[16].

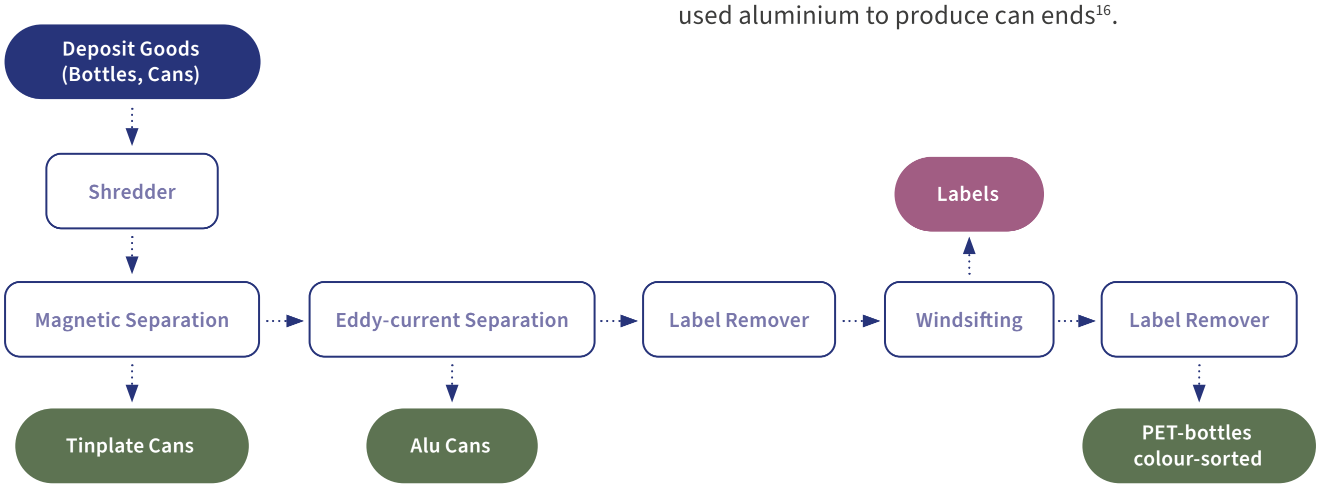


Figure 14: Pre-sorting deposit stream, simplified flow chart, ©CHI/HTP (2024)

[15] Press release European Aluminium & Metal Packaging Europe (10 Feb 2025)

[16] See: https://european-aluminium.eu/wp-content/uploads/2024/04/2024-04-18_Press-Release-European-Al-uminium-Producers-to-Boost-the-Circularity-of-Beverage-Cans-1.pdf

Other voluntary return schemes use the high scrap value ('cash for cans') or other incentives (collection of eco-points, donation to charities, etc.) as tools for improving the separate collection of beverage cans.

3.4 Applications and use of secondary aluminium

Reprocessed aluminium packaging scrap undergoes the refining process where it is melted in furnaces, allowing the removal of potential remaining non-aluminium constituents and producing secondary aluminium.

Aluminium can be repeatedly recycled without loss of properties. In addition, the high market value of aluminium scrap is a key incentive for recycling.

There are different "types" of aluminium, which differ in their alloying elements. These types can be merged with each other, thus potentially resulting in a material with different properties that are decisive for the applications. Although recovered aluminium concentrates from the mixed collection generally contain a mix of alloying elements, they can be used directly for many applications in which primary aluminium is otherwise used, even without further metallurgical refinement: e.g., aluminium casting alloys in secondary smelters, aluminothermic ferroalloys, pre-material for pyrotechnic aluminium powders, alloy tablets as an additive to produce aluminium alloys, aluminium flake powders and pastes. Secondary applications are then typical for mixed alloys.

The more selectively the individual alloys are recovered, the more likely it is that they are able to return to their own primary application. This option is essentially dictated by the collection process and does not apply to many aluminium applications from the packaging sector, as these enter the cycle via mixed collection systems. Exceptions are aluminium beverage cans under a deposit-return scheme, which are collected in a separate stream, and aluminium closures collected and recovered from returnable glass systems.

Whereas primary aluminium is mainly used to produce wrought alloys, secondary aluminium is generally processed into cast alloys (or potentially used in deoxidation processes for steelmaking - depending on its degree of impurity). Mixed scrap (with non-application specific aluminium alloys) can be used with appropriate dilution for the production of most alloys.

Wrought alloys can also be produced from secondary aluminium in the case of unmixed scrap treated separately, e.g., beverage cans (from deposit-return scheme) and bottle caps (from returnable glass system).

The recovery of aluminium is much affected by the purity and morphology of the scrap. Surface area is a major factor that determines metal recovery; organics and other coatings and materials attached to the aluminium can create compounds, such as sulphides, phosphides, hydrides or carbides, which result in losses (compounds collect in the salt-slag phase) and other possible issues (combustible or explosive compounds).[17]

Wrought alloys are identified by a four-digit system. Unalloyed wrought aluminium alloys are designated with 1XXX, whereby the last two digits characterise the purity of the metal. The second digit indicates modifications in impurity levels.

[17] Schaik, Reuter (2014)

***Table 2:** Designation for wrought aluminium alloys*

Packaging	Wrought alloy series			
	1000 99%+ Aluminium	**3000** Manganese	**5000** Magnesium	**8000** Others
Aluminium aerosol cans	x	x	x	
Aluminium beverage cans (body)		x		
Aluminium beverage cans (ends and tabs)		(x)[18]	x	
Aluminium bottles	x	x		
Aluminium food cans		x	x	
Aluminium tubes	x			
Aluminium closures				x
Aluminium trays		x		x
Aluminium foil flexibles	x			x

Aluminium cans are made in most cases of 3000-series alloys, whereas the can end and the opening tab consist of 5000-series aluminium alloys.

Non-heat treatable alloys are those in the 1XXX, 3XXX, 4XXX, 5XXX and 8XXX groups. They can have their properties adjusted by cold working, e.g. **cold rolling**.

[18] Subject to a further standardisation - European Aluminium (2024-4)

4. Status quo of the classification of aluminium in packaging according to the PPWR

It is to be expected that existing national regulations on packaging recycling within the EU will be harmonised by EU-wide provisions within the framework of the PPWR. In the context of recyclability and D4R, the following articles are of relevance: Article 3, Article 6 incl. Annex II and Article 30, whose significance for the application to aluminium as a packaging material is referred to in detail in the following section and in chapters 6 to 10.

Article 3(1), number (24):

"'composite packaging' means a unit of packaging made of two or more different materials which are part of the weight of the main packaging material and cannot be separated manually and therefore form a single integral unit, unless one of the materials constitutes an insignificant part of the packaging unit and in any event no more than 5% of the total mass of the packaging unit and excluding labels, varnishes, paints, inks, adhesives and lacquers. This is without prejudice to Directive 2019/904".

Following the PPWR, from 2030, an assessment based on design for recycling criteria shall be carried out per each packaging category in Table 1 of Annex II by providing an indicative list of packaging materials, types and categories referred to in Article 6 PPWR. The categories relevant for aluminium (aluminium as predominant packaging material and aluminium as non-predominant packaging material) are highlighted in colour/shown in Table 3.

***Table 3:** Indicative list of packaging materials, types and categories referred to in Article 6 PPWR, (Aluminium as predominant packaging material, dark violet; aluminium as possibly non-predominant packaging material, light violet)*

Cat. No	Predominant packaging material	Packaging type	Format (illustrative and non-exhaustive)
1	Glass	Glass and composite pack-aging, of which the majority is glass	Bottles, jars, flacons, cosmetics pots, tubs, ampoules, vials made of glass (soda lime silica), aerosol cans
2	Paper/ cardboard	Paper/cardboard packaging	Boxes, trays, grouped packaging, flexible paper packaging (e.g. films, sheets, pouches, lidding, cones, wrappers
3	Paper/ cardboard	Composite packaging of which the majority is paper/ cardboard	Liquid packaging board, and paper cups (i.e. laminated with polyolefin and with or without aluminium), trays, plates and cups, metallised or plastic laminated paper/card-board, paper/ cardboard with plastic liners/ windows
4	Metal	Steel and composite pack-aging of which the majority is steel	Rigid formats (aerosols cans, cans, paint tins, boxes, trays, drums, tubes) made of steel, including tinplate and stainless steel

Cat. No	Predominant packaging material	Packaging type	Format (illustrative and non-exhaustive)
5	Metal	Aluminium and composite packaging of which the majority is aluminium – rigid	Rigid formats (food and beverage cans, bottles, aerosols, drums, tubes, cans, boxes, trays) made of aluminium
6	Metal	Aluminium and composite packaging of which the majority is aluminium – semi-rigid and flexible	Semi rigid and flexible formats (containers and trays, tubes, foils, flexible foil) made of aluminium
7	Plastic	PET – rigid	Bottles and flasks
8	Plastic	PET – rigid	Rigid formats other than bottles and flasks (including pots, tubs, jars, cups, mono- and multilayer trays and containers, aerosol cans)
9	Plastic	PET – flexible	Films
10	Plastic	PE – rigid	Containers, bottles, trays, pots and tubes
11	Plastic	PET – flexible	Films, including multilayer and multi-material packaging
12	Plastic	PP – rigid	Containers, bottles, trays, pots and tubes
13	Plastic	PP – flexible	Films, including multilayer and multi-material packaging
14	Plastic	HDPE and PP – rigid	Crates and pallets, corrugated board plastic
15	Plastic	PS and XPS – rigid	Rigid formats (including dairy packaging, trays, cups and other food containers)
16	Plastic	EPS – rigid	Rigid formats (including fish boxes / white goods and trays)
17	Plastic	Other rigid plastics (e.g. PVC, PC) including multi-materials – rigid	Rigid formats, including intermediate bulk containers, drums
18	Plastic	Other flexible plastics in-cluding multi-materials – flexible	Pouches, blisters, thermoformed packaging, vacuum packaging, modified atmosphere/modified humidity packaging, including flexible intermediate bulk containers, bags, stretch films
19	Plastic	Biodegradable plastics - rigid (e.g. PLA, PHB) and flexible (e.g. PLA)	Rigid and flexible formats
20	Wood, cork	Wooden packaging, including cork	Pallets, boxes, crates
21	Textile	Natural and synthetic textile fibres	Bags
22	Ceramics or porcelain stoneware	Clay, stone	Pots, containers, bottles, jars

> ***PPWR/Side note:*** *to be defined as "recycled at scale" each packaging category as listed in Annex II, Table 2 has to reach a minimum of 55% recycling rate at EU level on an annual basis.*

Table 4: *Indicative list of packaging materials, types and categories referred to in Article 6 PPWR, Annex II, Table 2*

Materials	Categories	Link to Table 1, Annex II
Plastic	PET rigid	categories 7, 8
	PE rigid, PP rigid, HDPE and PP rigid	categories 10, 12, 14
	Films/flexible	categories 9, 11, 13, 18
	PS, XPS, EPS	categories 15, 16
	Other rigid plastics	category 17
	Biodegradable (rigid and flexible)	category 19
Paper/cardboard	Paper/cardboard (except liquid packaging board)	categories 2, 3
	Liquid packaging board	category 3
Metal	Aluminium	categories 5, 6
	Steel	category 4
Glass	Glass	category 1
Wood	Wood, cork	category 20
Others	Textile, ceramics/porcelain and others	categories 21, 22

5. Existing design for recycling guidelines and recyclability assessments

A comparison has been made between existing design for recycling guidelines and recyclability assessments that thematically include aluminium as a major and minor material (see Annex 2). The aim is to visualise similarities, differences and possible gaps and inconsistencies in detail in this direct comparison. In particular, the sometimes widely differing classifications and evaluations show the need for harmonised assessments of recyclability based on technical and scientific principles and laws.

The focus of existing design for recycling guidelines is mainly on plastics and partly on fibre-based packaging. There are also guidelines that deal with all types of material, in which design for recycling recommendations for aluminium often only play a subordinate role. For the present study, more than 15 design for recycling guidelines were reviewed regarding the recommendations made for aluminium as a major or minor material. These include:

- ACE[1], BEVERAGE CARTONS, DESIGN FOR RECYCLABILITY GUIDELINES,
- **AIRG**, ALDI's International Recyclability Guideline,
- **ALUTREC**, LA MATRICE DE RECYCLABILITÉ DES EMBALLAGES SOUPLES EN ALUMINIUM,
- APR Design Guide® for Plastics Recyclability[2],
- CEFLEX, "DESIGNING FOR A CIRCULAR ECONOMY GUIDELINES" D4R-Guideline[3], part 1,
- **CIAL, Aluminium Packaging Guidelines for an ecofriendly design,**
- **CIRCPACK by VEOLIA,** Design for Recycling Guidelines for packaging (aluminium),
- **CIRCULAR Packaging Design Guideline,** FH Campus Wien,
- **COTREM, La matrice de recyclabilité des emballages rigides en aluminium,**
- COTREP, "COTREP GUIDELINES"[2],
- **ECR** Community Austria in collaboration with WPO (World Packaging Organisation), **Packaging Design for Recycling,**
- **KIDV Recycle Check** for aluminium,
- **LIDL,** Sustainable Packaging design,
- RECOUP PLASTIC PACKAGING RECYCLABILITY BY DESIGN 2023, Recycling of Used Plastic Ltd. (RECOUP), Version 10[2],
- RecyClass, "Design for Recycling Guidelines"[2],
- **RecyClass by CIRCPACK**

Ten of the above-mentioned guidelines (those highlighted in bold) cover aluminium packaging (with aluminium as predominant material); the other ones have been drawn up exclusively for plastics or cartons and therefore focus on aluminium only as a minor material.

In addition, three standards were included in the evaluation. As these apply to all types of material, they are briefly characterised below:

- **CHI-RA:** The CHI Recyclability Assessment is published by the cyclos-HTP Institute (CHI)

[1] relates exclusively to liquid packaging cartons
[2] relates exclusively to plastic packs
[3] relates exclusively to PO-based flexible packs

- **EN 13430:** Packaging – Requirements for packaging recoverable by material recycling; EN 13430:2004 by the Technical Committee TC 261 „Packaging“ of the **European Committee for Standardisation (CEN).**

- **German minimum standard, ZSVR:** The minimum standard is issued by the Central Agency Packaging Register (Zentrale Stelle Verpackungsregister - ZSVR)

For aluminium packaging (with aluminium as the predominant material), it can be observed that the recommendations for the recycling-compatible design are of a general nature and are mainly aimed at the basic rules of simple packaging design:

- Preference for mono-material structures,
- Avoidance of unnecessary decoration,
- Preference for EuPIA compliant printing inks

Only a few additional specific aspects are addressed by one or the other guideline, e.g. the question of product residues (RecyClass by CIRCPACK) or chlorine-based lacquers (ALUTREC, COTREM).

For other packaging categories (plastics, paper, metals and glass) the presence of aluminium as minor material and how it is assessed in the guidelines was also studied.

As a constituent or component in packaging formats which are mainly made of glass, metal and to a lesser extent paper, aluminium is generally rated as a well recoverable material. In plastic packaging in which aluminium foil serves as a barrier layer, the overall evaluation is more ambiguous and mainly connected to the assumption that plastic material gets lost during the sorting process, when such composite packaging is sorted into the aluminium fraction.

Please refer to Annex 2 for further details.

6. Design for Recyclability Guidelines – general considerations and principles

6.1 Methodological approaches for evaluating and measuring recyclability

There are currently two fundamentally different methodological approaches for evaluating or measuring recyclability and design for recycling: **evaluation of recycling compatibility in the (extended) traffic light system and criteria-based assessment of recyclability.**

6.1.1 Evaluation of recycling compatibility in the (extended) traffic light system

Examples of this methodological approach include the design for recycling guidelines such as by ACE, COTREP, the European PET Bottle Platform (EPBP), RecyClass, etc.

In methodological terms, this involves the direct categorisation of design parameters in a three-stage ordinal-scaled evaluation system. The so-called recycling compatibility serves as the evaluation parameter.

6.1.2 Criteria-based assessment of recyclability

Examples of this methodological approach are EN 13430, the German minimum standard and the CHI Recyclability Assessment.

These are descriptive methods for a metric-scaled assessment of recyclability based on fact-based balancing rules.

The following aspects must be considered for this first methodological approach, also with respect to the requirements of Article 6 and Article 35 of the PPWR:

- From a methodological point of view, a measurement rather than an evaluation is performed.
- Metrically scaled data are „downward compatible“, i.e. they can be converted to a less differentiated scale, such as an interval scale (Table 2, Annex II, PPWR).
- Analogue distributed property characteristics can be mapped metrically scaled 1:1.
- High transparency of the assessment results, as these are determined according to criteria and by defining verifiable assessment rules.
- From a methodological point of view, no assessment based on „expert opinion“ is required. In the individual criteria, the results can be determined purely based on facts.

The above list emphasises that the conventional D4R guidelines (with recyclability evaluation in the traffic light system) are methodologically less appropriate instruments regarding the requirements of Article 6 and Article 30 of the PPWR. Their advantage is solely in the simple categorisation of design parameters as an orientation guide for packaging development. The recyclability assessments are difficult for packaging developers to handle if design parameters are not explicitly categorised in the assessments.

To fulfil this original function of D4R guidelines, i.e. to not only display an assessment result for recyclability but also design rules, a method for the categorical classification of design parameters is developed and explained below, which is consistent with the method for determining recyclability.

6.2 Methodological principles of the Design for Recyclability Guidelines and Recyclability Assessment

There are fundamental differences between D4R Guidelines and Recyclability Assessments. Guidelines work with evaluation categories. Assessments, on the other hand, use measurements. To resolve this methodical discrepancy between these two approaches, it is proposed to switch directly to measurement categories instead of the categorical evaluation in the guidelines, i.e. to make recyclability itself a direct classification criterion.

The underlying criteria for the Design for Recyclability Guidelines and for the Recyclability Assessment are determined on a fact-based and scientific basis. The requirements for recyclable product design are based on the state of the art (TRL 9) and include the entire recycling process from the generation of packaging waste (collection) to the recyclate application. This creates the necessary scope for future developments in both products and recycling technologies, by ensuring that the Design for Recyclability Guidelines and Recyclability Assessments can be adapted and updated with each innovation.

Recyclability is the capability of packaging measured against the requirements of (high-quality) recycling. Design for Recyclability is the result of a design that conforms to these requirements. Against this background, the technical-scientific and legal terminology must be adjusted to develop Design for Recyclability Guidelines and Recyclability Assessments. Once the terminology has been clarified, the recycling processes from which these requirements are to be derived must be identified.

The criteria for describing the capability of packaging for recycling and the requirements for packaging design must be developed from the physico-chemical (and metallurgical) laws of the individual process operations. It goes without saying that the criteria that determine recyclability are identical to those for packaging design.

First, the used definitions according to the philosophy of the underlying Design for Recyclability Guidelines and Recyclability Assessment for aluminium containing packaging are described and placed in the context of the PPWR to emphasise their full conformity (PPWR legal text in blue infographic).

The following explains how the terms

- “Recycling” and “high quality recycling” (6.3.1)
- “Recycling capability” (6.3.2)
- “Design for recycling” (6.3.3)
- “State of the art” (6.3.4)
- “Recyclability” (6.3.5)
- “Object of assessment/object of investigation” (6.3.6)
- “Separate packaging component” (6.3.7)
- “Integrated packaging component” (6.3.8)
- “Criteria based assessment” (6.3.9)

are to be understood and how they are handled.

6.3 Terminology

6.3.1 (High-quality) recycling

Recycling is the processing and recovery of raw materials that have already been used, i.e. the return of materials to the cycle. In this context, recycling always means processing waste into concentrates, recyclates, regenerates, blends or alloys that can replace corresponding new material (with comparable processing requirements) in standard applications.

The necessary recyclate quality for secondary applications and the processes required to achieve this form the reference point for the assessment and at the same time the definition basis for „**high-quality recycling**“.

§ 3 (41) “high-quality recycling“

means any recycling process which produces recycled materials that are of equivalent quality to the original materials, based on preserved technical characteristics, and that are used as a substitute to primary raw materials for packaging or other applications where the quality of the recycled material is retained;

Figure 15: *Definition high-quality Recycling, PPWR, January 2025*

> ***Side note:*** *Processes in which waste is incorporated into new products, but which do not correspond to a typical virgin material application, are not considered as a reference benchmark.*

6.3.2 Recycling (-capability)

The definition of **recycl**[*ing - cap*]**ability** is handled in a process-open manner, as it is fundamentally irrelevant whether a required quality level of recyclates/alloys is realised via physical, chemical or thermal waste processing technology, respectively via combined process technology steps.

The boundaries between the individual process engineering disciplines are fluent or the overlaps are large, and combinations of processes and individual disciplines are usually required anyway to produce high-quality recyclates or concentrates from waste for applications typical for virgin materials (e.g. processing of aluminium packaging using pyrolysis as a digestion process or refinement stage for pre-concentrates)[19].

6.3.3 Design for recycling

Packaging has a significant advantage over the primary raw materials from which it is made: it is of anthropogenic origin and can therefore be designed for its subsequent use and its circularity during the conception phase, which is known as design for recycling. This means that design-related and therefore influenceable characteristics can be taken into account, which refer to the functional requirements of the recycling process as comprehensively as possible.

§ 3 (37) “design for recycling“

means the design of packaging, including individual components of packaging, that ensures the recyclability of the packaging with established collection, sorting and recycling **processes proven in an operational environment;**

Figure 16: *Definition “design for recycling”, PPWR, January 2025*

[19] Assessment of recyclability, CHI-D4R$_{PD}$ Guidelines, Version 6.1, March 2025

> ***Note:*** *Outside the packaging manufacturer's influence on the recyclable design of his packaging, there are practical deficits, such as inadequate collection structures and insufficient sorting and recycling processes, which can be traced back to the economic constraints of other participants in the value chain. Therefore, such factors should not be methodically considered when assessing recyclability.*

6.3.4 State of the art of recycling processes

Another important point is the definition of the recycling technology and its degree of development, from which the criteria for suitability for recycling or recycling-friendly design and thus also the assessment of recyclability can be derived. The **„practice of sorting and recycling"** is not a suitable reference, as this is characterised by the different levels of development of processes and entails the **risk of a stagnation for both packaging development and recycling.**

The **state of the art, TRL 9,** is therefore chosen as the reference point. Accordingly, the processes against which recyclability is measured must be available on an operational scale and proven from a technical and economic perspective.

The definition of state of the art on which the guidelines are based always refers to processes and not to individual plants and includes operating methods and machine settings.

6.3.5 Recyclability

Recyclability means conformity with the requirements of a recycling process and is defined in these guidelines as follows:

Recyclability is the individual gradual suitability of a packaging or a product to factually substitute material-identical virgin material in its post-use phase; "factually" means that collection and processing structures at industrial scale are established and available.

§ 3 (38) "recyclability"

means the compatibility of packaging with the management and processing of waste by design, based on separate collection, sorting in separate streams, recycling at scale and the use of recycled materials to replace primary raw materials;

Figure 17: *Definition "Recyclability", PPWR, January 2025*

6.3.6 Object of assessment and object of investigation

The distinction between object of assessment and object of investigation is necessary because the **waste-specific condition** in the sense of the assessment is not a quantitatively fixed value, but depends on the product consistency (liquid, pasty, solid) and disposal behaviour, etc. However, as the waste-specific condition can be decisive for the behaviour in the process, it must be considered in the context of investigations.[20]

The **object of the assessment** and the reference for calculating recyclability is the **packaging unit (by weight)** containing aluminium (incl. all associated packaging components, such as closures, tamper-evident seals, lids etc.) without residual contents (means the **new state of a packaging**).

The **object of investigation** is the packaging after use, i.e. more or less the stage in which the packaging accumulates as waste (means the **used state of a packaging,** including residual contents and other contaminants). The item to be analysed is the **packaging in its waste-specific condition.**[21]

[20] The recyclability is measured with reference to the weight of the new (empty) packaging. The translucency criterion for glass recycling plays a decisive role in the test result for specific packaging like a nail varnish bottle. The requirement regarding this criterion may no longer be met for the glass cullet from a nail varnish bottle, as it has an opaque „inner coating" in the waste-specific state. An example from the aluminium sector is chocolate aluminium foil, which in the waste-specific state (crumpled, folded) is sorted out with high efficiency in practice via eddy-current separator; if a flat sheet of aluminium foil were to be examined regarding sortability, the factual sorting result would be reduced due to the high air resistance.

[21] This aspect is of minor importance for aluminium (compared with plastics and the separation requirement using NIR technologies) because the criteria for determining recyclability are less sensitive in this respect.

6.3.7 Separate packaging component

If use by the consumer requires disassembly into individual packaging components, these are categorised, examined and assessed individually. The same also applies if disassembly can be assumed or plausibly presumed to occur because of stress during transport up to the first material-specific sorting step.

Example:

Aerosol can with overcap (without undercut) in a gift box.

The folding box, the overcap and the aerosol can must be assessed individually.

> ***Side Note:*** *The overcap without undercut typically separates during the transport process of the collected material. Thus, the aerosol with overcap (without undercut) is split into 2 objects of assessment and consequently 2 objects of investigation.*

§ 3 (44) "separate component"

means a packaging component, whether or not from the same material as the main body of the packaging unit, that is distinct from the main body of the packaging unit, that needs to be disassembled completely and permanently from the main body of the packaging unit and that is typically discarded prior to and separately from the main body of the packaging unit, including packaging **components that can be separated from each other simply through mechanical stress during transportation or sorting;**

Figure 18: *Definition "separate component", PPWR, January 2025*

> ***Side note:*** *According to this definition, the following aluminium applications in packaging would be considered as separate packaging components:*
>
> - *Aluminium tamper-evident seals on toothpaste tubes and ketchup bottles*
> - *Top part (detachable) of an aluminium precut overcap (over the agraffe) of a sparkling wine bottle*

§ 3 (44) "separate component"

[...] Where a unit of packaging includes separate components, the assessment of compliance with the design for recycling requirements and with the recycled-at-scale requirements shall be carried out **separately for each separate component.**

All components of a unit of packaging shall be compatible with the established collection, sorting and recycling processes proven in an operational environment and **shall not hinder the recyclability of the main body** of the packaging unit.

Figure 19: *Dealing with "separate component" in § 6, PPWR, January 2025*

6.3.8 Integrated packaging component

If packaging contains integrated packaging components, these must be categorised, examined and assessed with the main packaging component.

§ 3 (43) "integrated component"

means a packaging component, whether or not of the same materials as, or distinct from, the main body of the packaging unit, that is integral to the packaging unit and its functioning, that does not need to be separated from the main body of the packaging unit in order to **ensure the functionality of the packaging unit** and that is typically discarded at the same time as the main body of the packaging unit, although not necessarily via the same disposal route;

Figure 20: *Definition "integrated component", PPWR, January 2025*

§ 6 (9) Recyclable packaging

[...] Where a unit of packaging includes integrated components, the assessment of compliance with the design for recycling criteria and with the recycled-at-scale requirements shall **include all integrated components.**

A separate assessment shall be carried out for integrated components that can become separated from each other as a result of mechanical stress during transportation or sorting. [...]

***Figure 21:** Dealing with "integrated component" in § 6, PPWR, January 2025*

> ***Side note:** According to this definition, the following aluminium applications in packaging would be considered as integrated packaging components:*
>
> - *Aluminium closures on glass bottles*
> - *Aluminium based push through foil on plastic-based blister*
>
> *Typical integrated packaging components in aluminium packaging are:*
>
> - *Plastics closures on aluminium tubes*
> - *Steel valve disc on an aluminium aerosol can*

6.3.9 Criteria based assessment

Advantage: Criteria-based assessments can be **methodically applied to all types of packaging and materials.** This is an essential prerequisite in the context of European harmonisation of standards. The present assessment for packaging containing aluminium follows the logic of a criteria-based assessment. This also reflects the fact that Article 6 of the PPWR refers to all types of material and therefore, although different criteria are applied, the method of assessment must be identical.

§ 3 (42) "packaging category"

means a combination of material and specific packaging design which determines recyclability by reference to established state-of-the-art collection, sorting and recycling processes proven in an operational environment and which is relevant for the definition of the design for recycling criteria;

***Figure 22:** Definition "packaging category", PPWR, January 2025*

6.4 Development of Design for Recyclability Guidelines and Recyclability Assessments in five steps

Based on the topics as explained above, the development of Design for Recyclability Guidelines and Recyclability Assessments require five essential steps:

1. **Determination of the state of the art** for the entire process chain (sorting, reprocessing, refining for intended applications of recycled material).
   (The recycling paths according to the state of the art are described in chapter 3.2 to 3.3.8.)

2. **Identifying relevant individual operations** within the process stages.
   (The relevant unit operations are marked in the flowcharts, see chapter 3.2 to 3.3.8.)

3. **Analysing the material properties** (physical-chemical) that are decisive for the success (qualitative and quantitative) of the individual process stages.
   (Physical-chemical packaging properties that determine the success of the process are shown based on the functional principle of the unit operations, see chapter 3.2 to 3.3.8.)

4. **Formulation of criteria** for the assessment of recyclability, considering

- Infrastructural criteria;
- Process-specific criteria (quantitative criteria);
- (Recyclate) application-specific criteria (quantitative and qualitative criteria) (see chapters 6.5.1 – 6.5.3).

5. **Grouping of the criteria** formulated above **according to properties** that are functionally **dependent and independent** of the product design.

   For example, the baffle settings of the eddy current separator have a major influence on the separation success. Differences in the baffle settings are often due to contractual specifications. These causal relationships are not dependent on the design of the packaging. Real losses of small-format aluminium packaging due to fine screening in the sorting process without feeding to an eddy current separator have the same reason. These are also not dependent on the design and are therefore not considered in the Recyclability Assessment.

These Design for Recyclability Guidelines and the underlying Recyclability Assessment follow these steps and therefore have the same logic. In this logic, no direct evaluation is carried out via the parameter „recycling compatibility“, but rather a categorisation of the qualitative and quantitative factors determining recyclability (see Figure 26).

6.5 Different categories of criteria

6.5.1 Infrastructure criteria

Infrastructure criteria are only relevant for a Recyclability Assessment to the extent that a state-of-the-art process within the meaning of TRL 9 is available at all. The existing state-of-the-art processes, insofar as they are relevant in the context of the use of aluminium in packaging, can be found in chapters 3.2 to 3.3.8 (reference above).

The quantitative availability of recycling technology, which would have to be considered for a claim in accordance with ISO 14021, for example, is not a criterion for assessing recyclability, but is only relevant for „recycling at scale“ in accordance with the PPWR.

6.5.2 Process-specific criteria

Process-specific criteria are the criteria that determine the quantitative recycling success of a process chain according to the state of the art. For aluminium packaging, these are, at the upper differentiation level, the target material content of the packaging, the behaviour during (pre-)sorting, the behaviour during mechanical or thermal disintegration and the behaviour during the required concentrating and upgrading of the metal.

In the practice of packaging recycling, different material-specific physical and chemical properties are used to achieve the lowest possible loss of target materials which is required for high-quality recycling. The decisive criterion for packaging containing aluminium in this respect is its electromagnetic properties, which are used for separation via eddy-current separator and/or induction sorting technologies both in the sorting process for the packaging[22] and during reprocessing after the packaging has been broken down. Separability via eddy-current separator can be taken for granted due to the high conductivity of aluminium.

[22] Packaging unit or separate packaging components in case of separate packaging components.

According to the operating principle of the machine, the mass and the air resistance of the packaging counteract the separation. Eddy current separation cannot be used to separate out packaging where the electromagnetic repulsion only causes a torque (e.g. plastic bottles with aluminium caps).

There are also limitations if, for example, spherical or stem-like particle shapes are produced by the disintegration process.

Otherwise, format criteria only play a subordinate role; according to the state of the art, it can be assumed that the sorting of packaging containing aluminium is carried out across the entire particle size spectrum, including the finest grain sizes.

In addition, the disintegration behaviour itself plays a role as a criterion; this applies both to mechanical disintegration and to the thermal (pyrolytic) disintegration of the packaging.

Oxidation and melting losses as a function of the packaging composition must also be discussed. According to published scientific studies, metal losses from pyrolysis of aluminium packaging are approx. 1-2%, depending on the material thickness[23]. Oxidation and melting losses in the recycling of aluminium packaging are essentially dependent on the technical efficiency of the pyrolysis according to the state of the art and predominantly not design-related. Therefore, they are not to be considered a packaging characteristic for recyclability. Losses due to surface oxide layers which are already formed during the production of aluminium (and that - according to relevant literature sources - are formed in the order of 10 nanometres), are not due to technical reasons and could be considered design-related. Since the aluminium bound in the oxide layer cannot be recovered as metal in the recycling process, these metal losses should be methodically considered either under the recyclable material content criterion or under melting and oxidation losses. These amount to:

- approx. 0.2% of the metal content for thin aluminium foils,
- approx. 0.02% for tubes and
- approx. 0.01% for cans.

Marginal in themselves; however, due to the accuracy of the calculation method required under Article 35 of the PPWR, the authors recommend that they should at least be considered and reported if the recyclability determined is close to the threshold values of the recyclability performance grades.

6.5.3 Application-specific criteria

Application-specific criteria are the criteria that determine the quality of the recyclate. For aluminium, as for all other packaging, these are the criteria of target material definition and (application) incompatibilities.

The leading criterion for determining recyclability is the target material content of packaging. Which materials are to be characterised as target materials is determined by the description of the recycling path, considering the recyclate properties required for the recyclate application. The target material share is directly incorporated into the rules for assessing recyclability and is directly proportional to the recyclability in % by weight of the assessed packaging. The consequence of this is that the maximum recyclability corresponds to the target material share (please refer also to chapter 7.1). This should not be understood as an invitation to make already optimised packaging thicker to increase the target material share and achieve recyclability. The priorities of the Waste Hierarchy of the Waste Framework Directive must be observed: “Reduce” takes a higher priority than “Recycle”.

Finally, it must be investigated whether the packaging design has incompatibilities, i.e. contains contaminants that significantly degrade the recyclate properties and massively impair the reprocessing or the technology of downstream processes.

[23] Giese (2007)

7. Design for Recyclability Guidelines ($D4R_{PD}$) for aluminium packaging

To distinguish from conventional design for recycling (D4R) guidelines, the term Design for Recyclability Guidelines $D4R_{PD}$[24] is introduced.

The principles and methods for formulating Design for Recyclability Guidelines ($D4R_{PD}$) explained in chapter 6 will be used in this section, including categorical classification of design parameters.

7.1 Methodological development of Design for Recyclability Guidelines ($D4R_{PD}$)

According to the PPWR, from 2030, recyclability performance is based on design for recycling criteria per packaging categories. The following packaging categories are relevant for packaging containing aluminium as predominant packaging material (PPWR, ***Annex II, Table 1,*** Extract):

Parameters for design for recycling criteria

As mentioned before, according to the PPWR, recyclability performance is based on design for recycling criteria. The relationship between criteria and parameters is not yet further specified. However, there is a (not yet exhaustive) list of „parameters for design for recycling criteria“ that should be considered. The following are listed:

1. Additives
2. Labels
3. Sleeves
4. Closures and other small packaging components
5. Adhesives
6. Colours
7. Material composition
8. Barriers / coatings
9. Inks and laquers / printing / coding
10. Product residues / ease of emptying
11. Ease of dismantling

Cat. No	Predominant packaging material	Packaging type	Format (illustrative and non-exhaustive)
5	Metal	Aluminium and composite packaging of which the majority is aluminium – rigid	Rigid formats (food and beverage cans, bottles, aerosols, drums, tubes, cans, boxes, trays) made of aluminium
6	Metal	Aluminium and composite packaging of which the majority is aluminium – semi-rigid and flexible	Semi rigid and flexible formats (containers and trays, tubes, foils, flexible foil) made of aluminium

Figure 23: *Annex II, Table 1 (extract), PPWR, January 2025*

[24] $D4R_{PD}$ = D4R Guidelines incl. a method for the categorical classification of design parameters

Table 3 “Recyclability performance grades“

[...] From 2030, **recyclability performance is based on design for recycling criteria.** [...]

The assessment based on design for recycling criteria shall be carried out for each packaging category listed in Table 1, taking into account the methodology established under Article 6 (4) and the related delegated acts, as well as the parameters established in Table 4. After weighing the criteria per packaging unit, it will be classified into categories A, B or C. [...]

Figure 24: *Annex II, Table 3 “Recyclability Performance Grades”, PPWR, January 2025*

For the methodical development of applicable Design for Recyclability Guidelines the design for recycling criteria must be translated into an assessment and into the format of Design for Recyclability Guidelines. This requires a causal link between the assessment criteria and the product design parameters.

The following criteria must be considered in accordance with Annex II:

- Separability of any packaging component, either manually by consumers or in processing plants,
- Efficiency of sorting and recycling processes,
- Evolution of sorting and recycling technologies (to address the aspect if the packaging cannot be sorted today, but might be sortable in 2 years),
- Preservation of functionality of secondary raw materials enabling the substitution of primary raw materials.

Table 4 “Non-exhaustive list of parameters for setting design for recycling criteria under Article 6“

The list in this Table shall be used as a basis when defining design for recycling criteria [. . .]. The design for recycling criteria shall then be used in order to set the calculations leading to the performance grades listed in Table 3. [...]

Figure 25: *Annex II, Table 4 “List of parameters”, PPWR, January 2025*

The parameters explicitly mentioned in this list represent possible design variants of plastic packaging or fibre-based packaging regarding their potential relevance for recycling. Almost all these parameters (such as colour, label cover, sleeves, etc.) are irrelevant for the recycling of metal packaging due to the excellent mechanical separability of metals. Only the **material composition of the packaging containing aluminium,** and, to a lower extent, the format (possibly very small parts) need to be discussed.

According to the requirements of the PPWR, appropriate criteria must therefore reflect the qualitative and quantitative effects of the design parameters on recyclability. The requirements of the PPWR are met by a methodology in which design parameters are categorised according to **design for recycling criteria. Quantitative and qualitative impact categories** are distinguished from each other. The design parameters to be categorised for Design for Recyclability Guidelines are then classified with the necessary differentiation according to packaging components (main body, closure, label, etc.) and the respective design variants (material, colour, structure, etc.).

By differentiating between quantitative and qualitative impact categories on recyclability, guidelines can be linked to the rules of the recyclability assessments and ensure maximum transparency and verifiability of the categorisation of individual design variants. In addition, the differentiation of quantitative and qualitative causalities ensures that the categorisation can be updated easily and transparently in line with changes in the state-of-the-art technology (development of new process technologies, innovations) or in the event of an increase in knowledge.

Considering the criterion of sortability and separability, the material composition of the packaging must be assigned to quantitative and qualitative impact categories as follows:

Quantitative impact categories	Qualitative impact categories
Target material (**M_T**) (share)	Target material (**M_T**) (definition)
Design related losses (of target material) (**CAT 0**)	
Category 1 (**CAT 1**): materials or constituents that are separable during reprocessing steps, are not recycled and do not impact the recycling of the target material	
	Category 2 (**CAT 2**): contaminants that are not (sufficiently) separable during reprocessing steps, which, however, can be regarded as **limited compatible contaminant.** CAT 2 contaminants have no or negligible impact on recyclate properties in practice.
	Category 3 (**CAT 3**): contaminants that are not sufficiently separable during reprocessing steps and which must be classified as **incompatible constituents.** CAT 3 contaminants cannot be separated or cannot be separated sufficiently and jeopardise the process or contaminate the recyclate application.

***Figure 26:** Differentiation and categorisation of qualitative and quantitative impact categories*

The categories represent the following aspects:

- **Target material** (M_T) represents the positive initial value in the assessment; share of recyclable material in % = maximum recyclability potential in % of weight of the individual packaging.

- **CAT 1, CAT 2, CAT 3** represent categories for **non-target materials or constituents,** wherein

  - **CAT 1** represents the reduction in recyclability potential without loss of quality in the recyclate;

  - **CAT 2** represents design-related material or constituents leading to tolerable recyclate impurities that do not make a positive contribution for closing the loop;

  - **CAT 3** represents recyclate contaminations or process-jeopardising materials that are considered a knock-out criterion in the recyclability assessment.

    The materials that are converted into recyclates (M_T) need to be distinguished from those classified as non-targets or contaminants of the various categories (CAT 1, CAT 2, CAT 3).

- It should be noted that not all design features can be meaningfully categorised. There are limits when, due to complex dependencies between several design features, only an individual examination can provide actual information about the sorting and separation behaviour. This methodological restriction is met by introducing a 5th category for parameters or „parameter combinations“. The reference is then made under the assignment for the respective criterion.

  Thus, **CAT 0** indicates implied **design-related losses of target materials** (process-specific criteria). Typically, target material losses may occur due to aluminium losses resulting from a lack of sortability at the eddy current separator or due to oxidation losses in reprocessing steps. As a rule, there is generally no question of sortability. Exceptions are very thin, light packaging in a shape for which the deflecting force does not always take effect due to the high air resistance at the eddy current separator.

  A major advantage of this approach is that the list of possible product design parameters does not have to be exhaustive. In many cases, the users of the catalogue will be able to research the product information required for classification and make their own categorisation thanks to the transparent presentation of the design regulations.

The advantage of this categorisation is that the $D4R_{PD}$ Guidelines, and the Recyclability Assessment, are in principle applicable to all packaging containing aluminium that are transferred to metal recycling, regardless of their aluminium content. The reference to the criteria for recycling-friendly design is maintained, as the category definitions can be transferred to design rules; for example: CAT 3 must be avoided at all costs, see chapter 7.2 “Messages”.

We deviate from the conventional system of categorisation „according to recycling compatibility“ for the following reasons:

- The term „recycling compatibility“ is not defined anywhere and presumably cannot be defined precisely.

- Assessment and evaluation criteria of “recycling compatibility” are not apparent (resulting in a lack of transparency).

- Certain design features (e.g. target material content) cannot be categorised according to “recycling compatibility” or to recyclability, respectively can only be categorised inadequately.

7.2 Design for Recyclability Guidelines ($D4R_{PD}$) for aluminium packaging

The following table shows the Design for Recyclability Guidelines $D4R_{PD}$ for aluminium packaging, resulting from the categorical classification of design parameters applied to aluminium packaging.

This table is applicable to aluminium packaging (with aluminium as predominant material) and to separate packaging components predominantly made of aluminium material.

In principle (and in line with the requirements of the German minimum standard, ZSVR), it can also be applied to packaging containing aluminium that is sorted into the aluminium fraction.

For packaging with aluminium as a minor material that is not sorted in the aluminium fraction (e.g., liquid packaging cartons), the table is not applicable and other guidelines (specific to the main material of the packaging format) are relevant.

The reading of the table is described step by step below.

***Figure 27:** $D4R_{PD}$ Guidelines for aluminium packaging*

$D4R_{PD}$ Guidelines for aluminium packaging					
A | Main Body					
Design Parameter	**Recyclability categories**				
Material type	Target material (M_T)[25]	Separable by reprocessing (CAT 1)	Limited compatible (CAT 2)	Incompatible (CAT 3)	Examination required: Design-related losses (CAT 0)
Aluminium	x				
Non-metallic aluminium					x[26]
Plastics		x			
Paper		x			
Steel (unspecified)	x				
Stainless steel	x				
Chrome-plated steel	x				
Tin-plated steel (tinplate)	x				
Non-ferrous metals	x				
Printing inks, coatings, adhesives					
Printing inks		x			
Coatings (inner and outer coatings)		x			
Adhesives		x			

[25] The column “target material" represents the maximum recyclability in % by weight of the individual packaging unit for main and minor materials. M_T specifies the target materials: aluminium (only metallic aluminium is to be considered), but also other ferrous and non-ferrous metals: non-metallic aluminium, steel (unspecified), stainless steel, chrome-plated steel, and tin-plated steel (tinplate).

[26] Melting- and oxidation losses.

B | Integrated (minor) packaging component(s)

Design Parameter	Recyclability categories				
Closure/Functional cap: Material type	Target material (M_T)[25]	Separable by reprocessing (CAT 1)	Limited compatible (CAT 2)	Incompatible (CAT 3)	Examination required: Design-related losses (CAT 0)
Aluminium	x				
Non-metallic aluminium		x			
Plastics		x			
Paper					
Steel (unspecified)	x				
Stainless steel	x				
Chrome-plated steel	x				
Tin-plated steel (tinplate)	x				
Non-ferrous metals	x				
Label: Material type					
Plastics		x			
Paper		x			
Label: Adhesive					
Adhesive		x			
Label: Decoration					
Printing colour		x			
Foil stamping		x			
Release agents and others					
PFAS coating ≥ threshold according to article 5 (5) PPWR				x	
Silicon		x			

> ***Side Note:*** *For its critical role of enhancer of barrier properties, chlorine is contained in certain polymers used for components or constituents of aluminium packaging (e.g., PVC layer for pharma applications, chlorine-containing lacquers for sensitive food applications).*

As for other plastics or lacquers, these chlorine-containing constituents or components are removed during the reprocessing (and not sent for recycling) and do not impact the recycling of aluminium. Indeed, at the pyrolysis plant, chlorine-containing components or constituents are completely removed. However, an excessive level of chlorine in the material entering the pyrolysis process may cause equipment damage (corrosion), which requires a special attention from the operator when preparing the input batch. For this reason, it is recommended to minimise the chlorine content in aluminium packaging when feasible.

How to read the table – packaging with aluminium as the main material?

Example: Aerosol can with a snap-on cap (without undercut)

Packaging description: The aerosol can is made up of the following packaging components: aluminium can body (with inside and outside lacquer), tinplate valve cup, gasket, dip tube (PVC), plastic snap-on cap.

Step 1: Characterisation of the main body and the individual packaging components

aluminium can body with integrated packaging components as per § 3 (42) PPWR: tinplate valve cup, gasket, PVC dip tube

snap-on cap (without undercut) as separate packaging component as per § 3 (43) PPWR

Step 2: Categorisation of the main body and the integrated individual packaging components

This categorisation will allow the calculation of the „target material share“ which represents the **maximum recyclability potential by weight** of the individual packaging components. For aluminium packaging (i.e. for packaging with aluminium as predominant material), these include in addition to aluminium also other ferrous and non-ferrous metals: steel (unspecified), stainless steel, chrome-plated steel and tin-plated steel (tinplate).

The overview also provides users with a calculation tool to assess the material recyclability percentage by weight. This is explained in chapter 7.3.

$D4R_{PD}$ Guidelines for aluminium packaging

A | Main body

Design Parameter	Recyclability categories				
Material type	Target material (M_T)[25]	Separable by reprocessing (CAT 1)	Limited compatible (CAT 2)	Incompatible (CAT 3)	Examination required: Design-related losses (CAT 0)
Aluminium	x				
Non-metallic aluminium					x[26]
Plastics		x			
Paper		x			
Steel (unspecified)	x				
Stainless steel	x				
Chrome-plated steel	x				
Tin-plated steel (tinplate)	x				
Non-ferrous metals	x				
Printing inks, coatings, adhesives					
Printing inks		x			
Coatings (inner and outer coatings)		x			
Adhesives		x			

Starting with the main body:

2a | Categorisation of the packaging components and constituents:

- Can body: aluminium = M_T ✓
- Inner and outer lacquer = CAT 1 ✓
- Printing = CAT 1 ✓

B | Integrated (minor) packaging component(s)

Design Parameter	Recyclability categories				
Closure/Functional cap: Material type	Target material (M_T)[25]	Separable by reprocessing (CAT 1)	Limited compatible (CAT 2)	Incompatible (CAT 3)	Examination required: Design-related losses (CAT 0)
Aluminium	x				
Non-metallic aluminium		x			
Plastics		x			
Paper					
Steel (unspecified)	x				
Stainless steel	x				
Chrome-plated steel	x				
Tin-plated steel (tinplate)	x				
Non-ferrous metals	x				
Label: Material type					
Plastics		x			
Paper		x			
Label: Adhesive					
Adhesive		x			
Label: Decoration					
Printing colour		x			
Foil stamping		x			
Release agents and others					
PFAS coating ≥ threshold according to article 5 (5) PPWR				x	
Silicon		x			

Continuing with the integrated components:

2b | Categorisation of the packaging components and constituents:

- Plastic snap-on cap (without undercut) = CAT 1 ✓
- Dip tube (PVC) = CAT 1 ✓ in case of PE design (PE) = CAT 1 ✓
- Plastic gasket = CAT 1 ✓
- Tin-plate valve cap = M_T ✓

Step 3: The plastic snap-on cap (without undercut) is categorised, examined and assessed in accordance with the respective $D4R_{PD}$ Guidelines for plastic based packaging and can be categorised as a target material, if designed accordingly.

Messages:

- Maximise “Target material (M_T)” category, by minimising the share of non-metallic materials.
- Minimise „Separable by reprocessing (CAT 1)“ category, as far as possible.
- Avoid “Limited compatible (CAT 2)” category, if possible.
- Absolutely avoid “Incompatible (CAT 3)” category.

7.3 Recyclability in percentage by weight

7.3.1 Method for calculating recyclability in percentage by weight

As soon as the categorisation is completed, the rules for calculating the recyclability percentages by weight are applied.

That means the recyclability percentage by weight of the packaging unit is calculated as follows:

The sum of the packaging material shares (relating to the weight of the packaging element including the main body and all integrated components), categorised as Target material (M_T) category, corresponds to the maximum recyclability potential [%].

A special feature of metal-based packaging is that, according to all previous findings, the "Limited compatible (CAT 2)" category is not occupied.

Category 0 ("Design related losses"; grey) is of secondary importance compared to other materials due to the highly efficient aluminium-specific recycling technology. For the materials and other design parameters listed in the grey category, it is necessary to check whether the individual packaging design results in losses of recyclable materials. These must be quantified and subtracted from the recyclable material content. Thus, the grey category always refers to an examination requirement.

Materials assigned to the "Incompatible (CAT 3)" category lead to an assessment result of 0%.

7.3.2 Recyclability in percentage by weight and recyclability performance grades in PPWR

Recyclability in percentage by weight (of which calculation is explained above and examples of application on aluminium packaging formats are presented below) is a relevant metric to consider when assessing the recyclability of a packaging. It will potentially be one of the criteria used to determine the recyclability performance grades under PPWR, since it can be determined easily and accurately (see calculation examples on the following pages). Whether recyclability in percentage by weight will lead directly to a classification into grades has not yet been clarified as the secondary legislation of PPWR intended to address it must be awaited. Since the regulator might want to include several other parameters when determining the recyclability grades, corresponding transfer factors may need to be considered.

In this regard, it is important to appreciate that the use of the recyclability percentage by weight (as calculated here) as the only criterion to determine the recyclability performance grade under PPWR might lead to an undesired situation where very light packaging would be discriminated and potentially classified in grade C or D, only because it is designed to minimise the amount of structural material used, even though it can be sorted and recycled (with the recovery of the structural material). See chapter 10.1 on resource efficiency.

Indeed, certain packaging formats (such as flexible formats) would be unfairly penalised just because the necessary functional constituents (e.g., printing inks, coatings or adhesives), automatically represent a non-neglectable part of the total packaging weight (contrary to heavier packaging solutions although the amount of functional constituents used is generally of the same level of magnitude in absolute terms).

To mitigate this unfairness, and in case the percentage of recyclable material by weight is used as a key metric to assess the recyclability of a packaging (for the purpose of the grading in PPWR), a possible variant would be to calculate this recyclability percentage by disregarding at least functional constituents such as varnishes, paints, inks, adhesives and lacquers, in line with the exemptions present in the definition of composite packaging in PPWR, or to limit (for the calculation) the amount of these necessary functional constituents to a maximum value of 5% to 10% of the total mass of the packaging unit.

7.4 Design for Recyclability Guidelines ($D4R_{PD}$) and calculation of recyclability in percentage by weight applied to a selection of typical aluminium packaging formats

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Calculation example 1:
Aluminium tray (for catering)

Total packaging weight: 30 g

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Aluminium tray		**30**	
Aluminium tray	M_T	29.92	**+ 99.7**
Lubricant (inside, outside)	CAT 1	0.08	
Non-metallic aluminium share (oxidation losses)	CAT 0	0.006	**- 0.2***
Result		**29.92 g**	**99.7% by weight**

*corresponds to the non-metallic aluminium-content of the tray

Calculation example 2:
Aluminium bottle

Total packaging weight: 39 g

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Aluminium bottle		**39.0**	
Aluminium bottle	M_T	37.0	**+ 94.9**
Closure, metallic	M_T	1.0	**+ 2.56**
Printing ink	CAT 1	0.2	
Lacquer	CAT 1	0.8	
Non-metallic aluminium share (oxidation losses)	CAT 0	0.004	**- 0.01***
Result		**38.0 g**	**97.4% by weight**

*corresponds to the non-metallic aluminium content (bottle, closure)

Calculation example 3:
Aerosol can

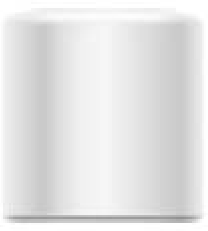
Total packaging weight: 40 g

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Can body/ Valve assembly		**40**	
Aluminium can	M_T	27.0	**+ 67,5**
Lacquers (outside/inside)	CAT 1	0.3	
Printing inks	CAT 1	0.2	
Valve assembly (metal parts)	M_T	3.0	**+ 7.5**
Valve assembly (non-metal parts)	CAT 1	9.5	
Non-metallic aluminium share (oxidation losses)	CAT 0	0.003	**-0.01***
Result		**30 g**	**75% by weight**

* corresponds to the non-metallic aluminium content (can body)



The plastic "snap-on" cap without undercut is categorised, examined and assessed in accordance with the respective $D4R_{PD}$ Guidelines for plastic based packaging and can be categorised as a target material, if designed accordingly.

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
"Snap-on" cap without undercut (separate component)		**5.0**	
Snap-on cap, PP	M_T	5.0	**+ 100**
Non-metallic aluminium share (oxidation losses)	CAT 0	none	
Result		**5.0 g**	**100% by weight**

Assumption for the example:
Cap made of non-filled PP, colour: NIR detectable

> ***Side note:***
> *PP = M_T (for the respective PP recycling route)*

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Calculation example 4:
Petfood tray

Total packaging weight: 5.0 g

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Petfood-Container…		**5.0**	
Aluminium container	M_T	3.5	**+ 70.0**
Lacquer (inside, outside)	CAT 1	0.3	
Non-metallic aluminium share (oxidation losses)	CAT 0	0.007	**- 0.2***
… with Alu-Lid			
Aluminium Lid	M_T	0.9	**+ 18.0**
Printing ink	CAT 1	0.1	
Lacquer	CAT 1	0.2	
Non-metallic aluminium share (oxidation losses)	CAT 0	0.002	**-0.2****
Result		**4.4 g**	**88% by weight**

* / ** corresponds to the non-metallic aluminium content (container*, lid**)

Calculation example 5:
Chocolate foil

Total packaging weight: 1.2 g

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Chocolate foil		**1.2**	
Aluminium foil	M_T	1.05	**+ 87.5**
Printing lacquer	CAT 1	0.03	
Heat-sealing lacquer	CAT 1	0.12	
Non-metallic aluminium share (oxidation losses)	CAT 0	0.002	**- 0.2***
Result		**1.05 g**	**87.5% by weight**

*corresponds to the non-metallic aluminium content (aluminium wrap)

Calculation example 6:
Coffee capsule

Total packaging weight: 0.97 g

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Coffee capsule		**0.97**	
Aluminium (capsule)	M_T	0.77	**+ 79.4**
Lacquer (outside/inside of the capsule)	CAT 1	0.06	
Aluminium (lid)	M_T	0.07	**+ 7.2**
Lacquer (lid)	CAT 1	0.01	
LSR gasket	CAT 1	0.038	
PU filter	CAT 1	0.02	
Non-metallic aluminium share, cap (oxidation losses)	CAT 0	0.0015	**- 0.2***
Non-metallic aluminium share, lid (oxidation losses)	CAT 0	0.0001	**- 0.2****
Result		**0.97 g**	**86.6% by weight**

corresponds to the non-metallic aluminium content (cap, lid**)

Side note:
The empty capsule without coffee grounds needs to be considered for the calculation. The process-specific criteria are examined on the filled, brewed capsule.

Calculation example 7:
Aluminium tube

Total packaging weight: 17 g
(Aluminium tube with PE cap)

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Aluminium tube		**17**	
Aluminium tube	M_T	14	**+82.4**
Lacquer (outside/inside)	CAT 1	0.8	
Printing ink	CAT 1	0.2	
Closure	CAT 1	2.0	
Non-metallic aluminium share, lid (oxidation losses)	CAT 0	0.0028	**- 0.02***
Result		**14 g**	**82.4% by weight**

* corresponds to the non-metallic aluminium content (tube)

Calculation example 8:
Cheese foil

Total packaging weight: 0.3 g

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Cheese foil		**0.3**	
Aluminium foil	M_T	0.224	**+ 74,7**
Lacquer (outside/inside)	CAT 1	0.063	
Plastic tear strip	CAT 1	0.02	
Non-metallic aluminium share, lid (oxidation losses)	CAT 0	0.0004	**- 0.2***
Result		**0.224 g**	**74,7% by weight**

* corresponds to the non-metallic aluminium content (foil)

Calculation example 9:
Aluminium closures on glass bottles

Total packaging weight: 478.15 g
(Glass bottle with aluminium closure as integrated packaging component)

General information

The results of the recyclability calculation are expressed as a recyclability percentage by weight. **No direct correlation must be made** between the recyclability percentage by weight and the **recyclability performance grade A, B or C** of the PPWR as the secondary legislation intended to address the question is still outstanding.

Classification according to the $D4R_{PD}$ Guidelines		Calculation of recyclability	
Description of individual packaging components/constituents	**Category**	**Packaging weight [g]**	**Recyclability percentage by weight [%]**
Glass bottle (wine) with aluminium closure		**478.15**	
Glass bottle	M_T	472.00	**+ 98.7**
Paper label	CAT 1	2.0	
Aluminium closure	M_T	3.80	**+ 0.8**
Liner (closure)	CAT 1	0.35	
Non-metallic aluminium share, lid (oxidation losses)	CAT 0	0.0004	**- 0.01***
Result		**475.8 g**	**99.5% by weight**

* corresponds to the non-metallic aluminium content (closure)

Side note:
Here is the use of the **$D4R_{PD}$ for glass**. *Plastic sleeve 1 g (bottle neck) neglected in the example.*

8. Further reflections for all types of packaging containing aluminium

Table 3
Recyclability performance grades
Packaging recyclability shall be expressed in the performance grades A, B or C.

From 2030, recyclability performance is based on design for recycling criteria. The design for recycling criteria shall ensure the circularity of the use of the resulting secondary raw materials of sufficient quality to substitute the primary raw materials.

The assessment based on design for recycling criteria shall be carried out for each packaging category listed in Table 1, taking into account the methodology established under Article 6 (4) and the related delegated acts, as well as the parameters established in Table 4. After weighing the criteria per packaging unit, it will be classified into categories A, B or C. **When a packaging unit's recyclability performance grade is below 70 %, it is considered to be non-compliant with the recyclability performance grades and therefore the packaging will be considered technically non-recyclable and its placing on the market shall be restricted. [...]**

Figure 28: *Dealing with "design for recycling and recyclability performance grades", PPWR, January 2025*

Thus, the top priority when designing a packaging is to achieve a recyclability performance grade of at least C, and preferably of at least grade B, by 2030. As of 2035 the recyclability performance grade for the „recycled-at-scale assessment" also needs to be considered. From 2038, a market ban will apply to packaging achieving a recyclability performance of grade C.

Compared to other types of material, aluminium occupies a special position in relation to packaging applications, as it is used comparatively more frequently as a minor material than other materials, particularly due to its barrier properties. In this context, the following passage of the PPWR should be noted in particular:

„[...] design for recycling criteria and recyclability performance grades shall be developed **on the basis of the predominant material** [...]", (Extract from article 6, PPWR, January 2025).

As a result, for packaging containing aluminium, but predominantly made from other material, depending on the packaging category and the assessment method, the design optimisation often leads in practice to a substitution of aluminium.

The definition and design of integrated and separate packaging components is of particular importance in this context:

§ 6 (9) Recyclable packaging

[...] Where a unit of packaging includes separate components, the assessment of compliance with the design for recycling requirements and with the recycled-at-scale requirements shall be carried out **separately for each separate component.**

All components of a unit of packaging shall be compatible with the established collection, sorting and recycling processes proven in an operational environment and **shall not hinder the recyclability of the main body** of the packaging unit.

Figure 29: *Dealing with "separate component" in § 6, PPWR, January 2025*

When interpreted by its literal meaning, Article 6 (9) means that a packaging component that is categorised as a separate packaging component must undergo an individual assessment and that the same requirements are placed on it as on a packaging unit.

Consequently, the same relevance applies to any separate packaging component with aluminium as predominant material as to a whole aluminium packaging. This would lead to the questionable consequence that packaging in which a separate packaging component representing a very low weight proportion and with a possibly insufficient recyclability grade (if assessed alone) would lead to a market ban for the whole packaging. This could potentially, for example, be the case for tamper-evident safety seals on tubes although the recyclability of the tube would be very well rated whether excluding the safety seal or including it.

In this respect, it would be appreciated if the legal text (future delegated act) would allow the separate packaging component to be treated as an integrated packaging component up to a certain proportion by mass (e.g. 5 %). This would avoid non-intended market bans of those packaging units that are globally well designed for recycling although featuring a separate component (with essential functionality) representing only a very small proportion of the total mass and that is not recyclable.

With the background of the PPWR, conclusions and options for action must therefore be orientated towards the different case constellations (see chapters 8.1 to 8.6).

These are:

1. Packaging with aluminium as the predominant material: e.g., aluminium beverage can,

2. Packaging with aluminium as the predominant material featuring a non-metallic minor packaging component (to be assessed as a separate component): e.g., aerosol can with snap-on-cap (without undercut),

3. Packaging component with aluminium as minor material (to be assessed as a separate component): e.g., ketchup bottle with tamper-evident aluminium-containing seal,

4. Packaging (or separate packaging component) with aluminium as minor material (to be assessed on the basis of the main material), e.g., liquid packaging carton,

5. Packaging component with aluminium as predominant material to be assessed as integrated component of a non-aluminium packaging: e.g., glass bottle with aluminium closure,

6. Packaging component with aluminium as predominant material to be assessed partly as a separate component and partly as an integrated component of a non-aluminium packaging: e.g., aluminium capsule (hood) for a wine bottle, part of which is removed for uncorking and part of which remains on the glass bottle.

8.1 Packaging with aluminium as predominant material

In contrast to non-metallic packaging materials, aluminium has the advantage that there are almost no recycling incompatibilities, and all non-metallic materials present in the packaging can be classified as separable material (CAT 1) by state-of-the-art processes. If the packaging contains metals other than aluminium, their recycling via the aluminium route is also ensured.

It should be noted that, according to the state of the art, aluminium packaging is not only recycled via the aluminium fraction from the sorting of lightweight packaging (see the list below). Relevant contributions to the recycling of aluminium from packaging applications are made by the following material streams in addition to the aluminium packaging material stream from household collection:

- Waste glass (mainly closures),
- Deposit-return schemes (DRS), single use (beverage cans[27]),
- Deposit-return schemes (DRS) for returnable/ reusable bottles (closures),
- Municipal residual waste (all types of aluminium packaging) for residual waste processing or for incineration plants (reprocessing of bottom ashes),
- Municipal and commercial scrap collection (e.g. large containers, party crates),
- Commercial or charitable collection of recyclable materials (all types of aluminium packaging),
- Commercial municipal waste (all types of aluminium packaging).

Furthermore, the following sub-streams from which aluminium arises as a by-product, also contribute to the amount of recycled aluminium:

- Aluminium as by-product from the reprocessing of the ferrous metal fraction,
- Aluminium as by-product from the reprocessing of liquid cartons,
- Aluminium as by-product from the reprocessing of plastics.

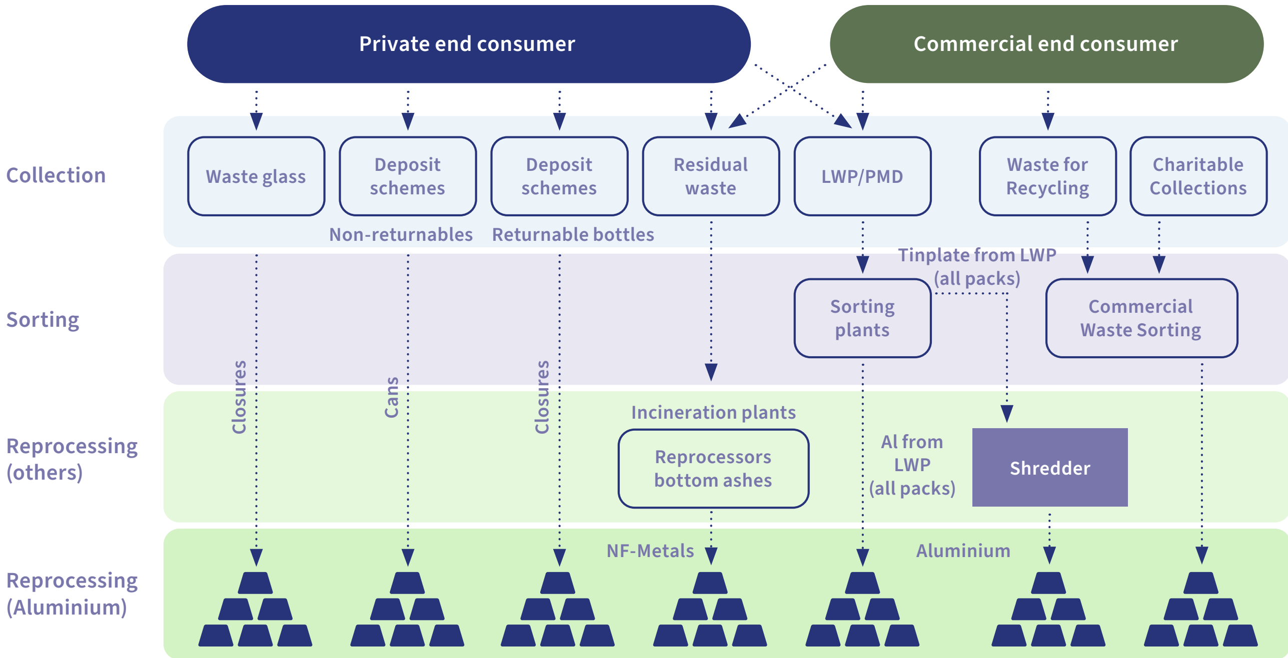


***Figure 30:** Possible material routes for aluminium packaging*

[27] Mandatory deposit-return schemes

8.2 Packaging with aluminium as the predominant material featuring a non-metallic minor packaging component (to be assessed as a separate component)

For this packaging group, (e.g., aluminium aerosol cans with plastic over caps, without undercut) the information in section 9.3 applies on the one hand; for the non-metallic separate component, the recyclability criteria of the respective material group must be observed.

8.3 Packaging component with aluminium as minor material (to be assessed as a separate component)

One example is a tamper-evident aluminium-containing seal on a ketchup bottle or on a toothpaste tube, or on composite cans (such as for snacks).

8.4 Packaging (or separate packaging component) with aluminium as minor material (to be assessed on the basis of the main material)

Examples of this group according to the current definitions of the PPWR would be plastic and paper-based packaging with an aluminium barrier and plastic/alu push-through blisters.

As an introduction, it should be reminded that according to Article 6 PPWR:

> „[...] design for recycling criteria and recyclability performance grades shall be developed **on the basis of the predominant material** [...]“

As already mentioned, this means that, depending on the definition of the design for recycling criteria, the focus of the optimisation of packaging made from other types of material is possibly on minimising or even completely substituting aluminium if aluminium is not classified as target material, or if classified as incompatible.

Therefore, even if not predominant material, aluminium should be considered as target material (M_T) when assessing the recyclability for other types of packaging.

One example is the classification of aluminium closures for glass packaging. Here, aluminium is a by-product of cullet[28] processing and classified as target material (M_T). Another example is the classification of aluminium as target material (M_T) in liquid packaging carton resulting from the already established industrial scale technologies to separate and recover the aluminium fraction. In contrast to aluminium lids remaining attached on plastic cups and trays due to the lack of aluminium recovery in most of the established operational plants, where aluminium is classified in category 1 (CAT 1) and not as target material M_T.

There are however cases, depending on the predominant material and the associated design for recycling criteria, where aluminium is not classified as a target material (M_T) (or even classified as incompatible). In such cases, the optimization of packaging design might lead to a minimization or even a substitution of aluminium.

This means that when defining the design for recyclability criteria and the recyclability assessment for other material categories than aluminium, attention must be paid to ensuring that no blanket, factually incorrect classifications of aluminium are made in CAT 3.

If the categorisation principles of these $D4R_{PD}$ Guidelines for packaging with aluminium would be applied in a similar way for guidelines of other material types or packaging types, the classification in Figure 31 is to be assumed based on established recycling processes:

[28] Technical term for glass shards.

***Figure 31:** D4R$_{PD}$ Categorisation for aluminium in non-aluminium-based packaging*

Packaging type	D4R$_{PD}$ Categorisation for aluminium as minor material in other packaging categories	
Tinplate	M_T	Recovery of non-ferrous metals; see flow chart, Figure 7
LPC[29]	M_T	Recovery of non-ferrous metals; see flow chart, Figure 8
Glass	M_T	In individual cases for aluminium foils also CAT 3 (if no reliable separation in reprocessing via ECS) / in general recovery of non-ferrous metals; see flow chart, Figure 13
PE flex	CAT 0	Possible total loss of the target material shares of the main component due to sorting into the aluminium fraction or due to density criterion[30]
PP flex	CAT 0	Possible total loss of the target material shares of the main material due to sorting into the aluminium fraction or due to density criterion[31]
PE rigid	CAT 1	No recovery of Al during reprocessing
PP rigid	CAT 1	No recovery of Al during reprocessing
PS rigid	CAT 1	No recovery of Al during reprocessing
PPC[32]	CAT 1	No recovery of Al during reprocessing
PET rigid	CAT 3	

The categorisations in Figure 31 and any options for action that are deriving from them are explained in the following.

The categorisation of **aluminium in ferrous-metal-based packaging as target material (M_T)** is because generally all metals are recycled. As already described in Chapter 3, the processing path for ferrous metals is complementary to the aluminium path. This also applies to other non-ferrous metals and stainless steels. In this respect, there is no need for action and, with fact-based consideration in guidelines, no risk of substitution of aluminium in ferrous-metal-based packaging.

The physical transfer of non-ferrous metal materials takes place after the material has been broken down in ferrous metal reprocessing. This affects not only presumably integrated components, such as lids, but also aluminium-based packaging that is initially 'misdirected' because of (poorly adjusted) magnetic separators due to the contained ferrous metal material, such as aerosol cans with Fe-valve lids. Such multiple recycling paths must be considered both when formulating a sorting protocol and when specifying the method for "recycling at scale"!

[29] LPC: Liquid packaging carton

[30] It should be noted that not all design features can be meaningfully categorised. There are limits when, due to complex dependencies between several design features, only an individual examination can provide actual information about the sorting and separation behaviour.

[31] It should be noted that not all design features can be meaningfully categorised. There are limits when, due to complex dependencies between several design features, only an individual examination can provide actual information about the sorting and separation behaviour.

[32] PPC: paper/paperboard/cardboard

The classification of **aluminium in liquid packaging cartons as target material (M_T)** results from the already established industrial-scale technologies to separate and recover aluminium (and the polymers) from PolyAl (see flow chart, Figure 8). Corresponding reference processes on a TRL 9 scale have already been implemented. This categorisation is already considered in the German minimum standard of the ZSVR. Previously, the PolyAl rejects from the processing of liquid packaging cartons were used for energy recovery (cement industry). The separable PolyAl material was to be categorised as CAT 1. The supplementation of the technology (PolyAl recycling) now enables categorisation as a target material (M_T).

For paper packaging (other than liquid packaging cartons), downstream recycling stages for the reprocessing of rejects (including aluminium) are not yet available. Therefore, contrary to liquid packaging cartons, where aluminium is categorized as M_T, **the aluminium in fibre-based packaging is categorized as separable (by reprocessing) constituent (CAT 1)**. However, EXTR:ACT is making efforts to include other compatible fibre-based packaging with an aluminium barrier in the recycling path for liquid packaging cartons.

Aluminium in glass-based packaging is categorized as target material (M_T), (see 3.3.6 and 3.3.7). Non-ferrous metals, predominantly lids, closures and aluminium bottleneck foil (hoods), are valuable by-products in every glass processing facility, which are sorted from the cullet fraction using eddy current separators and induction separators after the material has been crushed. However, very thin aluminium foils, such as those used for bottleneck foil on beer bottles, are difficult to sort. Due to the specific stresses in the glass treatment process, the foil pieces can become spherical in a very small size. As a result, they cannot be sufficiently separated using currently established metal sorting machines. There is therefore a risk that such designs will be assigned to category 3 in the development of recyclability guidelines. This can and should be prevented by improving the design for recycling.

Aluminium in PE-flex and PP-flex structures is assigned to CAT 0 in Figure 31. In the individual application of a criteria-based assessment, the aluminium foil barrier generally leads to a significant decrease in recyclability of the flexible packaging structure, with a risk of being considered as non-recyclable according to PPWR. This is currently leading to observed efforts to substitute aluminium foil in flexible plastic packaging, such as coffee or beverage pouches. From a technological point of view, it is also not possible to build on advanced recycling processes, such as those used for PolyAl. In fact, the advanced disintegration processes required for this are established for the PolyAl fraction from liquid packaging cartons (see above), but still under development for post-consumer plastic flexible packaging with aluminium. Indeed, the complexity of the material composition of the sorting fractions is not comparable with the PolyAl fraction. It is difficult to assess whether the required technology (for aluminium in PE-flex and PP-flex structures) will have reached TRL 9 by 2028.

The categorisation of **aluminium in PE/PP/PS packaging (rigid) as separable material (CAT 1)** is because aluminium is only sorted out as an impurity in these paths, i.e. no recovery of aluminium is established and aluminium, which is usually released after material disintegration, is transferred to the RDF fraction with the other separated materials. Aluminium material in this fraction comes predominantly from aluminium foil lids on trays and cups. The reason for the lack of sorting of aluminium for recovery is not technical. In the past, there were already operational plants that produced aluminium granulate for high-grade applications from the sinking material of the regrind density sorting (Sortec Hannover, Germany, from 1999 to 2010).

Recategorisation as a target material (M_T) would therefore be justified from a technological point of view. To this end, it is necessary to establish at least a reference process on a TRL 9 scale by 2028.

The categorisation of **aluminium in PET packaging as incompatible (CAT 3)** is essentially based on the insufficient separability in reprocessing in conjunction with the restrictive requirements for PET flakes regarding residual metal concentration (usually < 25 ppm).

PET reprocessing plants therefore have several separation stages for metals connected in series, whereby both eddy current separators and induction separators are used. The objective of these separation stages after grinding (flake sorting) is not to generate metal scrap but is solely for PET flakes quality protection; accordingly, sorting here is not very selective. This series of separation stages is associated with a high loss of PET flakes, but it cannot be completely prevented that aluminium components materials (especially needle-shaped ones) remain and lead to production losses during the manufacture of end products.

To be noted that aluminium foil lids on trays and cups can be considered as separate component, if there is a corresponding consumer behaviour; means the consumer separates the lids before disposal. Appropriate sorting instructions can be printed on the packaging. It must be assumed that a classification as a separate component always requires evidence (sampling, sorting analysis, etc).

8.5 Packaging component with aluminium as predominant material to be assessed as integrated component of a non-aluminium packaging

A typical example for such formats are aluminium closures on glass bottles. Both the glass and the aluminium material can be sorted and retrieved via the glass recycling route.

8.6 Packaging component with aluminium as predominant material to be assessed partly as a separate component and partly as an integrated component of a non-aluminium packaging

Aluminium packaging of this type is extremely rare. An example is the capsule (hood) for corked wine bottles, part of which is removed separately for uncorking and part of which remains on the bottle. Although both parts are potentially recyclable (via the lightweight packaging route on the one hand and via the glass recycling route on the other hand) the recommendation would be, if individually necessary, to make design changes to the packaging component so that the component either fully remains on the bottle or is completely separated in the post-consumer phase.

9. Design recommendations for selected packaging formats

The following illustrative examples shall help to transfer the messages which are given in chapter 7.2 from the concept of $D4R_{PD}$ to real packaging formats.

This transfer is guided by the following approach:

(1) Identify the packaging components and constituents

(2) Categorise the components and constituents according to the $D4R_{PD}$, as explained in chapter 7.2

(3) Identify opportunities for design optimization by component and constituent

The list of examples comprises rigid, semi-rigid and flexible packaging formats with aluminium as predominant material, which are considered as representative.

1. Beverage can
2. Food can
3. Aerosol can
4. Aluminium tube
5. Aluminium tray for convenience food
6. Pet food tray
7. Aluminium-based coffee capsule
8. Aluminium lid on plastic cup
9. Alu-alu blister pack
10. Cheese foil
11. Aluminium household foil
12. Wine bottle with aluminium closure

The following recommendations only focus on factors which are relevant for the design for recycling of aluminium packaging and aluminium containing packaging. It goes without saying that compliance with provisions in existing regulations which address other aspects of packaging such as food contact or cosmetics regulations must be ensured.

9.1 Beverage can

Recommendations for design for recyclability

Body & Top End

- Favour aluminium alloys which facilitate the recycling of used cans via can-to-can remelting*.
- Minimise coating thicknesses within the limits of their protective functionalities. Favour systems without chlorine, or at least with a reduced level of chlorine.
- Reduce the use of printing inks without compromising regulatory or marketing purposes.
- Avoid the use of labels and/or sleeves, in particular plastic-based ones. Favour easy-to-remove paper-based alternatives.
- Avoid "floating" and "top hat" widgets.
- A non-aluminium inclusion or attachment should not be constructed or include any polymers containing chlorine or carbon black.

* Within the foreseeable future, the industry will publish the results of its standardisation project recommending only one or maximum two very similar alloys for the manufacturing of the aluminium beverage can.

9.2 Food can

Recommendations for design for recyclability

Body & Closure system

- Favour design and alloys that allow lightweighting and inclusion of recycled content.
- Minimise coating thicknesses within the limits of their protective functionalities. Favour systems without chlorine, or at least with a reduced level of chlorine.
- Reduce the use of printing inks without compromising regulatory or marketing purposes.
- Avoid the use of labels and/or sleeves, in particular plastic-based ones. Favour easy-to-remove paper-based alternatives.

Tab for easy-open-end

- Avoid non-metallic parts.
- Favour design and alloys that allow lightweighting and inclusion of recycled content.

9.3 Aerosol can

Recommendations for design for recyclability

Overcap

- Avoid chlorine containing polymers.
- Avoid carbon black.
- Reduce the weight of the cap without compromising its integrity.

Valve assembly

- Non-metal parts: Reduce the weight without compromising their functional requirements.

Body

- Reduce the weight of printing inks without compromising regulatory/market requirements.
- Minimize thicknesses of coatings without compromising their functionality in protecting the safety of the filled product.
- For decoration, avoid use of external sleeves or labels.
- Avoid chlorine containing polymers in coatings and printing inks.

9.4 Aluminium tube

Recommendations for design for recyclability

Body

- Minimise the thicknesses of coatings (lacquers, varnishes and sealings) within the limits of their functionalities.
- Minimise the use of inks within the limits of their functionalities.
- Favour coatings and ink systems with no chlorine, or at least with a reduced level of chlorine.
- Avoid the use of labels.

Tamper-evidence membrane

- Prefer aluminium push-through membrane.
- Avoid plastic tear-off membranes.

Closure

- Minimise the amount of polymer in case a plastic closure is used.
- Use weight-optimized aluminium closures, if possible.

9.5 Aluminium tray for convenience food

General information

An aluminium tray is considered packaging (according to EU definition) if it is used by food suppliers to contain and dispense the food (= service packaging).

TYPICAL DESIGN FEATURES

Container
Aluminium foil (M_T)
Possible residual deep-drawing lubricant (**CAT 1**)
Possible inner/outer lacquer (**CAT 1**)
Possible inner plastic layer (extrusion coating) (**CAT 1**)
Possible printing inks (**CAT 1**)

Recommendations for design for recyclability

Container

Minimise the presence of residual deep-drawing lubricant on the surface

- Minimise the amount of (food grade) lubricant used within the limits of its functionalities as process auxiliary for the good deep drawing of the tray (and the proper destacking).

Question the use and necessity of lacquers

- Minimise the amount of lacquer used within the limits of its protective/sealing functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

Question the use and necessity of an inner plastic layer

- Favour mono-material structures, if possible.
- Minimise the amount of polymer used in case an inner plastic layer (extrusion coating) is necessary to ensure proper sealing and/or proper product protection and conservation.

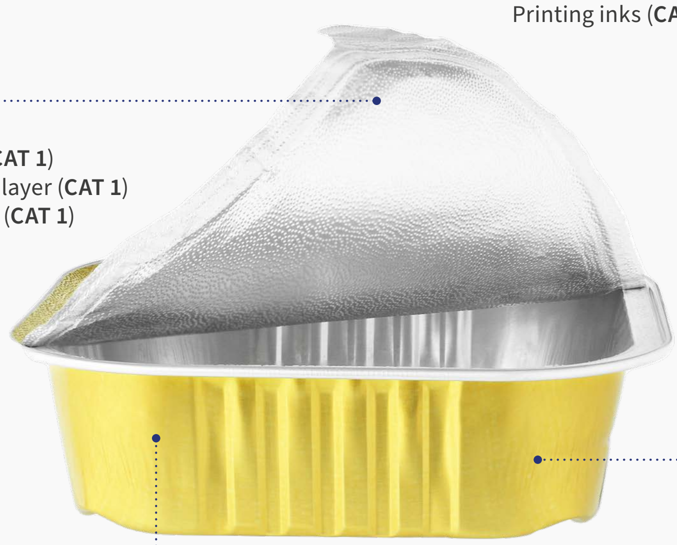
Question the use and necessity of printing inks

- Reduce (potentially avoid) the use of inks to the minimum necessary for the essential labelling function.

Optimise shape and inner surface for reduced risks of food residues

- Depending on the application.

9.6 Pet food tray



Recommendations for design for recyclability

Container

Optimise the use of lacquers

- Minimise the amount of lacquer used within the limits of its protective functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

Question the use and necessity of an inner plastic layer

- Favour mono-material structures if possible.
- Minimise the amount of polymer used in case the inner plastic layer is necessary to ensure proper sealing and/or proper product protection during heating process and long-life conservation.

Minimise the use of printing inks

- Reduce (potentially avoid) the use of inks to the minimum necessary for the essential labelling function.

Optimise shape and inner surface for reduced risks of pet food residues

→

Recommendations for design for recyclability

Lid

Optimise the use of lacquers

- Minimise their thicknesses and surfaces within the limits of their protective and sealing functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

Question the use and necessity of an inner plastic layer

- Favour mono-material structures if possible.
- Minimise the amount of polymer used in case an inner plastic layer is necessary to ensure proper sealing and/or proper product protection during heating process and long-life conservation.

Minimise the use of printing inks

- Reduce (potentially avoid) the use of inks to the minimum necessary for the essential labelling function.

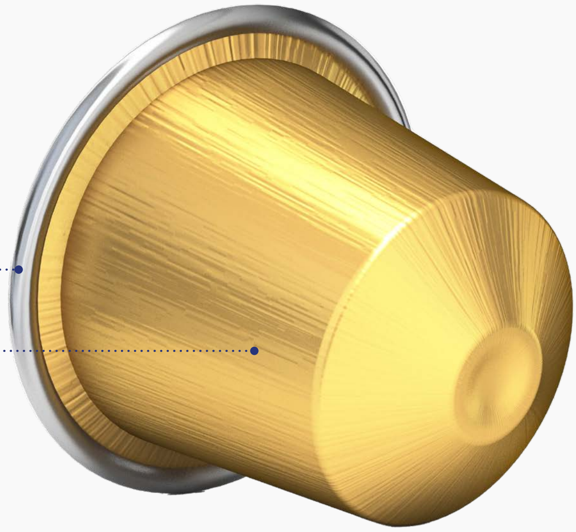
Label(s)

Question the relevance of labels and minimise their weight and printing to the minimum necessary for the essential labelling function.

9.7 Aluminium-based coffee capsule

TYPICAL DESIGN FEATURES

Lid
Aluminium foil (M_T)
Inner/outer lacquer (**CAT 1**)
Possible inner plastic layer (**CAT 1**)
Possible printing inks (**CAT 1**)



Body
Aluminium foil (M_T)
Inner plastic layer (**CAT 1**)
Outer lacquer (**CAT 1**)
Printing inks (**CAT 1**)

Recommendations for design for recyclability

Body

Optimise the use of lacquers

- Minimise the amount of lacquer used within the limits of its protective functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

Question the use and necessity of an inner plastic layer

- Favour mono-material structures if possible.
- Minimise the amount of polymer used in case the inner plastic layer is necessary to ensure proper sealing and/or proper product conservation and/or proper use of the capsule in the machine.

Minimise the use of printing inks

- Reduce (potentially avoid) the use of inks to the minimum necessary for the essential labelling function.

Lid

Optimise the use of lacquers

- Minimise their thicknesses and surfaces within the limits of their protective and sealing functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

→

Recommendations for design for recyclability

Question the use and necessity of an inner plastic layer

- Favour mono-material structures if possible.
- Minimise the amount of polymer used in case an inner plastic layer (extrusion coating) is necessary to ensure proper sealing and/or proper product protection and conservation and/or proper use of the capsule in the machine.

Minimise the use of printing inks

- Reduce (potentially avoid) the use of inks to the minimum necessary for the essential labelling function.

9.8 Aluminium lid on plastic cup

TYPICAL DESIGN FEATURES

Lid
Aluminium foil (M_T)
Inner/outer lacquer (**CAT 1**)
Possible inner plastic layer (**CAT 1**)
Possible printing inks (**CAT 1**)

Body
PP, PE, PS

Lid as separate or integrated component?

Based on the definitions provided by the PPWR so far two scenarios are possible: If the consumer removes the lid from the cup, the lid can be considered as separate component, if not, the lid is to be considered as integrated component. It should be noted that acceptance as a separate component will require verification (sampling, sorting analysis, etc.).

Recommendations for design for recyclability

Lid

Optimise the use of lacquers
- Minimise their thicknesses and surfaces within the limits of their protective and/or sealing functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

Avoid composite structure with plastic layer
- Favour mono-material structures if possible.
- Minimise the amount of polymer used in case the inner plastic layer is necessary to ensure proper protection and conservation of certain applications.

Minimise the use of printing inks
- Reduce (potentially avoid) the use of inks to the minimum necessary for the essential labelling function.

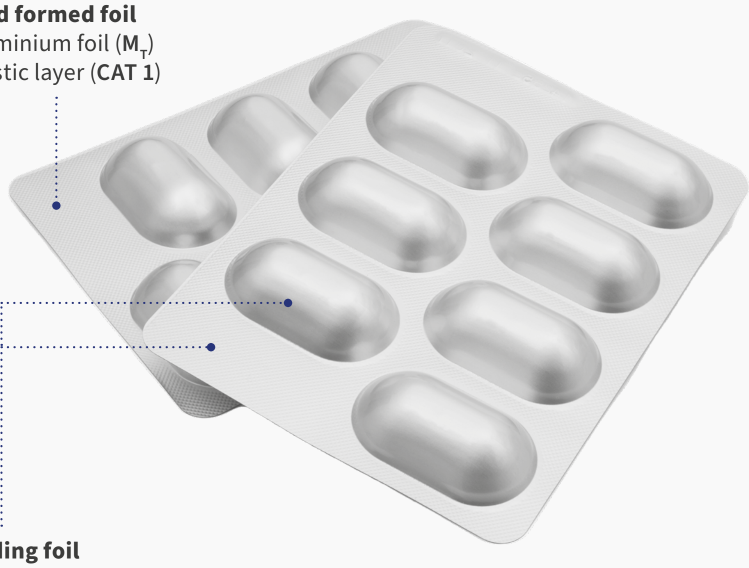
Optimise peelability
- Optimise the sealing (sealing surfaces, sealing equipment) to facilitate the complete removal of the lid from the cup by the end-consumer.

Provide sorting instructions to end-consumers
“For disposal, please completely remove the lid from the cup and scrunch it.”

9.9 Alu-alu blister pack

TYPICAL DESIGN FEATURES

Cold formed foil
Aluminium foil (**M_T**)
Plastic layer (**CAT 1**)



Lidding foil
Aluminium foil (**M_T**)
(hard metallurgical temper to allow push-through ability)
Inner/outer lacquer (**CAT 1**)
Possible printing inks (**CAT 1**)

Recommendations for design for recyclability

Cold formed foil

Optimise the plastic layer

- Minimise the amount of polymer used within the limits of its necessary mechanical and protective properties.
- Favour non-chlorinated polymers.

Lidding foil

Optimise the use of lacquers

- Minimise their thicknesses and surfaces within the limits of their protective and sealing functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

Minimise the use of printing inks

- Reduce (potentially avoid) the use of inks to the minimum necessary for the essential labelling function.

9.10 Cheese foil

Recommendations for design for recyclability

Foil

Optimise the use of lacquers

- Minimise their thicknesses within the limits of their protective and/or sealing functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

Question the use of printing inks

- Reduce (potentially avoid) the use of inks to the minimum necessary for the essential labelling function.

Opening system

Question the necessity of a plastic tear strip

- Minimise the size/weight of the plastic tear strip within the limits of its opening functionality to ensure proper access to the product and reduced risk of food waste.

Label(s)

Question the relevance of a label

- Minimise its weight and printing to the minimum necessary for the essential labelling function.
- Favour direct printing instead of a label, if possible.

9.11 Aluminium household foil

TYPICAL DESIGN FEATURES

Foil
Aluminium foil (M_T)
(the shiny/mat sides are resulting from the standard foil rolling process of thin gauges where 2 foils are rolled together (double-rolling) before being separated)

General information

Aluminium household foil is considered packaging (according to EU definition) if it is used by food suppliers to wrap and dispense the food (= **service packaging**).

Recommendations for design for recyclability

Adequately label and inform end-consumers with sorting information

- Encourage end-consumers to scrunch the foil before disposal.
- Use logo developed and made available by the industry.

9.12 Glass bottle with aluminium closure

TYPICAL DESIGN FEATURES

Aluminium closure
Aluminium sheet (M_T)
Plastic inner liner (in the detachable/reclosable screw part) (**CAT 1**)
Lacquers (**CAT 1**)
Inks (**CAT 1**)

Body
Aluminium (M_T)
Coatings (**CAT 1**)
Printing ink (**CAT 1**)

Recommendations for design for recyclability

Aluminium Closure

Optimise the use of lacquers

- Minimise their thicknesses within the limits of their protective functionalities.
- Favour lacquers with no chlorine, or at least with a reduced level of chlorine.

Optimise the weight and composition of the liner

- Minimise the amount of polymer used for the inner liner (to the necessary for proper product conservation).
- Favour non-chlorinated polymers.

Minimise the use of printing inks

- Reduce (potentially avoid) the use of inks and labels (to the minimum necessary for the essential labelling function).

10. Outlook and considerations

10.1 Resource-efficient packaging should not be penalised

The main options for action focus on $D4R_{PD}$ results in the following order of priority:

1. "Substitution" of CAT 3 components and constituents (PFAS, see Figure 27),
2. Maximising the aluminium content (or more generally the targeted material content) of the packaging by minimising the remaining non-aluminium constituents (or more generally non-targeted material constituents).

The latter should not be misunderstood as optimising the aluminium content by only reinforcing the weight of the basic aluminium structure. This is counterproductive and not politically intended.

On top **"Reduce" has a higher priority than "Recycle"** in the Waste Hierarchy of the Waste Framework Directive (WFD):

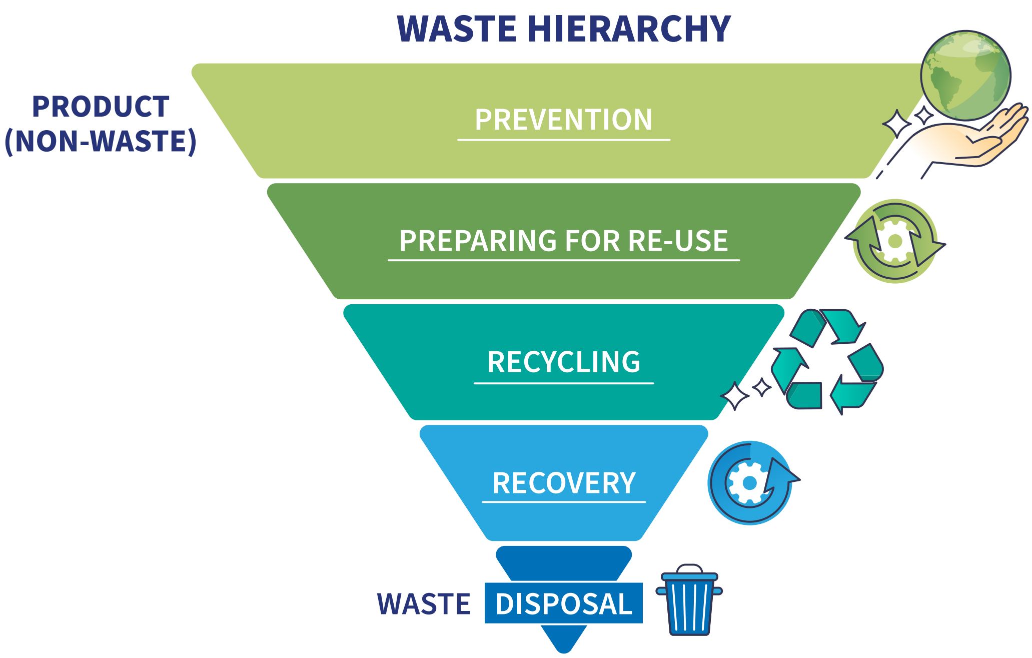


__Figure 32:__ Waste Hierarchy of the Waste Framework Directive

For these reasons resource-optimised packaging with highly reduced weight (such as flexible formats) should not be unfairly penalised just because the necessary functional constituents (e.g., printing inks, lacquers or adhesives), automatically represent a non-neglectable part of the total packaging weight (contrary to heavier packaging solutions although the amount of functional constituents used is generally of the same level of magnitude in absolute terms).

To mitigate this unfairness, and in case the percentage of recyclable material by weight is used as a key metric to determine the recyclability grade of the PPWR, the aluminium industry recommends, that the calculation of such a metric is done by disregarding, among others, varnishes, paints, inks, adhesives and lacquers, in line with the exemptions present in the definition of composite packaging in the PPWR.

Resource efficiency competes with recyclability here. Design for recyclability criteria should not have the effect of encouraging increased material use.

Likewise, it would also make sense to consider other sustainability aspects such as the status of permanent material (which applies to aluminium as it can be recycled repeatedly without loss of quality) as possible additional parameters for the calculation method of recyclability performance grades as set by the PPWR.

10.2 State-of-the-art process technology

Furthermore, in the context of the concretisation of the PPWR by secondary legislation, it is important to ensure that the assessment of recyclability is based on the state of the art of process technology and not on the way technology is applied in practice. Thus, it is important to avoid assessing recyclability based on practices that are only due to economic system optimisation of individual participants in the value chain.

The specific examples of such “non-state-of-the-art” practices are the sieving of small-format packaging without further separation of recyclable materials, or neglecting to use state-of-the-art optimised machine equipment and adjusted operations so that also small and light formats can be sorted.

Furthermore, for enhancing the actual recycling performance (also regarding “recycling at scale”), the end-consumers should be informed about how the sortability of packaging can be improved (e.g., for certain flexible aluminium packaging (or components), by crumpling or flattening it for collection). This can be done by end-consumer information by the Producer Responsibility Organizations (PROs) and through sorting instructions labelled on the packaging items.

10.3 Recycling at scale

As an additional consideration, the PPWR formulates **requirements regarding ‘recycling at scale’**. From 2035, proof of high-quality recycling must be provided across the EU for 55% of the market volume of a category (according to Table 2 in Annex II of PPWR) in order not to be subject to a market ban. It should be emphasised here that this is not a requirement for packaging at individual unit level and therefore the achievement of this target is not dependent on $D4R_{PD}$, or only to some extent. On the other hand, there is a high degree of dependence on the existence of specific recycling infrastructure.

10.4 Outlook – further development of the PPWR

The further development of the PPWR in the context of delegated and implementing acts will lead to important concretisations, and the process can be supported by these $D4R_{PD}$ Guidelines, which are subject to adaptations based on the further technical development. This means that constituents which are today assigned to CAT 3 or to CAT 0 might be regarded as M_T or assigned to CAT 1 in the future.

The applied assessment method is coherent in itself. In the view of the authors, it is ensured that the assessment procedure does not trigger any environmentally undesirable effects. However, it is questionable whether recyclability per se always reflects environmental policy objectives. The fact is that packaging produced in a highly resource-efficient manner tends to be less easily recyclable than packaging with a higher material input. It is therefore to be expected that politics will make adjustments or special arrangements in this respect to comply with the legal Waste Hierarchy.

10.5 Design for recycling criteria and Design for Recyclability Guidelines ($D4R_{PD}$)

When developing design criteria and guidelines, the following aspects must be considered, also regarding the requirements of Articles 6 and 35 of the PPWR:

- It is crucial that any evaluation shall reveal the underlying criteria that led to the allocation of a design feature to one of the categories.
- All assessment parameters should be objectively defined.
- The applied methodology should allow the categorisation of analogously distributed property characteristics.
- A mathematical aggregation of intermediate results in the evaluation process should be possible.

These Design for Recyclability Guidelines ($D4R_{PD}$) follow the above principles by assigning design parameters to individual impact categories for the assessment criterion of recyclability and not to evaluation categories. Despite the equally simple form of presentation, this approach makes it possible to ensure connectivity to the individual recyclability assessment.

Annex 1: Overview of typical packaging formats containing aluminium

The annex includes an overview of typical formats of packaging (or packaging components) containing aluminium:

- Aluminium foil applications
- Aluminium aerosol can
- Aluminium can
- Aluminium tube
- Other aluminium packaging

(see following pages)

Packaging (or packaging component) formats			Physical characteristics		Aluminium as major material		Aluminium as minor material in a composite structure			Aluminium as major material of a minor component (separate or integrated) of the packaging			
			Rigid format[1]	Semi-rigid / flexible format[1]	in a non-composite structure	in a composite structure	mainly made of glass	mainly made of paper	mainly made of plastic	mainly made of glass	mainly made of steel	mainly made of paper	mainly made of plastic
Aluminium foil applications		**Aluminium household foil**		x	x								
	Wrapper	Aluminium confectionary wrap (chocolate, sweets, marzipan….)		x	x								
		Aluminium-laminated confectionary wrap (chocolate, sweets, mar-zipan….)		x		x							
		Aluminium-laminated wrapper (e.g., butter, margarine, cheese, yeast)		x		x							
		Aluminium-laminated paper wrapper (e.g., butter, margarine, cheese, yeast)		x				x					
		Aluminium-laminated plastic wrapper (e.g., butter)		x					x				
		Aluminium wrapper for spreadable cheese portions (triangle, square…)		x		x							
	Aluminium lid	on plastic cup (e.g., yogurt and other dairy products)		x		x							x_s x_i
		on metal (steel) can (e.g., peanuts or milk powder)		x		x					x_s		
		on semi-rigid aluminium container (e.g. pet food)		x		x	(x)				x_i		
		on semi-rigid aluminium container (e.g. ready meals)		x		x					x_s		
		on paper composite can (e.g., crisps, chocolate powder, loose tobacco)		x		x						x_s	
		on glass jar (e.g., chocolate spread, instant soups, instant coffee)		x		x	(x)			x_s x_i			
	Aluminium-laminated lid	Aluminium-laminated lid (e.g. applied to a cup for yogurt and other dairy products)		x		x							x_s x_i
		Aluminium-laminated (sealed/removable) lid for plastic bottle (milk, fermented dairy drink…)		x		x							x_s
		Aluminium-laminated lid sealed/removable for ketchup/mayonnaise plastic bottle		x		x							x_s
	Overcap	Aluminium overcap lid on metal beverage can (for hygiene purposes)		x	x						x_s		
		Aluminium-laminated capsule (overcap) for champagne and sparkling wine		x		x				x_s x_i			
		Aluminium-laminated overcap for corked bottle of still wine		x		x				x_s x_i			

Packaging (or packaging component) formats			Physical characteristics		Aluminium as major material		Aluminium as minor material in a posite structure			Aluminium as major material of a minor component (separate or integrated) of the packaging			
			Rigid format[1]	Semi-rigid / flexible format[1]	in a non-composite structure	in a composite structure	mainly made of glass	mainly made of paper	mainly made of plastic	mainly made of glass	mainly made of steel	mainly made of paper	mainly made of plastic
Aluminium foil applications		**Aluminium bottle neck foil (e.g. beer bottles)**		x	x				x_s x_i				
Aluminium foil applications	Aluminium blister	Aluminium blister packaging (e.g., push-through strip sealed on plastic body for chewing gum or pills)		x					x				
Aluminium foil applications	Aluminium blister	All-aluminium blister packaging (e.g., push-through strip sealed on alu body for pills)		x		x							
Aluminium foil applications	Tray	Aluminium tray (bread for pre-baking, pies, fish, lasagnes, frozen meals...)		x	x								
Aluminium foil applications	Tray	Coated aluminium tray (e.g., pet food tray)		x		x							
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminum-paper laminated bag (e.g., for dry ready-made soup and sauces)		x				x					
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminium-plastic laminated bag (e.g., for dry food, milk powder)		x					x				
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminium-laminated vacuum bag with aroma valve for coffee		x					x				
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminium-laminated pouch for preserved food (pet food, pasta sauce…)		x					x				
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminium-laminated squeeze pouch with/without caps (drinks, baby food, energy fluid, fruit puree…)		x					x				
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminium-laminated sachet or stick for single-serve instant drinks (cacao, coffee tea)		x					x				
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminium-laminated pouch for (multi-serve) dry powder (e.g. milk powder, instant drink) potentially as inner pack of cardboard box		x					x				
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminium-laminated portion sachet for condiments (e. g. for mayonnaise, ketchup, salad dressings)		x				x	x				
Aluminium foil applications	Bag/ Pouch/ Sachet	Aluminium-laminated sachet pack for cosmetic products (e.g. for face masks)		x					x				
Aluminium foil applications	Coffee capsule / pad	Aluminium coffee capsule (single serve unit intended to be used and disposed together with the product)		x		x							
Aluminium foil applications	Coffee capsule / pad	Aluminium-laminated coffee pad (single serve unit intended to be used and disposed together with the product)		x		x							
Aluminium foil applications	Coffee capsule / pad	Aluminium lid on non-alu coffee capsule (mainly plastic) with aluminium lid (single serve unit intended to be used and disposed together with the product)		x	x								x_i

Packaging (or packaging component) formats			Physical characteristics		Aluminium as major material		Aluminium as minor material in a composite structure			Aluminium as major material of a minor component (separate or integrated) of the packaging			
			Rigid format[1]	Semi-rigid / flexible format[1]	in a non-compo-site structure	in a com-posite structure	mainly made of glass	mainly made of paper	mainly made of plastic	mainly made of glass	mainly made of steel	mainly made of paper	mainly made of plastic
Aluminium foil applications		**Aluminium foil label (luxury spirit bottles)**		x		x		(x)		x_i			
		Aluminium-laminated liquid packaging carton (e.g., juice, milk)	x					x					
		Aluminium-laminated inner liner for cigarettes		x	(x)	x						x_s x_i	
	Screw cap	with attached skirt/ring (e.g., bottle for wine)	x			x				x_i			
		without skirt/ring (e.g., bottle for water)	x			x				x_i			
		with detachable alu ring (e.g., bottle for water)	x			x				x_i			
		with detachable plastic ring (e.g., bottle for water)	x			x				x_i			
		with attached skirt/ring and plastic insert (e.g., bottle for oil, vinegar, spirits)	x			x				x_i			
		Aluminium beaded rim cap for infusion bottle (medicine)	x				x						
Aluminium aerosol can		Cosmetics (Body & hair care)	x			x							
		Food	x			x							
		Household/Technical applications	x			x							
		Pharma	x			x							
Can		Aluminium beverage can (e.g. for soft drinks, beer, soft alcoholic drinks . . .)	x		x								
		Composite beverage can (paper can with alu-minium lid and base)	x					x					
		Aluminium can for spices and powdered spices	x		(x)	x							
		Aluminium food can (meat, fish, sausages, vegetables)	x		x								
		Aluminium can for cooking oil	x		x								

Packaging (or packaging component) formats			Physical characteristics		Aluminium as major material		Aluminium as minor material in a composite structure			Aluminium as major material of a minor component (separate or integrated) of the packaging			
			Rigid format[1]	Semi-rigid / flexible format[1]	in a non-composite structure	in a com posite structure	mainly made of glass	mainly made of paper	mainly made of plastic	mainly made of glass	mainly made of steel	mainly made of paper	mainly made of plastic
Tube	Aluminium tube	Cosmetics	x		x								
Tube	Aluminium tube	Food	x		x								
Tube	Aluminium tube	Household/Technical applications	x		x								
Tube	Aluminium tube	Pharma	x		x								
Tube	Aluminium tube	Toothpaste	x		x								
Tube	Aluminium laminated tube	Cosmetics		x					x				
Tube	Aluminium laminated tube	Food		x					x				
Tube	Aluminium laminated tube	Household/Technical applications		x					x				
Tube	Aluminium laminated tube	Toothpaste		x					x				
Tube	Aluminium laminated tube	Pharma		x					x				
Others	Aluminium pack for cosmetic articles (e.g. lipsticks with aluminium case, alu jar)		x		(x)	x							
Others	Aluminium bottle		x		x								
Others	Aluminium box (e.g. for soaps)		x		x								

x = existing recycling path available;
x = existing recycling path, country specific established (GER: alu-based composites)
x_s = separate component;
x_i = integrated component

[1] Note on the distinction between flexible and rigid aluminium packaging: From a process-engineering perspective, the packaging characteristic of flexible or rigid aluminium is irrelevant as this is not a separation characteristic for sorting using an eddy current separator.

Annex 2: Mapping of existing design for recycling guidelines and recyclability assessments for packaging containing aluminium

The annex includes a comparison between existing design for recycling guidelines and recyclability assessments that thematically include aluminium as a major and minor material:

- Dealing with aluminium as predominant packaging material in existing design for recycling guidelines and recyclability assessments

- Dealing with aluminium as a minor packaging material in existing design for recycling guidelines and recyclability assessments

  – Classification of aluminium in the context of glass

  – Classification of aluminium in the context of fibre-based materials

  – Classification of aluminium in the context of plastics

  – Classification of aluminium in the context of tinplate/metals

For this, design for recycling guidelines were reviewed regarding the recommendations made for aluminium as a major or minor material. These include:

- ACE[1], BEVERAGE CARTONS, DESIGN FOR RECYCLABILITY GUIDELINES,
- **AIRG**, ALDI's International Recyclability Guideline,
- **ALUTREC**, LA MATRICE DE RECYCLABILITÉ DES EMBALLAGES SOUPLES EN ALUMINIUM,
- APR Design Guide® for Plastics Recyclability[2],
- CEFLEX, "DESIGNING FOR A CIRCULAR ECONOMY GUIDELINES" D4R-Guidelines[3], part 1,
- **CIAL, Aluminium Packaging Guidelines for an ecofriendly design,**
- **CIRCPACK by VEOLIA**, Design for Recycling Guidelines for packaging (aluminium),
- **CIRCULAR Packaging Design Guideline**, FH Campus Wien,
- **COTREM, La matrice de recyclabilité des emballages rigides en aluminium,**
- COTREP, "COTREP GUIDELINES"[2],
- **ECR** Community Austria in collaboration with WPO (World Packaging Organisation), **Packaging Design for Recycling,**
- **KIDV Recycle Check** for aluminium,
- **LIDL**, Sustainable Packaging design,
- RECOUP PLASTIC PACKAGING RECYCLABILITY BY DESIGN 2023, Recycling of Used Plastic Ltd. (RECOUP), Version 102,
- RecyClass, "Design for Recycling Guidelines"[2],
- **RecyClass by CIRCPACK**

Ten of the above-mentioned guidelines (those highlighted in bold) cover aluminium packaging (with aluminium as predominant material); the other ones have been drawn up exclusively for plastics or cartons and therefore focus on aluminium only as a minor material.

In addition, three standards were included in the evaluation. As these apply to all types of material, they are briefly characterised below:

- **CHI-RA**: The CHI Recyclability Assessment is published by the cyclos-HTP Institute (CHI), an expert organisation which, as an independent third party, is dedicated to ecological product design in consulting, testing and R&D. The standard is addressed to manufacturers and distributors of all packaging materials and products with the aim of creating the basis for a manufacturer's declaration of conformity in accordance with ISO 14021. The purely engineering-based method[33] determines the recyclability according to the state of the art across the entire recycling process chain, including the recycling application.

[33] The method is non-evaluative and simply categorizes design parameters according to their recyclability in recyclability categories. This is done exclusively on an engineering / scientific basis with reference to the waste management context (separate collection, sorting into separate waste streams, reprocessing and the use of recycled materials).

- **EN 13430**: Packaging – Requirements for packaging recoverable by material recycling; EN 13430:2004. The recyclability assessment is published by the Technical Committee TC 261 „Packaging" (Secretariat AFNOR) of the **European Committee for Standardisation (CEN)**. The standard is addressed to distributors of packaging and specifies procedures for the assessment of packaging in normative annexes with the aim of classifying a certain percentage of the packaging material as recyclable and thus forming the basis for declarations of conformity. The recyclability assessment relates to all packaging materials and defines procedures for evaluating the criteria for determining recyclability.

- **German minimum standard, ZSVR**: The minimum standard is issued by the Central Agency Packaging Register (Zentrale Stelle Verpackungsregister - ZSVR), which publishes an annual minimum standard in accordance with the German Packaging Act in consultation with the Federal Environment Agency (Umweltbundesamt - UBA). The minimum standard is addressed to systems (system operators according to section 18 VerpackG – Packaging Act) to provide them with a standardised framework for assessing recyclability within the meaning of Section 21(1) VerpackG. Stakeholders are involved in the development of the standard in the form of an expert group (Expert Group III), which prepares draft proposals that are made public for commenting as part of a consultation process. The standard applies to all packaging/ packaging materials.

A 2.1 Dealing with aluminium as predominant packaging material in existing design for recycling guidelines and recyclability assessments

The following design for recycling guidelines were compared in terms of content:

- AIRG
- ALUTREC
- CIAL
- CIRCPACK
- COTREM
- ECR/WPO
- FH CAMPUS Wien
- KIDV
- LIDL
- RecyClass by CIRCPACK

Figure 33: Classification of the body material, aluminium

green / light green = compatible;
yellow = limited compatible;
red = not compatible

Body material

	AIRG	ALUTREC	CIAL	CIRCPACK	COTREM	ECR/WPO: Packaging Design for Recycling				FH Campus Wien	KIDV	LIDL	RecyClass Tool by CIRCPACK		
	aluminium	flexible aluminium packaging	aluminium packaging	aluminium	aluminium (rigid) packaging	aluminium trays and cups	aluminium flexible packaging	aluminium tubes	aluminium cans	aluminium	Recycling Check for aluminium	Aluminium packaging	Aluminium		
													rigid	semi-rigid	flexible
aluminium	aluminium (mono layer material) is used for the body	aluminium	Design packaging using single material. (...) (Extract from the 2nd PRINCIPLE)	aluminium	aluminium (mono layer material) is used for the body	the aluminium used should only consist of non-ferrous (NF) metal components to prevent contamination in recycling	the aluminium used should only consist of non-ferrous (NF) metal compnents to prevent contamina-tion in recycling.	the aluminium used should only consist of non-ferrous (NF) metal components to prevent contami-nation in recycling.	the aluminium used should only consist of non-ferrous (NF) metal compnents to prevent contamina-tion in recycling.	non-ferrous metal parts	is the packaging made mostly of aluminium? **Yes**	Monoma-terial with maximum possible PCR content	Class A: X ≥ 95		
					aluminium combined with plastic (chlorine content <8% of the total packaging mass)						is the packaging made of rigid aluminium? **Yes**		Class B: 90% ≤ X < 95%		
					aluminium combined with organic material	in a best case, it concerns a mono-material package in which all compo-nents are made of aluminium		in a best case, it concerns a mono-material package in which all components are made of aluminium	in a best case, it concerns a mono-material package in which all components are made of aluminium		is the packaging made of rigid aluminium? **No**		Class C: 70% ≤ X < 90%		
					aluminium combined with (magnetic stainless) steel								Class D: 50% ≤ X < 70% Class E: X < 50%		

The use of aluminium or non-ferrous metals is classified in the guides as „best case design", „preferred" or with "good recyclability". ECR/WPO subdivide by packaging application into trays and cups, flexible packaging, aluminium tubes, and aluminium cans without adapting design for recycling recommendations in this respect. KIDV[34] makes a differentiation in rigid and flexible packaging, in which flexible aluminium packaging are downgraded slightly with the reasoning in sorting difficulties and oxidation losses and recovery from incineration losses. In general, monolayer, or mono-material packages are preferred.

The RecyClass Online Tool takes oxidation loss into account by worsening the rating by one class (-) for the following aluminium packaging types: foil, capsules, screw cap, tube or container/tray.

There is no downgrade in the rating for rigid aluminium packaging types such as bottles and cans.

Recyclability assessments evaluate the metal content (Al and Fe share) positive (minimum standard) and consider process-related melting and oxidation losses (CHI-RA).

Figure 34: Cassification of the body material, others

Body material	AIRG	ALUTREC	CIAL	CIRCPACK	COTREM	ECR/WPO: Packaging Design for Recycling				FH Campus Wien	KIDV	LIDL	RecyClass Tool by CIRCPACK
	aluminium	flexible aluminium packaging	aluminium packaging	aluminium	aluminium (rigid) packaging	aluminium trays and cups	aluminium flexible packaging	aluminium tubes[35]	aluminium cans	aluminium	Recycling Check for aluminium	Aluminium packaging	Aluminium: rigid / semi-rigid / flexible
others	aluminium-composites show a limited recycling compatibility and should be avoided.	Aluminium/ polymer (chlorine-free*)	Avoid gluing and multi-layered materials. (...) (Extract from the 5th PRINCIPLE)	Aluminium with other metals <5%wt Plastic <20%wt	Zamak, tin	for aluminium in composite materials (e.g. in combination with plastic), there is usually no possibility for high-quality recycling	for aluminium in composite materials (e.g. in combination with plastic), there is usually no possibility for high-quality recycling	for aluminium in composite materials (e.g. in combination with plastic), there is usually no possibility for high-quality recycling	no entry	multilayer material	Is the packaging made mostly of aluminium? No	Plastic and ferrous composite materials	Alu with other metals (steel, stainless steel, copper, lead, etc.) < 5%wt (--)
		Aluminium/ organic material			non-magnetic stainless steel								Alu with other metals (steel, stainless steel, copper, lead, etc.) > 5%wt (!)
		Aluminium/ chlorinated polymer (chlorine content <20% of total packaging mass)			for valves and pumps: plastic, organic material, (magnetic stainless) steel								Presence of ferrous component: Testing the sorting behaviour is recommended
					for valves and pumps: non-magnetic stainless steel								Plastics between 10 and 15%wt (-)
		Aluminium/ chlorinated polymer (chlorine content >20% of total packaging mass)		Other metals >5%wt (e.g. steel, stainless steel, copper, lead...) Plastic > 20%wt	for valves, pumps and labels: chlorinated lacquers								Plastics between 15 and 20 %wt (--)
					paper or plastic sleeves								Plastics >20%wt (---)
													Other (!)

green / light green = compatible;
yellow = limited compatible;
red = not compatible

[34] To benefit from a reduced contribution rate for packaging in the Netherlands, packaging manufacturers are obliged to carry out the „KIDV Recycle Check" and provide proof of this to Verpact. It is a decision tree that asks the user a short series of questions about the material and packaging components that have an impact on sorting and recycling.

[35] The authors use the wrong terminology; laminate tube would be the correct term.

Aluminium in a composite material is classified as limited recyclable (yellow category) or to be avoided (red category). ECR/WPO provide the same recommendation independent of the packaging type. Alutrec is the only guideline to categorise the chlorine content. The decision tree of KIDV is not applicable for packaging types that are **not** mostly made of aluminium.

Where lacquers are mentioned, they are generally categorised as being uncritical. The exception is the categorisation by Alutrec of chlorine-based paints as acceptable but to be avoided above a threshold of 20% of chlorine on total packaging weight, and as hindering recyclability above this threshold. Same observation for COTREM (for rigid aluminium packaging) where the threshold for chlorine-based coating is 8%.

CIAL also states that inks and lacquers generally do not cause any problems during aluminium remodeling. It points out that chemicals harmful to health and the environment (Volatile Organic Compounds (VOCs)) can leak out from inks and lacquers.

Lacquers (as well as printing inks) are not counted as target materials in the recyclability assessments (minimum standard, CHI-RA).

Figure 35*: Classification of lacquers*

Barrier/coatings															
	AIRG	ALUTREC	CIAL	CIRCPACK	COTREM	ECR/WPO: Packaging Design for Recycling				FH Campus Wien	KIDV	LIDL	RecyClass Tool by CIRCPACK		
	aluminium	flexible aluminium packaging	aluminium packaging	aluminium	aluminium (rigid) packaging	aluminium trays and cups	aluminium flexible packaging	aluminium tubes	aluminium cans	aluminium	Recycling Check for aluminium	Aluminium packaging	Aluminium		
													rigid	semi-rigid	flexible
lacquers	mono-layer material (Alu) with minimisation of lacquer layers	Polyester lacquering	Minimizing the use of troublesome chemical substances in inks and lacquering. (Extract from the 3rd CRITERION)	no entry	chlorine-based lacquering < 8% of the total packaging mass	no entry	no entry	a lacquer coating does not interfere with the conventional recycling process	the aluminium used should only consist of non-ferrous (NF) metal components to prevent contamination in recycling.	Lacquer finish	no entry	lacquer coating	no entry		
	protective coatings are minimised and as conventional lacquer finishes compatible for recycling	Chlorine-based lacquering			chlorine-based lacquering > 8% of the total packaging mass										

green / light green = compatible;
yellow = limited compatible;
red = not compatible

Figure 36: *Categorisation of closures*

Closures

	AIRG	ALUTREC	CIAL	CIRCPACK	COTREM	ECR/WPO: Packaging Design for Recycling				FH Campus Wien	KIDV	LIDL	RecyClass Tool by CIRCPACK
	aluminium	flexible aluminium packaging	aluminium packaging	aluminium	aluminium (rigid) packaging	aluminium trays and cups	aluminium flexible packaging	aluminium tubes	aluminium cans	aluminium	Recycling Check for aluminium	Aluminium packaging	Aluminium rigid | semi-rigid | flexible
aluminium	closures are made of aluminium Safety seal is made from the same material as the body. For tubes: Safety seal is designed to be pierced through the closure (no removable seal)	no entry	Aluminium screw caps, such as those used for wine and water bottles, are generally made in aluminium from the 8000 series, and offer no problem in recovery and recycling. (Extract from the 4th CRITERION)	aluminium	aluminium Zamak, tin chlorinated lacquer (chlorine content >8% of the total packaging mass)	closure systems made of aluminium can be recycled together with the base material and are, therefore, to be preferred	no entry	no entry	closure systems made of aluminium can be recycled together with the base material and are, therefore, to be preferred	aluminium screw-cap mono-material packaging (all components are aluminium)	no entry	Material-identi-cal closures and foils made of alumunium Pull-on bands with aluminum content	Aluminium closures (0) Plastic Closures (0)
plastic	plastic components (closures and valve caps) are minimised and easy to separate from the metal body plastic components (closures and valve caps) cause a limited recycling compatibility	no entry	Omitting or minimizing plastic components as much as possible… (Extract from the 4th CRITERION)	plastic	plastic (chlorine content <8% of the total packaging mass), organic material, steel chlorinated lacquer (chlorine content >8% of the total packaging mass)	plastic closures should be designed in such a way that they can be separated before disposal or during the sorting process	no entry	no entry	plastic closures should be designed in such a way that they can be separated before disposal or during the sorting process	plastic closures and valve caps, if these can be separated before disposal or during the sorting process.	no entry	Plastic closures and valve caps, provided that these can be separated before disposal or during the sorting process Plastic films Other types of closures made of composite materials with plastic	Plastic Closures (0)

green / light green = compatible;
yellow = limited compatible;
red = not compatible

In all guidelines, closures made of the same material as the predominant material are preferred. Plastic closures are to be avoided; if present, they lead to a downgrade in classification.

***Figure 37**: Decoration: direct printing, inks*

Decoration															
	AIRG	**ALUTREC**	**CIAL**	**CIRCPACK**	**COTREM**	**ECR/WPO: Packaging Design for Recycling**				**FH Campus Wien**	**KIDV**	**LIDL**	**RecyClass Tool by CIRCPACK**		
	aluminium	flexible aluminium packaging	aluminium packaging	aluminium	aluminium (rigid) packaging	aluminium trays and cups	aluminium flexible packa-ging	aluminium tubes	aluminium cans	aluminium	Recycling Check for aluminium	Aluminium packaging	Aluminium		
													rigid	semi-rigid	flexible
inks	inks should be avoided as far as possible.	no entry	Minimizing the use of troublesome chemical substances in inks and lacquering. (Extract from the 3rd CRITERION) Direct printing on the aluminium container should be the first choice when possible. (Extract from the 4th CRITERION)	direct printing	no entry	direct print-ing on the packaging should be carried out with EuPIA-compliant coatings and printing inks	direct printing on the pack-aging should be done with EuPIA-compli-ant coatings and printing inks	direct printing on the packaging should be carried out with EuPIA-compliant coatings and printing inks	direct printing on the packaging should be carried out with EuPIA-compliant coatings and printing inks	aluminium with direct printing, EuPIA-compliant coatings and printing inks	no entry	direct printing	Direct Printing (0)		
	Not compatible with recycling and strictly to be avoided are inks containing components of the EuPIA exclusion list.	no entry		toxic inks (EuPIA list)		non-compliant inks can reduce the quality of the secondary material.	non-compli-ant inks can reduce the quality of the secondary material.	non-compli-ant inks can reduce the quality of the secondary material.	non-compli-ant inks can reduce the quality of the secondary material.	non-compliant colours	no entry				

green / light green = compatible;
yellow = limited compatible;
red = not compatible

The RecyClass Online Tool and CIRCPACK still evaluate residual content. At CIRCPACK, residues that limit sorting or product residues that are not allowed in the collection are categorised as incompatible (red category). With RecyClass, an “Easy-to-empty“/”Easy-to-access” index is determined. Depending on the level, this can result in a worsening of one (-) to four classes (----) as well as complete disqualification (!).

In addition, RecyClass also takes SVHCs (substances of very high concern) into account with a worsening by 3 classes (---).

Interim conclusion - rating of aluminium as a predominant material in packaging

The recommendations for the recycling-compatible design of aluminium packaging are mainly of a general nature and are aimed at the basic rules of simple packaging design:

- Preference for mono-material structures
- Avoidance of aluminium in composite materials
- Avoidance of unnecessary decoration
- Preference for EuPIA compliant printing inks

A 2.2 Dealing with aluminium as a minor packaging material in existing design for recycling guidelines and recyclability assessments

In addition, a comparison is made with guidelines that primarily deal with other types of material, such as glass, different plastics, paper and metals, and the classification of aluminium as minor material.

A 2.2.1 Classification of aluminium in the context of glass

There are only a few design for recycling guidelines considering glass packaging. In these, the use of aluminium closures on glass packaging is rated positively, as these are recyclable (AIRG, CIRCPACK) or separable components (ECR). In the context of glass, the guidelines do not address aluminium foil applications such as aluminium bottleneck foil.

Due to the established recovery of non-ferrous metals in state-of-the-art glass recycling processes, aluminium is considered as valuable material (in the same sense as target materials) in assessment standards (CHI-Standard, ZSVR minimum standard).

A 2.2.2 Classification of aluminium in the context of fibre-based materials

In the context of fibre-based packaging, the design for recycling guidelines focus directly on the separability of the aluminium foil (as barrier material) from the **paper composite** (AIRG, CIRCPACK) or indirectly on separability by distinguishing by process-specific criteria between standard recycling mills or specialised recycling mills (4evergreen). In the case of paper-based composite packaging, the fibre share of the packaging is considered as valuable material in the stricter sense in assessment standards; the other packaging materials are separated as rejects (CHI-Standard, ZSVR minimum standard).

Likewise, only a few design for recycling guidelines make statements about the recycling-friendly design of **aseptic liquid packaging cartons**. The use of aluminium is rated positively for the classic aseptic liquid carton structure (ACE, AIRG, CIRCPACK), as specialised paper mills are equipped to dissolve speciality papers and composite structures by means of appropriate process technology and longer pulping times.

Some guidelines mention PolyAl recycling processes in this context, however, without making detailed recommendations due to the relative recent development of process technologies (ACE). At the present time, the fibre share of liquid cartons is considered as valuable material, as well as PE and PP (CHI-Standard); for the ZSVR minimum standard all three main materials (fibre, polyolefins and aluminium) are considered as valuable materials. The 2025 minimum standard recommends individual evidence for the PO and Al share (ZSVR).

A 2.2.3 Classification of aluminium in the context of plastics

Aluminium as barrier material in **flexible plastic laminates** is consistently classified as incompatible or non-recyclable in all design for recycling guidelines (AIRG, APR, CEFLEX, CIRCPACK, COTREP, ECR, RECOUP, RecyClass).

The same applies to aluminium in closure systems (caps, functional closures, like pump heads) as well as aluminium in liners, seals and valves related to **PET rigids** (AIRG, COTREP, ECR, EPBP, RECOUP, RecyClass).

In contrast, the influence of aluminium in closure systems for **HDPE rigid** packaging is assessed very differently: Ranging from recycling compatible (AIRG) to limited compatible (COTREP) to not wanted/not suitable/not compatible (ECR/RECOUP/RecyClass).

Seals and lids are categorised differently based on their peeling properties, respectively on their residue-free removability as “limited” to “not compatible for recycling”.

Important packaging types for **PP rigid** and **PS rigid** are cups or trays with sealing lids **containing aluminium**. The COTREP guidelines show a very differentiated classification based on the peel properties (ranging from fully compatible (ideal) via limited compatible (conditional) to not compatible and/or disruptive). Other guidelines also classify differently depending on the peel properties (CIRCPACK, FH Campus Wien, RecyClass).

A 2.2.4 Classification of aluminium in the context of tinplate/metals

Aluminium in relation to tinplate is not described in any of the guidelines considered in the study.

In accordance with the state of the art (metal recycling), all metal contents, i.e. steel and aluminium, are counted positive as in the recyclability assessments (CHI-RA, ZSVR minimum standard).

Interim conclusion - rating of aluminium as a minor material in packaging

Aluminium as a minor material generally receives very poor ratings in the guidelines for plastics. This is technically justifiable, particularly in the context of PET, as the risk of cross-contamination must be classified as real due to the limited efficiency of metal separation in conjunction with exceptionally high-quality requirements for PET flakes and regranulates.

The negative assessment of aluminium foil barriers in the plastic guidelines is essentially based on the assumption of plastic loss because of the separability of the packaging via eddy current separators. In the recyclability assessments, this separation behaviour is also assumed or requires measurement regarding the probability of the sorting of the packaging into the aluminium fraction. In case that separation into the aluminium fraction can be expected, the assessment results in a recyclability equal to or lower than the aluminium content of the packaging.

The classifications of aluminium lids are incomprehensible and sometimes contradictory, which is not least because the categorical evaluation system used in most cases does not allow any differentiation between quantitative and qualitative criteria.

It is certainly correct to assume that peelable aluminium lids are easier to separate from the cup collar during the recycling process. However, regardless of the type of compound, aluminium residues do not actually end up in the recyclate to any significant extent, for several reasons. On the one hand, only small fractions of the packaging are affected anyway; on the other hand, the shear forces during shredding and washing are very high, so that the proportion of aluminium residues in the washed regrind is again significantly reduced. There are two possible routes for the remaining aluminium-plastic particles: separation via float-sink sorting (if the density of 1 g/cm^3 is exceeded) or separation of the aluminium content during melt filtration. Both options lead to marginal losses of target material(s), but do not justify categorisation for aluminium in the red category[36].

[36] CHI: Comparison of different standards for assessing the recyclability of plastic packaging, BKV study (2023), not published.

Glossary

ACE = Alliance for Beverage Cartons and the Environment

$D4R_{PD}$ = D4R Guidelines incl. a method for the categorical classification of design parameters

DRS = Deposit-return scheme(s)

ECS = Eddy current separation

EPS = Expanded Polystyrene

EXTR:ACT = European platform to improve and increase the recycling of beverage cartons and similar fibre-based multi-material packaging in Europe

IAI = International Aluminium Institute

LPC = Liquid packaging carton(s)

LWP = Lightweight Packaging

MPO = Mixed polyolefins (PE and PP)

NF = Non-ferrous (non-ferrous metals)

NIR = Near infrared

PE = Polyethylene

PE-LD = Polyethylene, low density

PET = Polyethylene terephtalate

PFAS = Per- and polyfluoroalkyl substances

PMD = Plastics, Metals, Drinks Cartons

PolyAl = Polyolefin-aluminium concentrate as a by-product of wet-mechanical disintegration of the liquid packaging carton sorting fraction, including polyolefins from PE/PP film and PE/PP caps and closures as well as aluminium foil

PP = Polypropylene

PPC = paper/paperboard/cardboard

PPWR = Packaging and Packaging Waste Regulation (REGULATION (EU) 2025/40 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 December 2024 on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC)

PS = Polystyrene

PVC = Polyvinyl chloride

RDF = Refuse derived fuel

TRL = Technology Readiness Level

WFD = Waste Framework Directive

ZSVR = Zentrale Stelle Verpackungsregister

Bibliography

CIAL (2018): ALUMINIUM PACKAGING GUIDELINE FOR AN ECO-FRIENDLY DESIGN
URL: https://www.cial.it/en/aluminium-packaging-guidelines-for-an-eco-friendly-design/ [retrieved on June 6, 2024]

European Aluminium (2024): Environmental profile report for the European aluminium industry, Life cycle inventory (LCI) data for aluminium protection and transformation processes in Europe, Executive Summary (November 2024)
URL: https://european-aluminium.eu/blog/environmental-profile-reports/ [retrieved on December 7, 2024]

European Aluminium (2024_4): Press-Release: European Aluminium Producers to Boost the Circularity of Beverage Cans, URL: https://european-aluminium.eu/wp-content/uploads/2024/04/2024-04-18_Press-Release-European-Aluminium-Producers-to-Boost-the-Circularity-of-Beverage-Cans-1.pdf [retrieved on January 21, 2024]

European Commission (2023): European Critical Raw Materials Act.
URL: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan/european-critical-raw-materials-act_en [retrieved on August 26, 2024]

EA-MPE (2024): URL: https://european-aluminium.eu/wp-content/uploads/2024/02/EA-MPE_BevCan-2021-Recycling-Results_Press-Release_23-February-2024final.pdf [retrieved on August 28, 2024]

FABES (2004): Piringer, O.; Brandsch, R., Migration/permeation investigation on barrier properties of Aluminium foils against organic molecules (Investigation report)

Giese (2007): Giese, Rahms, Mackenstedt: Optimierung der thermischen Prozessführung beim Recycling von Aluminiumschrott durch Pyrolyse; 2007, S. 6 and European Aluminium Industrie, 2018 DATA for year 2015, Tab 8-2

IAI, Global Cycle (2023): Global Aluminium Cycle 2023
URL: https://alucycle.international-aluminium.org/public-access/public-global-cycle/ [retrieved on August 28, 2024]

IAI (2023): IAI models 1.5-degree decarbonisation scenario in a bid to drive greater emissions reductions
URL: https://international-aluminium.org/iai-models-1-5-degree-decarbonisation-scenario-in-a-bid-to-drive-greater-emissions-reductions/ [retrieved on August, 26, 2024]

Krone/Beuth (2018): Drossel, G., Friedrich S., Kammer C., Lehnert W., Wenglorz H.-W.: Aluminium Taschenbuch 2 Umformung, Gießen, Oberflächenbehandlung, Recycling, DIN Deutsches Institut für Normung, 17. Auflage 2018, page 633

Pyral (2021): Reissner, A.: PreZero-Pyral – 15 years of circular economy, Ressource efficient recycling of mixed-Alu-Packaging including the aluminium foil and energy recovery with pyrolysis

Richardson & Morrison (2003): Metallurgical Balances and Efficiency in Fuerstenau M.C., Englewood, Colorado (2003)

The Alufoil File (2004): EAFA June 2004 URL: https://www.alufoil.org/alufoil_file-complete [retrieved on February, 23, 2024]

Taggart (1967): Handbook of Mineral Dressing, Wiley Handbook Series, New York 1967, page 19-190

VAW (2000): VAW Aluminium AG: Ökologische Effizienz der stofflichen Verwertung der DSD-Aluminiumverpackungs-Fraktion durch Pyrolyse, 2000.

WEWORUM (2023): Word Economic Forum 2023
URL: https://www.weforum.org/stories/2023/11/aluminium-demand-how-to-make-it-sustainable/ [retrieved on January, 17, 2025].