



METPAC-SA

Life cycle assessment (LCA) of beverage cans

LCA report

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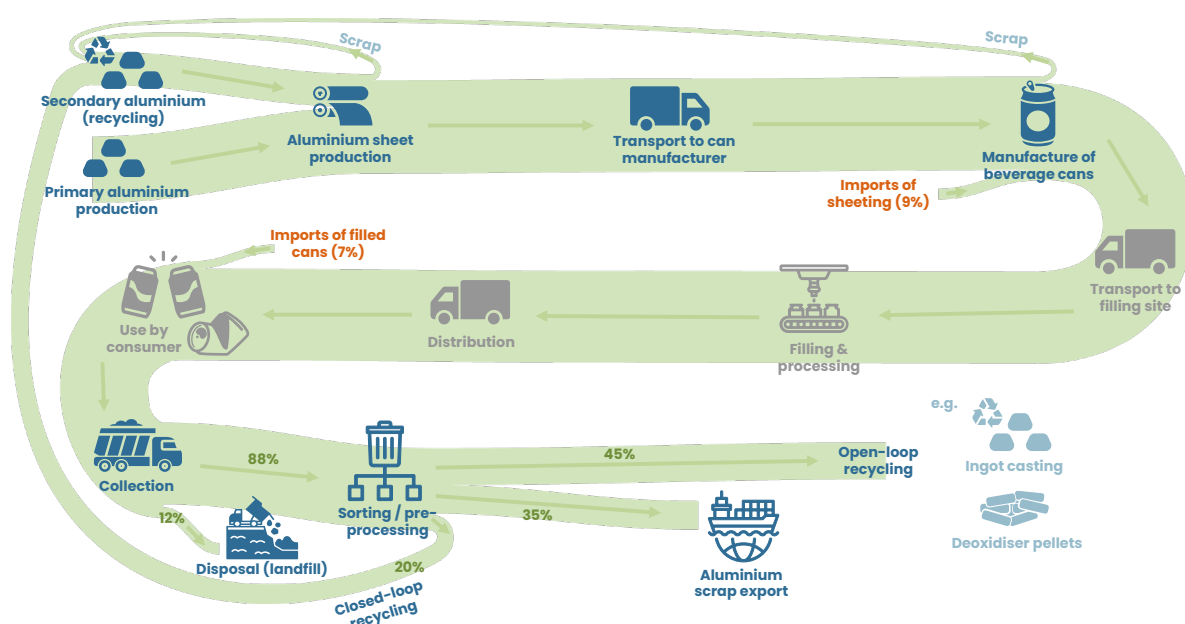
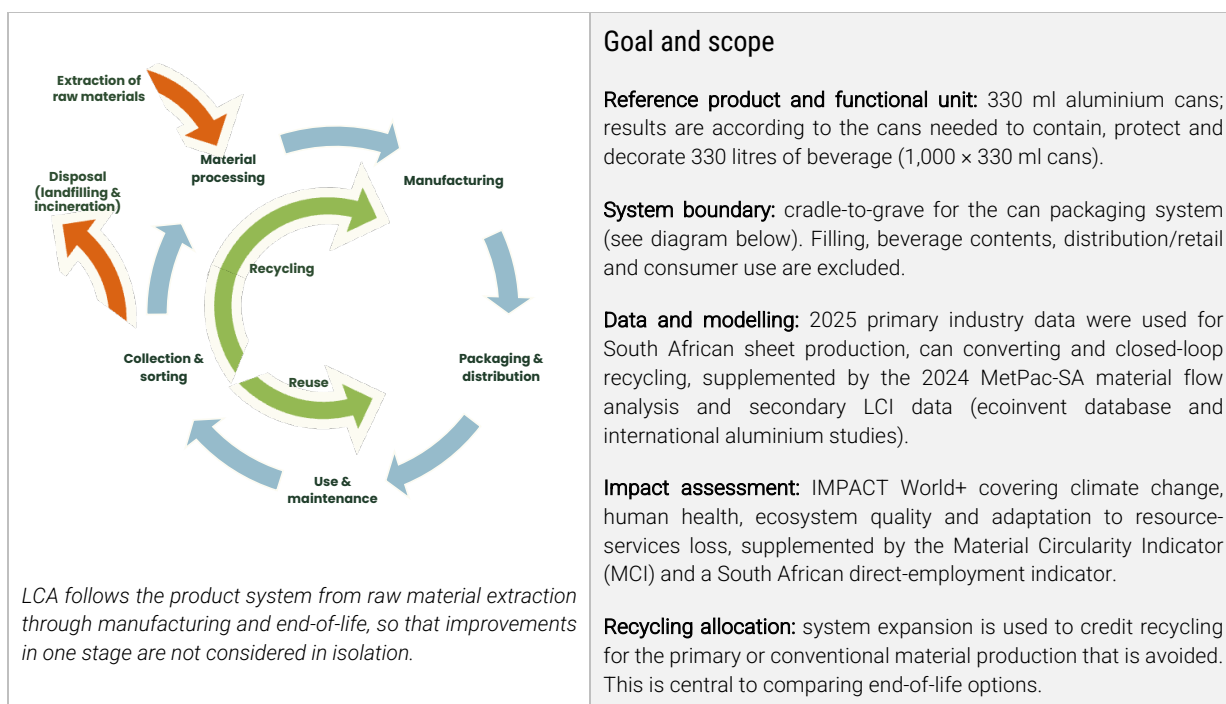
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EXECUTIVE SUMMARY

LIFE CYCLE ASSESSMENT OF ALUMINIUM BEVERAGE CANS IN SOUTH AFRICA

MetPac-SA commissioned this life cycle assessment (LCA) to meet South Africa's Extended Producer Responsibility (EPR) requirement for an LCA of identified packaging products placed on the SA market, and to provide the metal packaging sector with objective evidence on where environmental impacts arise and how they can be reduced. The study places particular emphasis on the end-of-life management of used beverage cans (UBCs), asking which management route delivers the greatest environmental, circularity and socio-economic benefit.

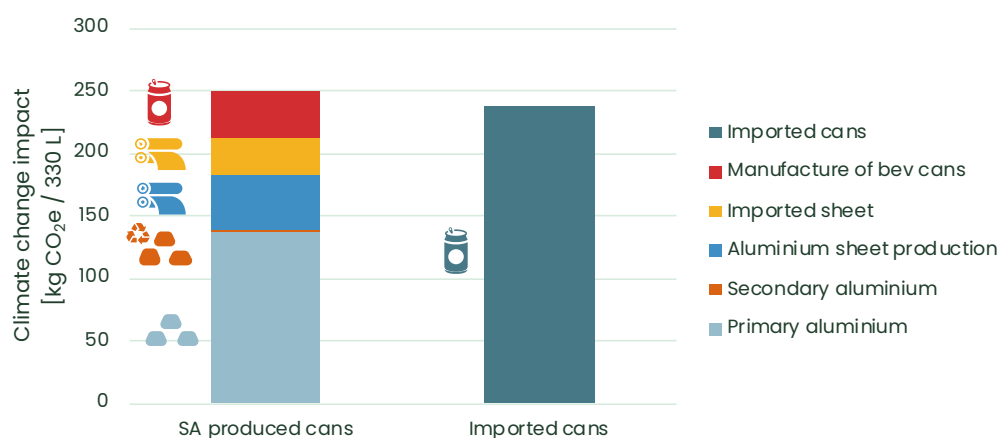


Flows of aluminium and cans on the South African market as modelled in the LCA. Greyed life-cycle stages are outside the modelled system boundary

THE ENVIRONMENTAL IMPACTS OF ALUMINIUM BEVERAGE CANS IN SOUTH AFRICA

The majority of aluminium beverage cans on the South African market are produced locally, using South African-produced aluminium sheet. However, some imported sheeting (9% of input to can converters) and cans (7% of cans on market) are part of the market mix. The **environmental impacts of an aluminium can is dominated by virgin aluminium production**. South African-produced virgin aluminium is the source of more than half (53%) of the potential environmental damages associated with producing a beverage can. Energy used in aluminium sheet rolling and can converting are the next largest source of potential environmental damages, accounting for 12% of human health and ecosystem quality damage apiece.

After use, the majority of used beverage cans (UBCs) are collected and sent for recycling, either within South Africa or internationally. **End-of-life management of UBCs contribute relatively little to their overall life cycle environmental impacts**, with end-of-life management of an average can on the South African market contributing just 6% to its life cycle climate change impact (and without applying recycling credits).



Contribution to climate change impact by production stage for South African-produced and imported 330 ml cans.

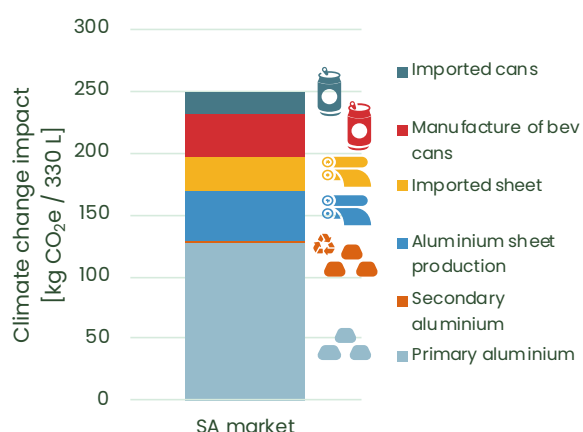
What drives environmental impacts?

Virgin aluminium production is by far the largest source of environmental impacts. For a South African-produced can, virgin aluminium (including virgin aluminium embodied in imported sheet) accounts for roughly two-thirds of its climate change impact. A result of the high amount of electricity required to produce primary aluminium, as well as fluorinated gases released during smelting.

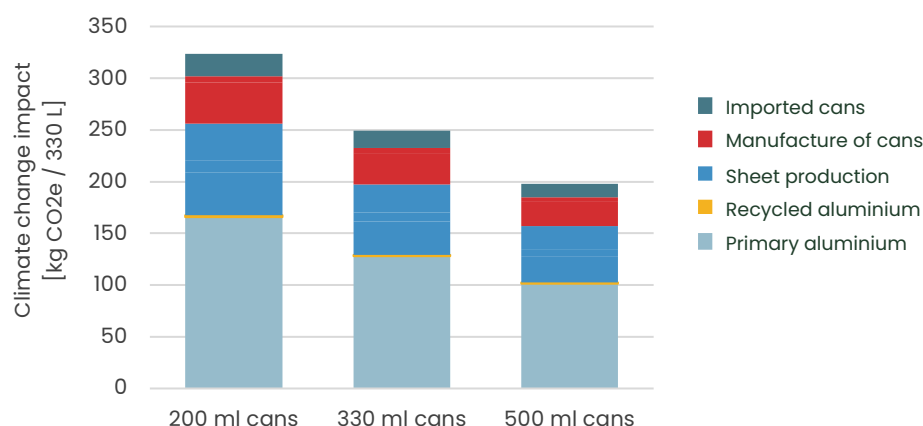
South African sheet rolling and can forming are the next major contributors. A consequence of the carbon intensity of South African electricity, which is largely coal-based.

Recycled aluminium has a very much smaller environmental footprint than virgin aluminium since it avoids the energy-intensive primary smelting step. The much lower environmental impacts of secondary aluminium compared to primary aluminium was found across all environmental impact indicators looked at in the study.

Imported cans have a marginally lower production carbon footprint but this result is sensitive to the recycled content of imported aluminium cans (the global average of 30% is assumed in the baseline results).



Climate change impact of aluminium beverage cans on the South African market (per 1,000 330 ml cans)

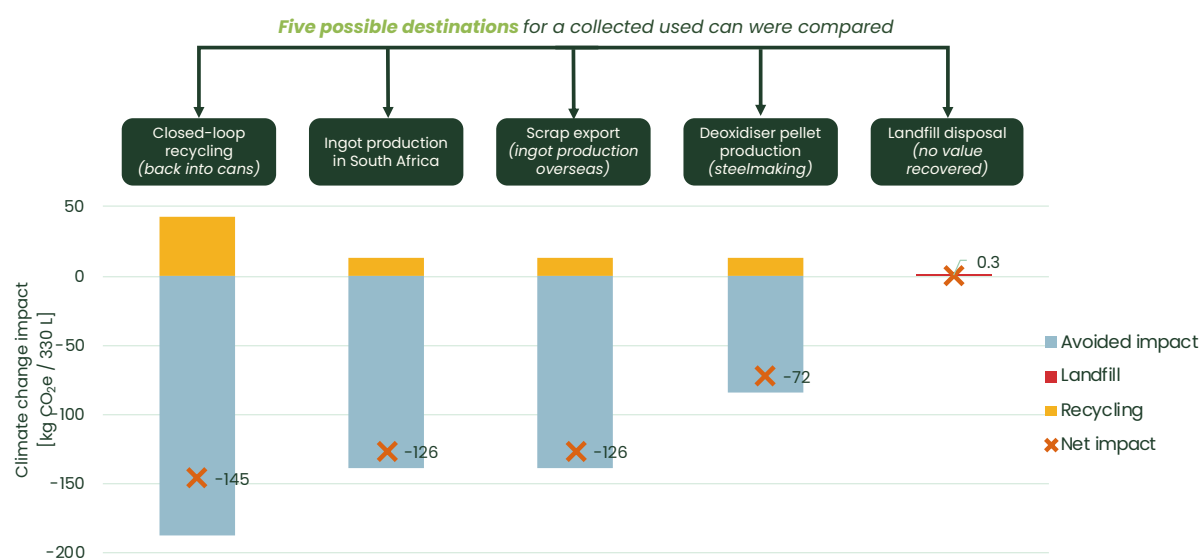


Effect of can size on climate change impact. Larger cans use less aluminium per litre packaged and therefore have lower life cycle environmental impacts when viewed on a per litre basis.

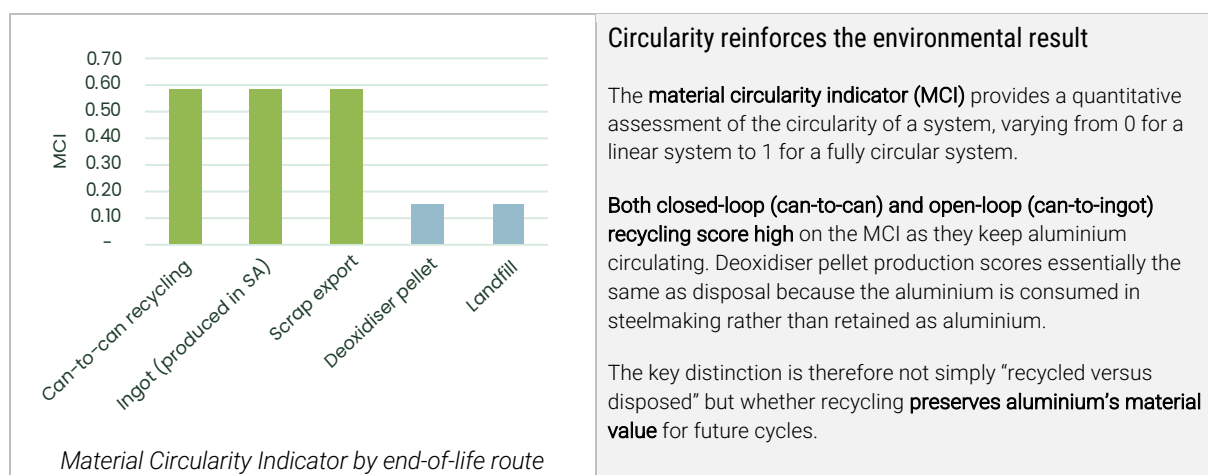
End-of-life management of aluminium beverage cans in South Africa

Recycling beverage cans after use delivers large environmental benefits, with closed-loop recycling delivering the highest benefits. South Africa has a high UBC collection rate: 88% of cans are collected. Of the collected cans, approximately 20% return to can-to-can recycling, 35% are exported as scrap, and the balance enter other recycling routes, modelled as equal shares to ingot recycling (open-loop recycling) and deoxidiser pellet production (dissipative recycling). Exported scrap is assumed to be cast into ingots, with both locally and internationally produced secondary ingots assumed to avoid global-average aluminium (70% primary and 30% secondary aluminium).

With system expansion applied, that is, when considering the products replaced by producing secondary aluminium, **all four recovery routes considered provide a net environmental benefit**. That is, the potential human health and ecosystem quality damage of collecting and processing UBCs is more than offset by the avoided primary aluminium production, and in the case of deoxidizer pellets, of avoided ferrosilicon production.



End-of-life climate change results applying system expansion. Net-negative values indicate that the benefits of avoided production of virgin materials exceed the impacts of collection and recycling.

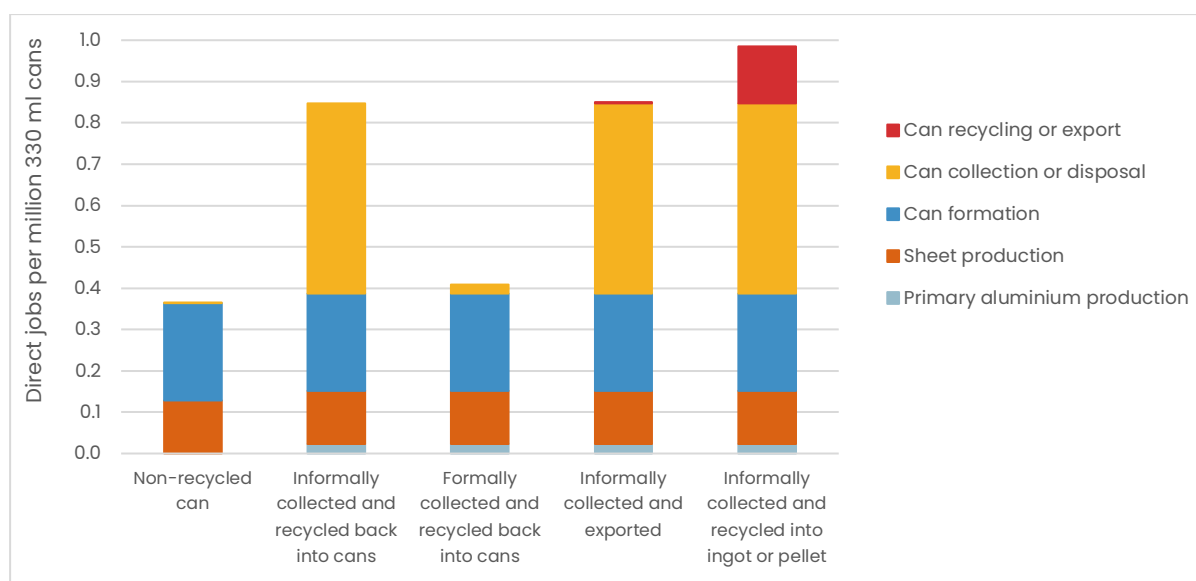


SOCIO-ECONOMIC IMPACT OF ALUMINIUM BEVERAGE CANS IN SOUTH AFRICA

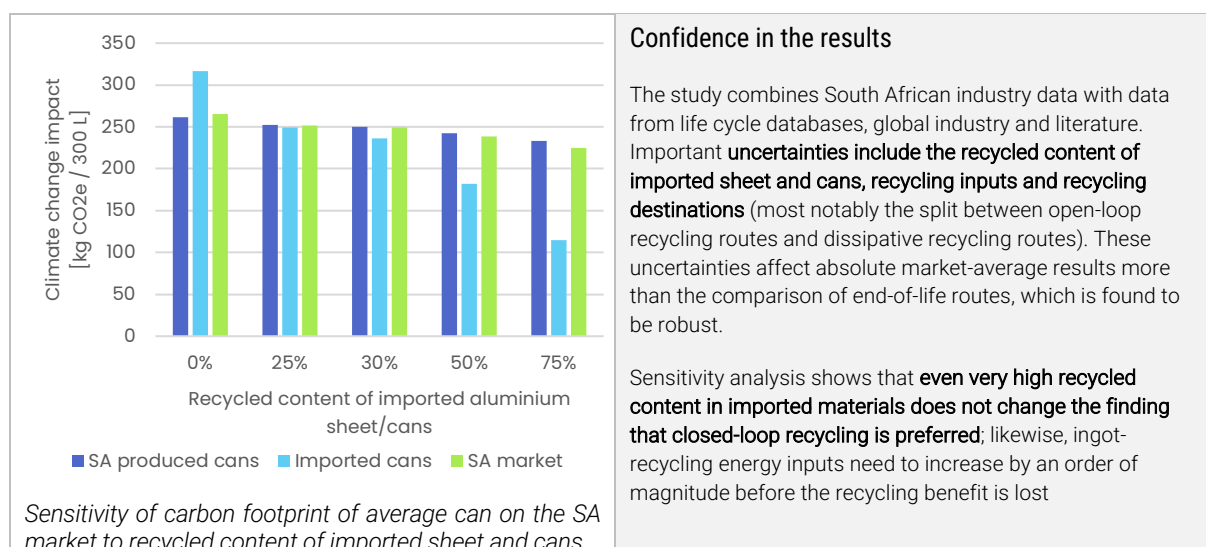
The socio-economic benefits associated with beverage cans on the South African market was assessed with a proxy indicator of income opportunities, covering direct jobs and informal collector livelihoods supported.

A can produced in South Africa has roughly 80 to 120 times the direct employment potential of an imported can. Can conversion accounts for the greatest share of direct employment (57%). Primary aluminium has a relatively small share (6.6%) despite locally-produced aluminium sheet having a high locally-produced virgin aluminium content.

A can produced, collected and recycled in South Africa is associated with ~0.9 direct jobs per million cans. Informal collection has nearly double the direct jobs of formal collection (municipal kerbside collection and sorting), as a result of jobs associated with scrap metal dealers. If informal collector livelihoods are included, the difference becomes very much higher – as high as 45 income opportunities (jobs plus livelihoods) per million cans produced, collected and recycled (depending on assumptions). Whilst it is challenging to estimate the share of UBCs to informal collector livelihoods, even when applying lower-bound assumptions, **an informally collected and recycled can has 16 times the income opportunities of a non-recycled can**, and nearly 5 times that of a formally-collected and recycled can.



Direct jobs associated with producing, collecting and recycling cans in South Africa



RECOMMENDATIONS AGAINST THE EPR REGULATIONS' FOCUS AREAS

1. **Minimise material impacts:** Increase recycled content in can body and end sheet where technically feasible. Lightweighting should not be at the expense of lower recycled content or decreased recyclability, which is where large environmental benefits can be realised, especially given the high collection and recycling rates achieved in South Africa. Larger can formats have lower impact per litre beverage packaged.
2. **Design for recyclability:** Prioritise closed-loop (can-to-can) recycling as it provides the largest environmental benefit and preserves aluminium at the highest material value. This process may be assisted through the alignment of can end and can body alloys in forthcoming years. Recycling cans to secondary aluminium ingots in South Africa (open-loop recycling) is also strongly beneficial, both from an environmental and socio-economic perspective.
3. **Reduce post-consumer impacts:** Keeping UBCs out of landfill disposal and avoiding recycling routes that dissipate the aluminium's material value provides the greatest environmental, circularity and socio-economic benefits.

MAIN TAKEAWAY

The largest opportunity to reduce the life-cycle environmental impacts of South African beverage cans whilst simultaneously maximising their socio-economic benefits, is to **use more recycled aluminium and keep collected UBCs in a high-value, can-to-can recycling system within South Africa.**

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1 INTRODUCTION

South Africa's Extended Producer Responsibility (EPR) regulations for paper, packaging and some single-use products require that a life cycle assessment (LCA) be conducted, "in relation to the identified product, in accordance with the applicable standards within 5 years of implementation of their extended producer responsibility scheme"¹. In line with these regulations, MetPac-SA has commissioned this LCA study to ensure their, and their members', compliance with the EPR regulations and to explore the insights and policy support that life cycle assessment can bring to the metal packaging sector in South Africa.

The LCA has a particular focus on the end-of-life of the used beverage cans (UBCs), in accordance with the purpose of the EPR regulations "to ensure the effective and efficient management of the identified product at the end of its life"¹. As such, one of the main objectives of the LCA is the identification of the lowest-impact waste-management option for UBCs in South Africa. The LCA captures the environmental impacts, circularity impacts and social benefits associated with UBC recycling and other end-of-life management options. Together these allow the LCA to provide recommendations in the focus-areas specified in the EPR regulations, namely:

- I. Minimisation of aluminium (and other materials) used in the production of beverage cans;
- II. Design of beverage cans to facilitate recycling or recovery, without compromising their functionality; and
- III. Reduction of environmental toxicity in the post-consumer waste stream.

This study is therefore a "cradle-to-grave" LCA, which has a particular focus on the end-of-life management scenarios for UBCs within South Africa. The report is laid out according to the stages of an ISO-compliant LCA study² (goal and scope definition, inventory analysis, impact assessment and interpretation), following a short introduction to life cycle assessment. The section on goal and scope definition lays out the main methodological considerations of the LCA, whilst the inventory analysis section details the life cycle models, particularly the data sources used to construct the life cycle models. Following this, the impact assessment section provides details on the environmental and social metrics used in the analysis. Life cycle interpretation presents the results and insights to be gained from the LCA, including recommendations around the sustainability of various UBC management options and key life cycle stages that can be targeted to improve sustainability. The report concludes with the main messages and recommendations that can be drawn from the study.

1.1 Life cycle assessment (LCA)

LCA provides a structured framework with which to model the consequences that a product (or service) has on the natural environment and society. In an LCA, all stages in the life cycle of the product are considered, from the mining, extraction or growing of its raw materials, through its manufacturing, distribution and use, right to the final disposal of its components. Raw materials and emissions are not only considered for the product under study, but also for all the other materials used in the life cycle of the product (e.g., packaging). Together all these stages - and the unit processes they are comprised of - make up the life cycle of the product, as shown in Figure 1. The term value chain,

¹ [Government Gazette No. 44539 – Amendments to the Regulations and Notices regarding Extended Producer Responsibility, 2020](#), 5 May 2021

² ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines, International Organization for Standardization, Geneva, Switzerland.

defined as the set of activities that businesses operating within a specific product system perform in order to deliver a good or service to the market, denotes a similar concept³.

The first stage of an LCA is Goal and Scope definition, in which the intended use of the study is clearly defined, together with what this means for the various methodological choices needing to be made, for example, the definition of the system boundary⁴. All raw materials and emissions (inputs and outputs) are considered for each of the processes included in the system boundary. Inputs include the use of natural resources, such as land and water, as well as manufactured materials, such as fuels, chemicals etc. Outputs are the releases to air, water and soil, as well as all products and by-products. The outcome of the second stage of an LCA study (Inventory Analysis) is thus a long list of resources and emissions (input and outputs) associated with delivering a particular product's function, termed the life cycle inventory (LCI). The subsequent stage of LCA (Life Cycle Impact Assessment) enables the interpretation of this long list of inputs and outputs by connecting them to their corresponding environmental impacts. In this way, the inputs and outputs are summed up into common areas of environmental concern, for example, impacts on human health, impacts on ecosystems etc. This can be done at varying degrees of complexity, and a number of different life cycle impact assessment (LCIA) methods have been developed to quantify the potential environmental impacts of a product system. The final stage of LCA is Interpretation, in which the results are analysed and the outcomes presented.

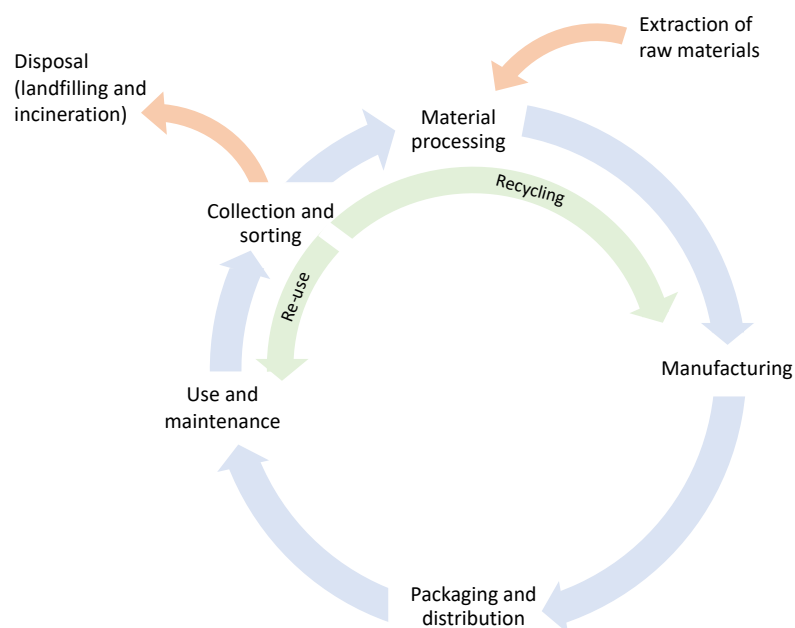


Figure 1: Representation of a product life cycle

An LCA is an inherently complex and data intensive undertaking and, as with any model, involves a simplification of reality. However, the ambitious undertaking of analysing product systems with LCA is driven by its benefits, which include:

- Creating awareness that decisions are not isolated, but that they influence a larger system;

³ The terms life cycle and value chain are used somewhat interchangeably in this report.

⁴ The system boundary encompasses all the processes that make up the life cycle of the product to be analysed.

- Promoting decision-making for the longer term, by considering all environmental and socio-economic issues and potential knock-on effects associated with a decision choice; and
- Improving entire systems and not just single parts of systems, by avoiding decisions that fix one problem but cause another unexpected problem (like mitigating air pollution but increasing water pollution).

LCIA predicts *potential* environmental impacts or damages. Life cycle inventory data typically span multiple geographical locations across countries and continents in today's global supply chains. LCIA's predictive models are therefore not like environmental impact assessment (EIA) models that accurately characterise the actual risks associated with emissions at a particular location. Indeed, the value of an LCA study lies not so much with the final numbers, but rather with the exploration and consequent understanding of the product system it assesses. Especially valuable is LCA's ability to highlight hotspots along the value chain, that is, to show the areas of highest potential impact, and also to highlight trade-offs between different impacts. It is seldom that one system or decision option performs better than another in all aspects of environmental impacts. Thus, understanding these trade-offs is a prerequisite towards improving the sustainability of product systems.

2 GOAL AND SCOPE DEFINITION

2.1 Goal of the study

The primary intention of the LCA is to assist MetPac-SA's members to meet the Extended Producer Responsibility (EPR) regulatory requirement to conduct an LCA on identified products. South Africa's (EPR) regulations for paper, packaging and some single-use products require that a life cycle assessment (LCA) be conducted, "in relation to the identified product, in accordance with the applicable standards within 5 years of implementation of their extended producer responsibility scheme"¹. A secondary intention of the LCA is to explore the insights that life cycle assessment can bring to the metal packaging sector in South Africa.

Although the LCA requirement in the EPR regulations is somewhat unclear (pending further guidance from DFFE), the LCA is scoped so as to provide input into the focus areas specified in the EPR regulations, namely to:

- Minimise the use of primary materials in the beverage can packaging system;
- Design beverage cans to facilitate recycling or recovery, without compromising their functionality; and
- Reduce environmental toxicity in the post-consumer waste stream.

As per SANS 14044:2006, the goal of an LCA study is defined through a consideration of the following:

- **The intended application** is regulatory compliance and member communication, which therefore includes being able to:
 - provide MetPac's members with reliable and objective information about the environmental and social impacts (including benefits) associated with the life cycle of aluminium beverage cans produced and used in South Africa.
 - build confidence, data and knowledge around life cycle assessment of beverage cans in South Africa.
- **The reasons for carrying out the study** are to
 - determine the environmental impacts and credits across the life cycle of aluminium beverage cans produced and used in South Africa.

- identify the lowest impact waste management option for used beverage cans (UBCs) in South Africa, taking into account the environmental, circularity and social benefits of end-of-life options.
- **The intended audience** is MetPac-SA and its members. The study findings may also be shared externally with interested stakeholders, such as DFFE. The study is not intended to support comparative assertions intended to be disclosed to the public.

2.2 Scope of the study

The scope of the study covers decisions relating to the detail and accuracy of the study and related methodological decisions, including the choice of functional unit, system boundaries and data requirements.

2.2.1 Product system

The product system assessed in this study is aluminium beverage cans produced and used (disposed) in South Africa. Figure 2 shows the life cycle flow diagram for the beverage can system. The scope of the study is **cradle-to-grave**, i.e. from the production and extraction of raw materials through to final disposal of the manufactured product. For beverage cans, the life cycle includes:

- Production of raw materials (bauxite mining, aluminium smelting, coatings etc.)
- Can body and can end manufacturing, can coating
- Packing (including the manufacturing of the packaging) and distribution
- Can filling, distribution, retail and consumer use
- Can end-of-life, including collection and transport to end-of-life processing (recycling or landfill disposal), as well as processes avoided through the production of recycled materials (e.g. production of primary aluminium)
- Transport of materials and of products between the life cycle stages, most notably raw materials imported into South Africa and metal scrap exported from South Africa.

As shown in Figure 2, transportation to fillers, filling, distribution, retail and consumer use are excluded from the product system to be modelled. These life cycle stages have only a small contribution to the life cycle environmental impacts of packaging systems, and furthermore, are not relevant for the goal of this study. The exclusion of the filling, distribution, retail and consumer use is consistent with international LCA studies on beverage cans⁵.

⁵ [Metal Packaging Life Cycle Assessment of Aluminium Beverage Cans in Europe; The Aluminium Association's Life Cycle Assessment of North American Aluminium Cans](#)

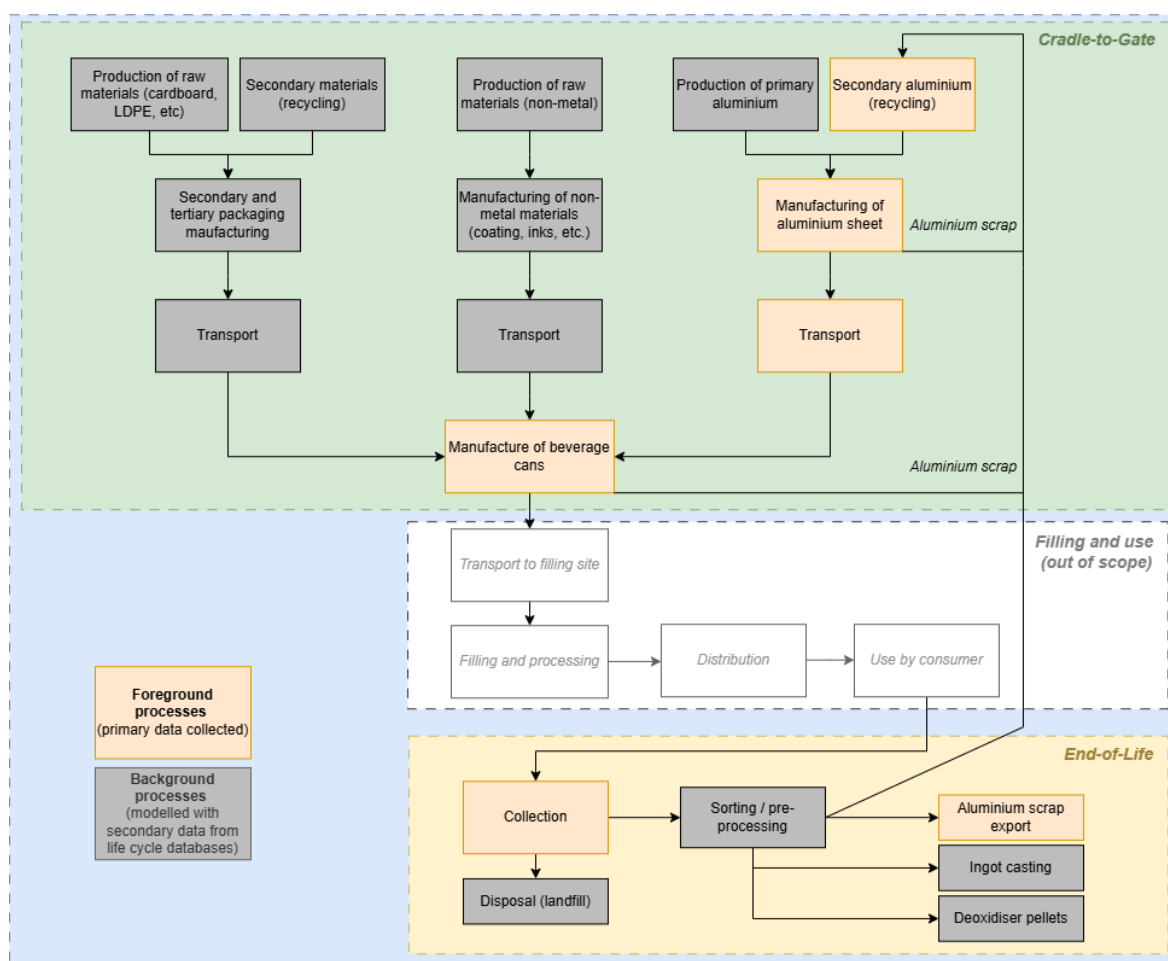


Figure 2: Life cycle flow diagram of aluminium beverage cans

2.2.2 Representative products

There are a number of different sizes of aluminium beverage cans available on the South African market, from 200 ml to 500 ml. Historically, **330 ml cans** made up approximately 70% of the volumes on the market and are the primary focus of the study (i.e. the baseline results will be for 330 ml cans). This also allows for direct comparison to international studies, such as Metal Packaging Europe's *Life Cycle Assessment of Aluminium Beverage Cans in Europe* study.

The impact of different can sizes and the resulting change in material requirements and aluminium scrap generated is analysed as part of the study, with all results benchmarked against the packaging required to hold the same volume of beverage.

2.2.3 Functional unit

The functional unit of an LCA study represents the quantified performance of the product system under study for use as a reference unit, i.e. it is the unit against which the life cycle environmental impacts are measured.

The function of the beverage can product system is the protection and distribution of beverages, such as carbonated soft drinks, from their manufacture to end-consumers. A further function is to present beverages in an aesthetically appealing manner to consumers. The functional unit is thus defined as:

“Units of aluminium beverage cans to contain, protect and decorate 330 litres of beverage on the South African market”

The rationale for the choice of “contained litres of beverage” as the functional basis is so that differences in material efficiency between the three can variants can be made explicit. For the baseline analysis of 330 ml cans, the functional unit simplifies to 1,000 units of aluminium beverage cans on the South African market (for a 250 ml can, this equates to 1,320 units; for a 440 ml can, 750 units).

The reference flow is the mass of beverage cans and associated materials required to fulfil the functional unit.

2.2.4 The system boundary

The life cycle system is made up of all the life cycle stages (unit processes) making up the product system, enclosed by the system boundary, as illustrated in Figure 2. The scope of the study is “cradle-to-grave”, with inclusions and exclusions to the system boundary listed in Table 1.

Table 1: System boundary inclusions and exclusions

Inclusions	Exclusions
Upstream processing and production of primary (virgin) and secondary (recycled) materials used in beverage can manufacturing	Transportation of beverage cans to fillers
Production of secondary and tertiary packaging materials (boxes, pallets etc.)	Filling of beverage cans and manufacture of can contents
Transport of materials and packaging to beverage can manufacturers; transport infrastructure	Packaging for filled beverage cans
Electricity, fuels, water and ancillary materials used in the manufacture of aluminium beverage cans	Distribution and retail of filled beverage cans
Collection and sorting of UBCs	Consumer use
Processing of pre- and post-consumer aluminium scrap	Employee commuting
Processing and transport to market of UBCs not recycled back into beverage cans, i.e. made into deoxidiser pellets, exported etc.	Maintenance of equipment
Recycling of packaging (cardboard, plastic, wood etc.)	
Landfill disposal of non-recycled packaging and UBCs	

2.2.5 Data requirements and sources

All LCAs utilise a blend of primary (data collected specifically for the project) and secondary (data sourced from life cycle databases and literature) data to model the life cycle systems within the system boundaries. Ideally, models are constructed using as much primary data as possible, especially for foreground life cycle stages such as aluminium production, sheet rolling and can converting.

Primary data on the following life cycle stages was provided by MetPac-SA and its members:

- Can body and can end (3104 & 5182 alloy) sheet production in South Africa, including manufacturing energy and raw material inputs & sources (2025 industry data)
- Share of aluminium sheets used for can production from South Africa (91%) and imported (9%) (2024 MetPac-SA Material Flow Analysis (MFA))
- Two-piece aluminium can converting, including manufacturing energy and raw material inputs & sources (2025 industry data)

- Share of aluminium cans on the market from local can production (93%) and imported cans (7%) (2024 MetPac-SA MFA)
- Used beverage can collection rate (88%) (2024 MetPac-SA MFA)
- UBC to beverage can sheet (i.e. closed-loop) recycling, including manufacturing energy and raw material inputs & sources (2025 industry data)

South African can body and can end sheet production uses a mixture of virgin aluminium, sourced from South32's Hillside plant, and recycled aluminium, recycled from pre-consumer and post-consumer sources. Virgin aluminium production is based on International Aluminium Institute (IAI) life cycle datasets, based on primary data from the Hillside plant (i.e. it is primary data for South Africa collected by the IAI). Recycled aluminium is based on the following data:

- **Pre-consumer scrap:** Average transportation from aluminium can converters to recycle furnace location
- **Post-consumer scrap:**ecoinvent inputs for transportation and pre-processing energy
- **Dross recovery:** Literature data on rotary furnace dross recovery⁶

Imported can body and can end sheet is modelled using IAI data for average global aluminium production and ecoinvent average global sheet rolling data.

Non-participating can converters were modelled using data from the *Life Cycle Assessment of North American Aluminium Cans*⁷. The aluminium sheet split (i.e. share from South African and imported sources) was based on MetPac-SA's 2024 material flow analysis, which showed that 91% of aluminium sheeting is produced in South Africa. Imported cans are likewise modelled using data from the *Life Cycle Assessment of North American Aluminium Cans* and IAI/ecoinvent data for aluminium sheets.

End-of-life processes are based on the following data:

- **Disposal:** South African average waste disposal split for metals
 - **Landfilling:** Doka/ecoinvent models⁸ for South Africa
 - **Open dumping:** Doka/ecoinvent models for South Africa
 - **Open burning:** ecoinvent dataset
- **UBC to can recycling:** Primary data from UBC to can body and end sheet production
- **Recycled ingot casting:** Secondary data from ecoinvent and *Life Cycle Assessment of North American Aluminium Cans*
- **Deoxidiser pellet casting:** Secondary data from ecoinvent and *Life Cycle Assessment of North American Aluminium Cans*

Background processes are all those processes that provide materials and services into the foreground life cycle stages, including raw material production, electricity generation and transmission, road and sea transport, production

⁶ Olivares et al. (2024) LCA of recycling aluminium incineration bottom ash, dross and shavings in a rotary furnace and environmental benefits of salt-slag valorisation. Waste Management. Volume 182

⁷ *Life Cycle Assessment of North American Aluminium Cans* (2021) Sphera, On behalf of the Aluminium Association. <https://sphera.com/wp-content/uploads/2024/06/2021-Alumium-Can-Full-LCA-Report.pdf>

⁸ Doka models are material-specific solid waste treatment life cycle assessment models developed by Gabor Doka for the ecoinvent database. They model all inputs to (infrastructure, energy etc.) and emissions from solid waste management based on climatic conditions and the technologies employed.

of fuels, production of chemicals, and water and waste treatment processes. Data for background processes are sourced from the ecoinvent database, adapted for the geographical context, where relevant.

Further details on the data used in the life cycle models are provided in Section 3.

2.2.6 Allocation

Allocation is encountered in life cycle models when the inputs and emissions of a process need to be apportioned between multiple products (**multi-output allocation**), or between products and waste streams that are reused and/or recycled (**recycling allocation**).

LCA studies broadly follow one or other of two system models to manage this problem. The **consequential** system model aims to avoid allocation by expanding the product system boundary to include the co-production (system expansion), whilst in the **attributorial** system model, an allocation method is applied to convert multi-product activities into single-product activities. Allocation factors derived from the chosen method determine the share of each input and emission to be assigned to the reference product and to the by-products.

Multi-output allocation is relevant for upstream semi-fabricated aluminium production, who manufacture multiple products and alloys, and beverage can producers, who manufacture various can products and sizes. Some MetPac-SA members already have systems in place to track and allocate input materials and energy consumption to various products. Where these systems are in place, the product-specific data is used directly. Allocation for other primary data follows ISO 14044 and the Product Environmental Footprint (PEF) guidelines⁹, which state that wherever possible allocation should be based on an underlying physical relationship (e.g. such as mass), or where no reasonable physical relationship between process inputs and co-product outputs can be determined, other relationships between the products and co-products, such as relative economic value, may be applied.

The ecoinvent system model “cut-off by classification” is chosen for datasets from the ecoinvent database used to model the background system. The “cut-off by classification” system model applies economic allocation (i.e., allocation based on price) with a few exceptions, such as for energy products, for which allocation is based on exergy (e.g. oil refinery).

Recycling allocation when modelling end-of-life is highly relevant for this study. Allocation choices are required for sharing the inputs and emissions from recycling processes, along with the benefits of avoided primary material production, between the producer of the recycled materials (in this case the beverage can system), with the user of the recycled materials. The user of recycled materials may be the same product system (i.e. materials recycled back into beverage cans), which is termed “closed-loop” recycling, and which considerably simplifies the accounting. More frequently, the recycled materials are used in a variety of other products systems (e.g. case aluminium ingots used for a range of applications, deoxidiser pellets etc). This is termed open-loop recycling, and for which allocation choices can be highly influential in determining the overall results. Allocation choices also play a role in accounting for recycled content in the aluminium sheet used in beverage can manufacturing, and also for the recycled content in packaging materials.

Three types of aluminium scrap can be distinguished in the beverage can product system: runaround, pre-consumer and post-consumer scrap.

⁹ [Product Environmental Footprint Category Rules Guidance \(Version 6.3\)](#).

Run-around scrap (relevant to manufacturing of aluminium sheet) is not explicitly modelled but rather handled as a manufacturing efficiency, i.e. by modelling the net input of primary aluminium to the manufacturing process.

Pre-consumer (arising from beverage can converting) and **post-consumer scrap** (UBCs) are modelled using **system expansion**, which aims to avoid allocation (the first-tier approach recommended by ISO 14044). This approach is the most relevant for determining which end-of-life process is the most sustainable, as is the objective of the study. System expansion avoids allocating burdens between product systems by including the avoided products in the system boundary. With system expansion, the beverage can system is credited with the avoided production of primary aluminium caused by the substitution of primary aluminium with secondary aluminium, where the latter is produced from recycled UBCs.

2.2.7 Impact categories selected and methodology of impact assessment

The purpose of life cycle impact assessment (LCIA) is to group and aggregate the life cycle inventory data according to their contribution to predefined environmental impact categories. Various life cycle impact assessment (LCIA) methods have been developed by research groups around the world, with end-point methods preferred for communicating LCA results to non-LCA experts as they allow the grouping of a large number of environmental impact indicators into a smaller number of damages or areas of concern, typically:

- **Damage to human health**, which occurs through a variety of effects, including the release of substances toxic to humans, substances that destroy the ozone layer, substances that cause respiratory illnesses and that cause global climate change;
- **Damage to ecosystems**, which occurs through a variety of effects including the release of substances toxic to ecosystems, the release of acidifying substances and excessive macronutrients, as well as ecosystem impacts arising from climate change, water deprivation and land transformation/occupation;
- **Resource depletion**, representing the concern around availability of non-renewable resources for future generations, and the use of renewable resources beyond their carrying capacity.

As such, the **IMPACT World+** impact assessment method, developed by the International Reference Centre for Life Cycle Assessment and Sustainable Transition (CIRAIG) and the Technical University of Denmark (DTU), is applied in this study. IMPACT World+ is the result of an update of three existing, well recognised LCA methods, namely: IMPACT 2002+, EDIP and LUCAS. An overview of the IMPACT World+ methodological framework is given in Figure 3.

IMPACT World+ is chosen for application in this study as it is a global methodology, which still provides country-level region-specific characterisation factors for those impact categories where this is relevant. The method calculates impacts at both the midpoint and damage (effect or endpoint) level, allowing for the estimation of potential damages to key areas of protection (AoP). Together this provides a holistic understanding of life cycle environmental impacts, allowing for determination of specific environmental impacts of interest (e.g. climate change impact, water scarcity), while also assessing damage-level effects of environmental impact categories on human health, ecosystem quality, and resource and ecosystem services.

The impact indicators that currently constitute the IMPACT World+ impact assessment method are summarised in Table 2. As can be seen in the table, 19 indicators are modelled at the midpoint and damage level, whilst six are modelled only at the damage level. Resource & ecosystem services are modelled only at the midpoint level (they are not yet extended to the damage level). As such, for resource & ecosystem services, the *Adaptation to resources services loss* midpoint indicator is applied in the study to represent non-renewable resource depletion.

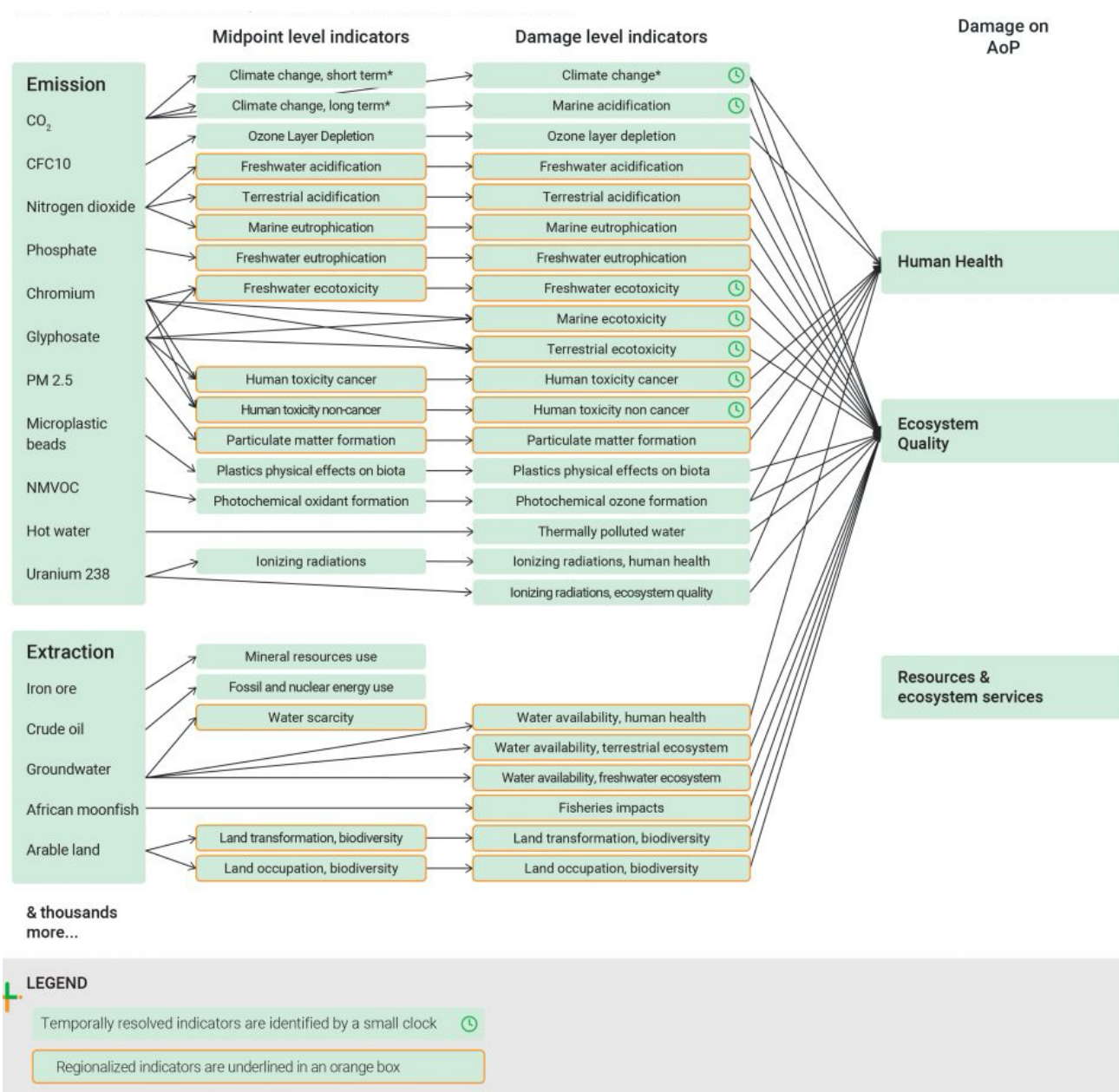


Figure 3: IMPACT World+ midpoint-expert methodological framework, showing the progression from midpoint level to damage level to Area of Protection (AoP)

Table 2: Description of impact category indicators covered by the IMPACT World+ impact assessment method¹⁰

Environmental impact category	Impact category indicator and units	Area of Protection (AoP)
Climate change, short-term	Radiative forcing as Global Warming Potential (GWP 100-year) in kg CO ₂ equivalents	Human health Ecosystem quality
Climate change, long-term	Long-term cumulative temperature changes as Global Temperature Potential (GTP 100-year) in kg CO ₂ equivalents	Human health Ecosystem quality
Adaptation to resources services loss	Additional effort to extract resources linked to resource dissipation (i.e. added difficulty to extract new resources) in MJ additional extraction energy	
Resources services deficit	Potential deficit of resources when looking at the future usage of mineral resources in the next 100 years in kg deficit	
Photochemical ozone formation	Photochemical ozone creation potential (POCP) in kg non-methane volatile organic compound (NMVOC) equivalents	Human health
Ozone layer depletion	Ozone depletion potential (ODP) in kg CFC-11 equivalents	Human health
Freshwater ecotoxicity	Ecosystem toxicity potential in Comparative Toxic Unit for ecosystems (CTUe)	Ecosystem quality
Human toxicity cancer	Estimated increase in morbidity in the human population per unit mass of chemical emitted in Comparative Toxicity Unit for humans (CTUh)	Human health
Human toxicity non-cancer	Estimated increase in morbidity in the human population per unit mass of chemical emitted in Comparative Toxicity Unit for humans (CTUh)	Human health
Freshwater acidification	Change in freshwater pH (freshwater acidification) in kg SO ₂ equivalents	Ecosystem quality
Terrestrial acidification	Change in terrestrial pH (terrestrial acidification) in kg SO ₂ equivalents	Ecosystem quality
Freshwater eutrophication	Increase in nutrients (phosphorous) in freshwater end compartment in kg PO ₄ equivalents (phosphorous considered the limiting factor in freshwater bodies)	Ecosystem quality
Marine eutrophication	Increase in nutrients (nitrogen) in coastal marine end compartment in kg N equivalents (nitrogen considered the limiting factor in marine bodies)	Ecosystem quality
Particulate matter formation	Estimated increased in human health impacts from particulates in kg of particles of less than 2.5 microns (PM2.5) emitted	Human health
Ionizing radiation	Ionising radiation potential in Bq C-14 equivalents	Human health Ecosystem quality
Land transformation, biodiversity	Biodiversity impacts from land transformation in square meters per year (m ² .year) of arable land	Ecosystem quality
Land occupation, biodiversity	Biodiversity impacts from land use in square meters per year (m ² .year) of arable land	Ecosystem quality
Water scarcity	Deprivation-weighted water consumption in global m ³ equivalents	<i>See water availability impact category</i>
Physical effects on biota	Physical impacts of microplastics and microparticles on biota in Comparative Toxic Unit for ecosystems (CTUe)	Ecosystem quality
Fisheries impact	Only as endpoint impacts	Ecosystem quality
Marine acidification	Only as endpoint impacts	Ecosystem quality
Marine ecotoxicity	Only as endpoint impacts	Ecosystem quality
Terrestrial ecotoxicity	Only as endpoint impacts	Ecosystem quality
Thermally polluted water	Only as endpoint impacts	Ecosystem quality
Water availability	Only as endpoint impacts	Human health Ecosystem quality

¹⁰ Further details on the IMPACT World+ are available from the project website (<https://www.impactworldplus.org/>) and the associated publication (<https://link.springer.com/article/10.1007/s11367-019-01583-0>).

To simplify the interpretation and presentation of results, the following disaggregated and partially aggregated IMPACT World+ indicators are reported in this study:

- Climate change (focussed on short-term)
- Human health AoP
- Ecosystem quality AoP
- Adaptation to resources services loss

The human health and ecosystem quality AoPs can also be summed into an aggregated “single-score” impact; however, this is used sparingly in reporting as it does not consider the impacts of non-renewable resource depletion.

For human health and ecosystem quality AoPs, impacts are also presented based on the IMPACT World+ normalisation and deterministic weightings. Although any weighting scheme is not wholly science based and inherently involves value judgements, reflecting the cultural, political and other values and preferences of those assigning the weights, weighting is beneficial as it allows for direct comparison, and even aggregation, of the AoPs impacts.

Impact assessment is carried out in SimaPro 10. The implementation of IMPACT World+ LCIA method in SimaPro is the IMPACT World+ 2.2.1 release (March 2026).

Even state-of-the-art LCIA methods, such as Impact World+, are limited to the assessment of environmental impacts. Whilst these methods consider socio-economic assets (natural resources and ecosystem services), LCIA methods do not evaluate material circularity (as an attribute in itself), nor do they look at wider socio-economic aspects (other than impacts on human health). However, circularity and socio-economic considerations are critical in the evaluation of end-of-life management options for UBCs in South Africa.

As such, alongside these life cycle environmental impact categories, the following indicators are reported in this study:

- Material Circularity Indicator (MCI)
- Employment indicator

The **Material Circularity Indicator (MCI)** provides a quantitative representation of the circularity of the product system, including waste management, according to the MCI methodology¹¹. The MCI thus provides a relative indicator on how decoupled a product system is from linear (“take-make-waste”) economy and how much value is extracted by the end-of-life management option.

The **Employment indicator** applied in the study provides an indication of **income opportunities** associated with the product value chain. Unlike the environmental indicators, the employment indicator considers only those processes in the direct aluminium beverage can value chain occurring in South Africa. That is, jobs associated with background processes, e.g. electricity production, packaging etc. are not included.

¹¹ Ellen MacArthur Foundation, ANSYS Granta, 2019. Material Circularity Index (MCI): Methodology - An approach to measuring circularity Published 2015, adapted in 2019. The MCI method complies with the new ISO 59020:2024 *Circular economy – Measuring and assessing circularity performance* Standard.

2.2.8 Assumptions and limitations

As with all life cycle models, a large number of assumptions are made when developing the models. The life cycle models are explained in Section 3, along with any assumptions made when constructing them.

LCA results are inherently limited by the quality of the data used to construct them. The considerable number of LCI datasets required to complete any LCA model means that simplifications and the use of proxy datasets are inevitable to some degree. This LCA is no different, with data quality considerations with respect to the quality of the results discussed in Section 4.3.

The key data-related limitations are the modelling of non-participating can producers with literature data, modelling of various end-of-life processes with literature data and uncertainty in the overall split of aluminium sent to each end-of-life process in South Africa.

3 THE LIFE CYCLE MODEL

The following sub-sections provide details on the “cradle-to-grave” life cycle models developed for the aluminium beverage can system. Unless otherwise noted, ecoinvent datasets applying the cut-off system model are used in the life cycle models.

3.1 Aluminium can body & end sheet

The aluminium can body and can end sheeting utilised by South African can converters is predominately produced in South Africa (91% from MetPac-SA’s 2024 material flow analysis (MFA)), with some sheeting imported from international producers (9%).

A South African sheeting producer supplied primary data for the study, covering raw materials (including sources), energy and other inputs. The company has systems in place to track aluminium (virgin and recycled), hardener, methane-rich gas, LPG and electricity inputs for the can body (3104 alloy) and can end (5182 alloy) sheets specifically, meaning that no allocation was required for these key inputs. All other inputs (water, solvents, lubricants, diesel) and outputs (solid waste) were allocated on a mass basis.

The aluminium utilised to manufacture these sheets includes virgin ingots supplied by South32 from their Hillside plant (Table 3), virgin ingots cast by the company from South32 Hillside liquid aluminium (Table 4), UBC aluminium scrap (Table 5), post-consumer aluminium scrap (Table 6), pre-consumer scrap from can converters (Table 7) and recycled dross recovered from the company’s waste (Table 8).

The datasets used to model the inputs and outputs from rolled aluminium sheets production within South Africa are summarised in Table 9.

Table 3: Inventory inputs for aluminium ingots from South32 Hillside

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Aluminium ingots	Aluminium, primary, ingot / South Africa	IAI datasets, developed from primary data from Hillside
Inbound transportation	Transport, freight, lorry, diesel, unspecified / South Africa	Transportation distance from Hillside

Table 4: Inventory inputs and outputs for aluminium ingot cast by company from South32 Hillside liquid aluminium

Resources	ecoinvent dataset applied / Geography	Data source
Water	Water, unspecified natural origin / South Africa	Company-specific – Mass allocated
Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Liquid aluminium	Aluminium, primary, liquid / South Africa	Company-specific – Internal tracking
Hardener	Silicon, metallurgical grade / Global Magnesium / Global Manganese / Global Titanium, triple-melt / Global Boron carbide / Global Copper, cathode / Global Pig iron / Global	Company-specific – Internal tracking
Industrial gases	Argon, liquid / Global Chlorine, liquid / Global Nitrogen, liquid / Global	ecoinvent ingot casting dataset
Consumables	Cryolite / Global Refractory, fireclay, packed / Global Stone wool / Global	ecoinvent ingot casting dataset
Infrastructure	Aluminium casting facility / Global	ecoinvent ingot casting dataset
Inbound transportation	Transport, freight, lorry, diesel, unspecified / South Africa	Transportation distance from Hillside
Inputs: Electricity & heat	ecoinvent dataset applied / Geography	Data source
Electricity	Electricity, medium voltage / South Africa	Company-specific – Internal tracking
Methane rich gas (Sasol gas)	Heat, district or industrial, natural gas, Sasol MRG / South Africa (adapted)	Company-specific – Internal tracking
Diesel	Diesel, burned in building machine / South Africa (adapted)	Company-specific – Mass allocated
Emissions to air	ecoinvent dataset applied / Geography	Data source
Casting emissions	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p- Hydrochloric acid Nitrogen oxides Particulates, < 2.5 um Particulates, > 10 um Particulates, > 2.5 um, and < 10um Sulphur dioxide	ecoinvent ingot casting dataset
Water emissions	Water/m3 / South Africa	Water balance
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
General waste	Municipal solid waste / South Africa (Doka/ecoinvent model)	Company-specific – Mass allocated
Hazardous waste	Hazardous waste, sanitary landfill / South Africa (Doka/ecoinvent model)	Company-specific – Mass allocated
Wastewater	Wastewater, average / South Africa (adapted)	Company-specific – Mass allocated

Table 5: Inventory inputs and outputs for aluminium UBC scrap

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Infrastructure	Waste preparation facility / Global	ecoinvent post-consumer UBC aluminium scrap preparation dataset
Inbound transportation	Transport, freight, lorry, diesel, unspecified / South Africa	ecoinvent UBC dataset
Inputs: Electricity & heat	ecoinvent dataset applied / Geography	Data source
Electricity	Electricity, medium voltage / South Africa	ecoinvent post-consumer UBC aluminium scrap preparation dataset
Diesel	Diesel, burned in building machine / South Africa (adapted)	ecoinvent post-consumer UBC aluminium scrap preparation dataset
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
General waste	Municipal solid waste / South Africa (Doka/ecoinvent model)	ecoinvent post-consumer UBC aluminium scrap preparation dataset

Table 6: Inventory inputs and outputs for aluminium post-consumer scrap

Resources	ecoinvent dataset applied / Geography	Data source
Water	Water, unspecified natural origin / South Africa	ecoinvent post-consumer aluminium scrap preparation dataset
Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Chemicals	Alkylbenzene sulfonate, linear, petrochemical / Global Hydrated lime, packed / Global Light fuel oil / South Africa Lubricating oil / Global	ecoinvent post-consumer aluminium scrap preparation dataset
Infrastructure	Scrap preparation facility / Global	ecoinvent post-consumer aluminium scrap preparation dataset
Inbound transportation	Transport, freight, lorry, diesel, unspecified / South Africa	ecoinvent UBC dataset
Inputs: Electricity & heat	ecoinvent dataset applied / Geography	Data source
Electricity	Electricity, medium voltage / South Africa	ecoinvent post-consumer aluminium scrap preparation dataset
Heat	Heat, chemical industry / South Africa (South African energy balance)	ecoinvent post-consumer aluminium scrap preparation dataset
Emissions to air	ecoinvent dataset applied / Geography	Data source
Processing emissions	Hydrochloric acid Particulates, < 2.5 um Particulates, > 10 um Particulates, > 2.5 um, and < 10um	ecoinvent post-consumer aluminium scrap preparation dataset
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
General waste	Municipal solid waste / South Africa (Doka/ecoinvent model)	ecoinvent post-consumer aluminium scrap preparation dataset
Waste oil	Waste mineral oil / Global	ecoinvent post-consumer aluminium scrap preparation dataset

Table 7: Inventory inputs for aluminium pre-consumer scrap

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Inbound transportation	Transport, freight, lorry, diesel, unspecified / South Africa	Transportation distance from can converters

Table 8: Inventory inputs and outputs for aluminium recovered from dross waste stream using rotary furnace

Outputs: Avoided products	ecoinvent dataset applied / Geography	Data source
Aluminium oxide	Aluminium oxide, metallurgical / Global	Olivares et al. ¹²
Ammonium sulphate	Ammonium sulphate, as N / Global	Olivares et al.
Resources	ecoinvent dataset applied / Geography	Data source
Water	Water, unspecified natural origin / South Africa	Olivares et al.
Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Sodium chloride	Sodium chloride, powder / Global	Olivares et al.
Potassium chloride	Potassium chloride / Global	Olivares et al.
Sodium fluoride	Sodium fluoride / Global	Olivares et al.
Lime	Hydrated lime, packed / Global	Olivares et al.
Oxygen	Oxygen, liquid / South Africa	Olivares et al.
Sulphuric acid	Sulphuric acid / Global	Olivares et al.
Nitrogen	Nitrogen, liquid / South Africa	Olivares et al.
Inputs: Electricity & heat	ecoinvent dataset applied / Geography	Data source
Electricity	Electricity, medium voltage / South Africa	Olivares et al.
LPG	Heat, district or industrial, other than natural gas, LPG / South Africa (adapted)	Olivares et al. Company-specific fuel type
Emissions to air	ecoinvent dataset applied / Geography	Data source
Process emissions	Carbon dioxide, fossil Sulphur dioxide / South Africa Nitrogen oxides / South Africa Particulates, unspecified Hydrochloric acid Hydrogen fluoride Heavy metals, unspecified Methane	Olivares et al.
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
Waste	Filter dust from Al electrolysis / Global	Olivares et al.

Table 9: Inventory inputs and outputs for aluminium sheet production

Resources	ecoinvent dataset applied / Geography	Data source
Water	Water, unspecified natural origin / South Africa	Company-specific – Mass allocated

¹² Olivares et al. (2024) LCA of recycling aluminium incineration bottom ash, dross and shavings in a rotary furnace and environmental benefits of salt-slag valorisation. Waste Management. Volume 182

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Aluminium	<i>Aluminium ingots from South32 Hillside</i> <i>Aluminium ingot cast from liquid aluminium</i> <i>Aluminium UBC scrap</i> <i>Aluminium post-consumer scrap</i> <i>Aluminium pre-consumer scrap</i> <i>Aluminium recovered from dross waste stream</i>	Company-specific – Internal tracking See Table 3 to Table 8 above
Hardener	Silicon, metallurgical grade / Global Magnesium / Global Manganese / Global Titanium, triple-melt / Global Boron carbide / Global Copper, cathode / Global Pig iron / Global Chromium / Global Zinc / Global	Company-specific – Internal tracking
Processing solvents and lubricants	Kerosene / South Africa Methanol / Global Benzene / Global Methyl ethyl ketone / Global White spirit / Global Solvent, organic / Global Lubricating oil / Global	Company-specific – Mass allocated
Industrial gases	Chlorine, liquid / Global Nitrogen, liquid / Global	ecoinvent cast alloy dataset
Processing chemicals	Hydrated lime, packed / Global Hydrochloric acid, without water, in 30% solution state / Global Sodium chloride, powder / Global Sodium hydroxide, without water, in 50% solution state / Global Sulphuric acid / Global	ecoinvent cast alloy dataset
Consumables	Cryolite / Global Refractory, fireclay, packed / Global	ecoinvent cast alloy dataset
Infrastructure	Aluminium casting facility / Global Aluminium melting furnace / Global Rolling mill / Global	ecoinvent cast alloy dataset ecoinvent sheet rolling dataset
Inputs: Electricity & heat	ecoinvent dataset applied / Geography	Data source
Electricity	Electricity, medium voltage / South Africa	Company-specific – Internal tracking
LPG	Heat, district or industrial, other than natural gas, LPG / South Africa (adapted)	Company-specific – Internal tracking
Methane rich gas (Sasol gas)	Heat, district or industrial, natural gas, Sasol MRG / South Africa (adapted)	Company-specific – Internal tracking
Diesel	Diesel, burned in building machine / South Africa (adapted)	Company-specific – Mass allocated

Emissions to air	ecoinvent dataset applied / Geography	Data source
Solvent and lubricant emissions	Kerosene Methanol Benzene Methyl ethyl ketone White mineral oil (petroleum) NMVOC, non-methane volatile organic compounds / South Africa	Mass balance For lubricants, the share to air is based on ecoinvent sheet rolling dataset
Casting emissions	Ammonia / South Africa Chlorine Hydrocarbons, chlorinated Hydrochloric acid Hydrogen fluoride Hydrogen sulphide Particulates, < 2.5 um / South Africa Particulates, > 10 um / South Africa Particulates, > 2.5 um, and < 10um / South Africa Phosphorus	ecoinvent cast alloy dataset
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
General waste	Municipal solid waste / South Africa (Doka modelling)	Company-specific – Mass allocated
Hazardous waste	Hazardous waste, sanitary landfill / South Africa (Doka/ecoinvent model)	Company-specific – Mass allocated
Wastewater	Wastewater, average / South Africa (adapted)	Company-specific – Mass allocated
Waste lubricant	Waste mineral oil / South Africa (adapted)	Mass balance

3.2 Aluminium can converting

Two-piece aluminium can converting utilises the South African produced aluminium sheets and some imported aluminium sheeting.

MetPac-SA can converting members supplied primary data on raw materials (including sources), energy and other inputs for can converting¹³. These facilities produce a range of aluminium cans, and in certain cases steel cans, with all inputs and outputs allocated on a mass basis. The datasets used to model inputs to and outputs from aluminium can converting developed from South African company-specific data are summarised in Table 10.

Table 10: Inventory inputs and outputs for aluminium can converting using South African company-specific data (applied to can converters providing data for the study)¹¹

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
South African aluminium sheet	<i>Aluminium sheet production</i>	Company-specific – Mass allocated <i>See Table 9 above</i>
International aluminium sheet	Aluminium, wrought alloy / Global or Country-specific Sheet rolling, aluminium / Global or Country-specific	Company-specific – Mass allocated

¹³ This data covers 51% of aluminium cans on the South African market.

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Liner	Styrene-acrylonitrile copolymer / Global	Company-specific – Mass allocated
Ink	Printing ink, offset, without solvent, in 47.5% solution state / Global Solvent, organic / Global	Company-specific – Mass allocated
Coating	Acrylic varnish, with water, in 53% solution state / Global Tap water / South Africa	Company-specific – Mass allocated
Water	Tap water / South Africa	Company-specific – Mass allocated
Lubricant	Lubricating oil / Global	North American aluminium can LCA
Inbound transportation	Transport, freight, lorry, diesel, unspecified / South Africa	Transportation distance from production site and/or supplier
Infrastructure	Metal working factory / Global	ecoinvent aluminium metal working dataset
Packaging	Polypropylene / South Africa (adapted) Injection moulding / South Africa (adapted) Extrusion, film blowing / South Africa (adapted) Corrugated board box / South Africa (adapted)	European aluminium can LCA
Inputs: Electricity & heat	ecoinvent dataset applied / Geography	Data source
Electricity	Electricity, medium voltage / South Africa	Company-specific – Mass allocated
LPG	Heat, district or industrial, other than natural gas, LPG / South Africa (adapted)	Company-specific – Mass allocated
Natural gas	Heat, district or industrial, natural gas / Global	Company-specific – Mass allocated
Emissions to air	ecoinvent dataset applied / Geography	Data source
Solvent and lubricant emissions	NMVOC, non-methane volatile organic compounds / South Africa	Mass balance For lubricants, share to air is based on North American aluminium can LCA
Converting emissions	Particulates, < 10 um / South Africa Nitrogen dioxide / South Africa Dinitrogen monoxide NMVOC, non-methane volatile organic compounds / South Africa Sulphur dioxide / South Africa	North American aluminium can LCA
Water emissions	Water/m3 / South Africa	Share to air based on North American aluminium can LCA
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
General waste	Municipal solid waste / South Africa (Doka/ecoinvent model)	Company-specific – Mass allocated
Hazardous waste	Hazardous waste, sanitary landfill / South Africa (Doka/ecoinvent model)	Company-specific – Mass allocated
Wastewater	Wastewater, average / South Africa (adapted)	Company-specific – Mass allocated

To model the share of cans on the South African market for which the converters did not provide data to the study, covering both South African producers and international producers, can converting is based on literature values (i.e. secondary data) (summarised in Table 11). To ensure the validity of this assumption, the inputs for can converting were compared between the member data and literature data, which showed that energy inputs varied by less than 5% (with South African-specific data being 4.7% lower than the literature value). As such, it was deemed that the literature data gave an effective proxy for can converters who did not supply data.

Table 11: Inventory inputs and outputs for aluminium can converting using literature data (applied to share of can converters for which no data was provided)

Inputs: Materials & fuels	South African producers ecoinvent dataset applied / Geography	International producers ecoinvent dataset applied / Geography	Data source
South African aluminium sheet	<i>Aluminium sheet production</i>		North American aluminium can LCA Split between SA and imported sheet based on MetPac-SA MFA See Table 9 above
International aluminium sheet	Aluminium, wrought alloy / Global Sheet rolling, aluminium / Global	Aluminium, wrought alloy / Global Sheet rolling, aluminium / Global	North American aluminium can LCA Split between SA and imported sheet based on MetPac-SA MFA
Liner	Styrene-acrylonitrile copolymer / Global	Styrene-acrylonitrile copolymer / Global	North American aluminium can LCA
Ink	Printing ink, offset, without solvent, in 47.5% solution state / Global Solvent, organic / Global	Printing ink, offset, without solvent, in 47.5% solution state / Global Solvent, organic / Global	North American aluminium can LCA
Water	Tap water / South Africa	Tap water / Global	North American aluminium can LCA
Lubricant	Lubricating oil / Global	Lubricating oil / Global	North American aluminium can LCA
Inbound transportation	Transport, freight, lorry, diesel, unspecified / South Africa	Transport, freight, lorry, diesel, unspecified / Global Transport, freight, sea, container ship, heavy fuel oil / Global Transport, freight, lorry, diesel, unspecified / South Africa	Transportation distance from production site Average transportation distances for import
Infrastructure	Metal working factory / Global	Metal working factory / Global	ecoinvent aluminium metal working dataset
Packaging	Polypropylene / South Africa (adapted) Injection moulding / South Africa (adapted) Extrusion, film blowing / South Africa (adapted) Corrugated board box / South Africa (adapted)	Polypropylene / Global Injection moulding / Global Extrusion, film blowing / Global Corrugated board box / Global	European aluminium can LCA
Inputs: Electricity & heat	ecoinvent dataset applied / Geography	ecoinvent dataset applied / Geography	Data source
Electricity	Electricity, medium voltage / South Africa	Electricity, medium voltage / Global	North American aluminium can LCA
Natural gas	Heat, district or industrial, natural gas / Global	Heat, district or industrial, natural gas / Global	North American aluminium can LCA

Emissions to air	ecoinvent dataset applied / Geography	ecoinvent dataset applied / Geography	Data source
Converting emissions	NMVOC, non-methane volatile organic compounds / South Africa Particulates, < 10 um / South Africa Nitrogen dioxide / South Africa Dinitrogen monoxide NMVOC, non-methane volatile organic compounds / South Africa Sulphur dioxide / South Africa Water/m3 / South Africa	NMVOC, non-methane volatile organic compounds Particulates, < 10 um Nitrogen dioxide Dinitrogen monoxide NMVOC, non-methane volatile organic compounds Sulphur dioxide Water/m3	North American aluminium can LCA
Outputs: Waste treatment	ecoinvent dataset applied / Geography	ecoinvent dataset applied / Geography	Data source
General waste	Municipal solid waste / South Africa (Doka/ecoinvent model)	Municipal solid waste / Global	North American aluminium can LCA
Hazardous waste	Hazardous waste, sanitary landfill / South Africa (Doka/ecoinvent model)	Hazardous waste, for underground deposit / Global	North American aluminium can LCA
Wastewater	Wastewater, average / South Africa (adapted)	Wastewater, average / Global	North American aluminium can LCA
Packaging waste	Waste polypropylene, market / South Africa Waste paperboard, market / South Africa	Waste polypropylene, market / Global Waste paperboard, market / Global	European aluminium can LCA

3.3 End-of-life

Used beverage cans (UBCs) (aluminium cans at end-of-life) in South Africa are predominantly (88%) collected and recycled in some form, as shown in Figure 4. It is known that 20% of the collected UBCs go into closed-loop (UBC to beverage can) recycling, while 35% of the collected UBCs are exported to processors overseas. The remaining 45% of collected UBCs enter unknown scrap recycling processes, which includes (amongst others¹⁴) ingot casting (i.e. scrap melting and ingot casting) and deoxidiser pellet casting (i.e. scrap melting and pellet casting for use as deoxidiser material in steel production). The further processing and use of ingots produced from aluminium scrap fall outside of the system boundary since they are used to produce a diverse range of aluminium number of products, with the majority understood to be exported (see Figure 5). The 12% of UBCs not collected are assumed to enter South Africa's municipal solid waste management system.

¹⁴ Other applications include the production of water treatment chemicals and military explosives, but it is assumed these applications are limited. These applications are also similar to deoxidiser production, in that aluminium is consumed during the use of these compounds. As such only deoxidiser production is covered in this study as representative of a consumptive recycling product.

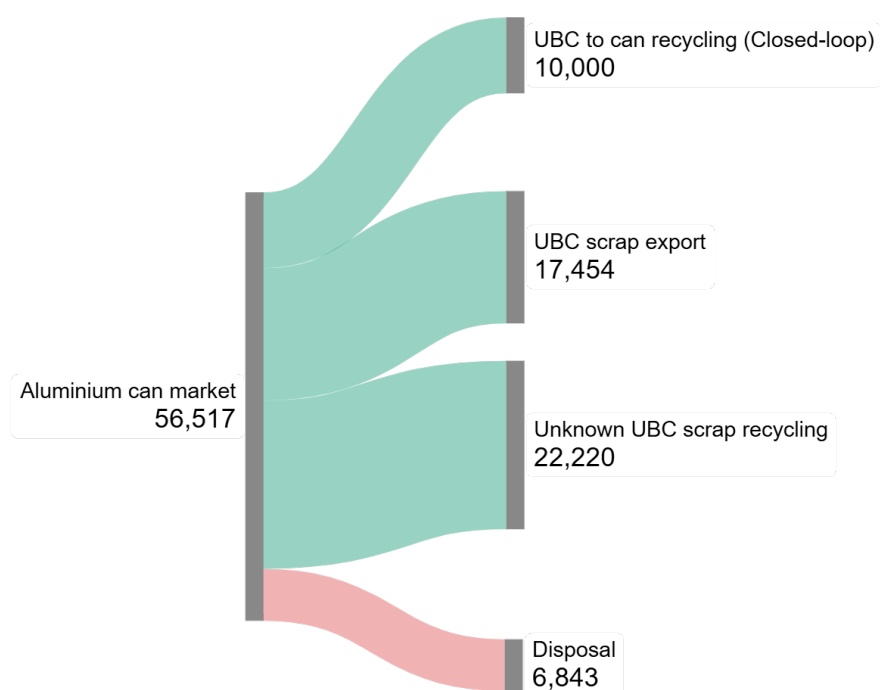


Figure 4: Sankey of UBC flows in South Africa based on MetPac-SA 2024 MFA¹⁵ [values in tonnes]

3.3.1 Disposal

Only a relatively small fraction of South Africa's waste ends up in well-managed sanitary landfills¹⁶. The possible destinations for disposed of UBCs are sanitary and unsanitary landfills, open dumps (unmanaged landfills) and open burning. Waste fractions landfilled, dumped and burned are based on household waste statistics and the percentage of household waste formally and informally managed in South Africa¹⁷. The split between sanitary and unsanitary landfill sites is based the percentage of landfills that are licenced¹⁸ and the percentage of waste that is treated in engineered landfills¹⁹.

In order represent landfilled waste as accurately as possible in the South African context, the waste model utilised by ecoinvent (on which the sanitary and unsanitary landfill datasets are derived)²⁰ was updated based on South African climatic and waste management data. The climatic data was weighted by population, with the key values applied in the model given in Table 12. Sanitary landfill sites are modelled with leachate sent to wastewater treatment plants,

¹⁵ UBC to can closed loop recycling based on Hualamin annual financial reporting (<https://finance.yahoo.com/markets/stocks/articles/hualamin-ltd-jse-hlm-full-010054746.html>). Exported scrap based on SARS trade data (Code 7602).

¹⁶ Rodseth, C., Notten, P. and von Blottnitz, H. (2020) 'A revised approach for estimating informally disposed domestic waste in rural versus urban South Africa and implications for waste management', *South African Journal of Science*, 116(1–2), pp. 1–6. Available at: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532020000100022.

¹⁷ StatsSA (2018) *General Household Survey 2018*. Available at: <http://www.statssa.gov.za/publications/P0318/P03182018.pdf>.

¹⁸ DEA (2018a) *South Africa State of Waste Report: First draft report*. Available at: <http://sawic.environment.gov.za/documents/8635.pdf>.

¹⁹ DEA (2020) *SAWIC Statistics*. Available at: <http://sawic.environment.gov.za/?menu=15>.

²⁰ Doka, G. (2021) New model for waste-specific and regionalised wastewater disposal and treatment.

with the resultant wastewater sludge sent to landfill for final disposal, while unsanitary landfill sites are modelled with no leachate collection or treatment. All landfill sites are modelled without landfill gas capture.

The datasets used to model UBC disposal are summarised in Table 13. Waste is assumed to be transported an average distance of 50 km to landfill.

Table 12: Key population weighted climatic value for landfill modelling

Climatic variable	Value
Evapotranspiration rate	331 mm/year
Precipitation	569 mm/year
Mean temperature	17.6 °C

Table 13: Inventory inputs and outputs for UBC disposal

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Transportation	Transport, freight, lorry, diesel, unspecified / South Africa	Assumed 50 km
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
Sanitary landfill	Waste metal, sanitary landfill / South Africa (Doka/ecoinvent model)	SA waste statistics: 42.4%
Unsanitary landfill	Waste metal, unsanitary landfill / South Africa (Doka/ecoinvent model)	SA waste statistics: 53.9%
Open dumping	Waste metal, open dump / South Africa (Doka/ecoinvent model)	SA waste statistics: 3.2%
Open burning	Waste steel, treatment of waste steel, municipal incineration / Global	SA waste statistics: 0.5%

3.3.2 UBC to can recycling (closed loop)

UBC closed loop recycling involves the collection, pre-processing (e.g. sorting and baling) and transportation of the UBCs to aluminium can body & end sheet producer, where they are melted in the recycling furnace and serve as feedstock for new sheet production. The recycled UBCs directly offset virgin aluminium that would otherwise be needed to produce the new aluminium sheeting.

As the LCA uses system expansion to avoid end-of-life allocation, the recycling system is credited for avoided virgin aluminium. This modelling is based on the primary data from the company that supplied data for the aluminium sheet production.

The datasets used to model UBC to can closed loop recycling are summarised in Table 14.

Table 14: Inventory inputs for UBC to can closed loop recycling

Avoided products	ecoinvent dataset applied / Geography	Data source
Aluminium can & body sheet with 0% UBC feedstock	Aluminium sheet production	See Table 9 above Same modelling as for standard aluminium sheeting, with UBC feedstock replaced with virgin aluminium ingots from South32

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Aluminium can & body sheet with 100% UBC feedstock	Aluminium sheet production	See Table 9 above Same modelling as for standard aluminium sheeting, with all aluminium feedstock replaced with post-consumer UBC feedstock (scaled up to account for additional losses of 3% as per ecoinvent cast ingot from UBC dataset)

3.3.3 UBC scrap export

Historically, UBCs have been collected, pre-processed (e.g. sorting and baling) and exported to international recyclers. This has dropped off substantially in recent years due to scrap-metal export bans, the implementation of a price preference system (PPS) by ITAC and growing demand for local UBC scrap, meaning that exported tonnages have dropped from over 70,000 tonnes in 2019 to 39,000 tonnes in 2023 and 17,500 tonnes in 2024 (MFA study year). Although scrap exports have dropped off because of these measures, the market has responded by processing the collected scrap to ingots prior to exporting (as seen in Section 3.3.4). The processed ingots are not subject to bans or PPS and can therefore be exported freely. Current trade statistics, as shown in Figure 5, suggest that exports of ingots have directly replace scrap export and that the volume of secondary aluminium exported from South Africa has remained relatively constant.

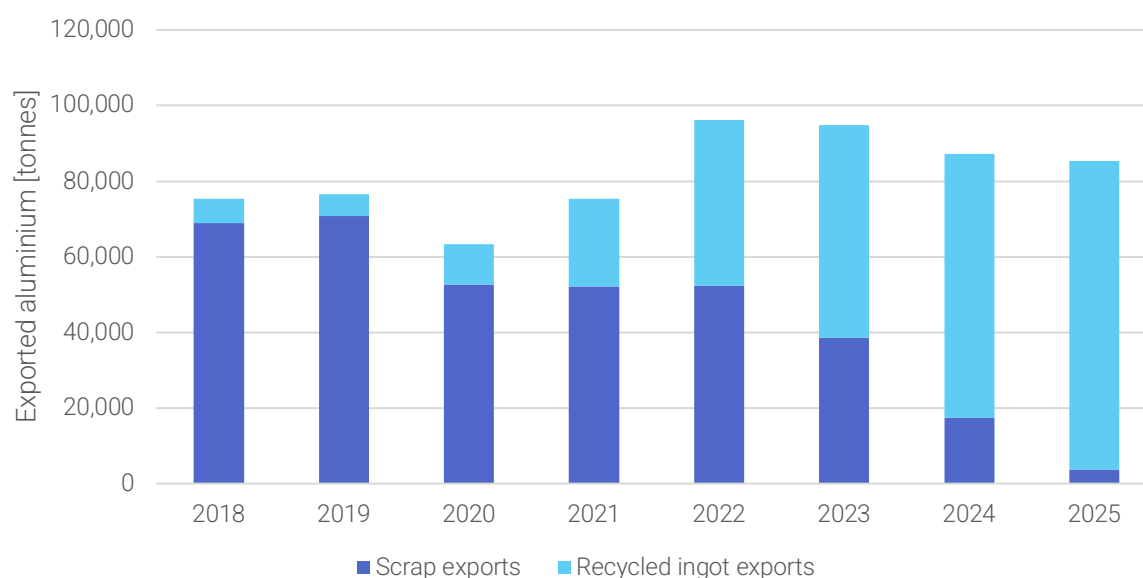


Figure 5: Aluminium scrap and recycled ingot exports from South Africa²¹

Overseas, where recycling occurs, the final use of the aluminium is unknown, e.g. UBC to can (closed loop recycling), UBC to engine blocks etc. (open loop recycling). The export recycling process is therefore modelled as aluminium ingot casting. In line with system expansion, the recycling system is credited for avoided “market-average” aluminium ingot use. This “market-average” aluminium ingot has a recycled content of 30%, as recycling is a fundamental

²¹ Based on SARS trade statistics. Scrap exports are export code 7602, recycled ingot exports are 7601-20. It was confirmed that 7601-10 exports align with exports of virgin ingots from Hillside aluminium.

component of the global aluminium industry (i.e. the recycling system is credited for 70% avoided virgin aluminium and 30% recycled scrap).

The datasets used to model aluminium scrap export and ingot casting are summarised in Table 15. The datasets used to model UBC scrap export recycling are summarised in Table 16.

Table 15: Inventory inputs and outputs for aluminium scrap recycling to ingots in export markets

Resources	ecoinvent dataset applied / Geography	Data source
Water	Water, unspecified natural origin / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Infrastructure for scrap pre-processing	Waste preparation facility / Global	ecoinvent UBC processing dataset
Export transport	Transport, freight, lorry, diesel, unspecified / Global Transport, freight, sea, container ship, heavy fuel oil / Global Transport, freight, lorry, diesel, unspecified / South Africa	Transportation distances based on export locations of five most important export partners
Hardener	Silicon, metallurgical grade / Global Copper, cathode / Global Zinc / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Industrial gases	Argon, liquid / Global Chlorine, liquid / Global Nitrogen, liquid / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Processing chemicals	Hydrated lime, packed / Global Hydrochloric acid, without water, in 30% solution state / Global Sodium chloride, powder / Global Sodium hydroxide, without water, in 50% solution state / Global Sulphuric acid / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Lubricants	Light fuel oil / Global Lubricating oil / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Consumables	Cryolite / Global Refractory, fireclay, packed / Global	ecoinvent cast alloy from post-consumer aluminium dataset
Recycling infrastructure	Aluminium casting facility / Global Aluminium melting furnace / Global	ecoinvent cast alloy from post-consumer aluminium dataset
Inputs: Electricity & heat	ecoinvent dataset applied / Geography	Data source
Diesel for scrap pre-processing	Diesel, burned in building machine / South Africa (adapted)	ecoinvent UBC processing dataset
Electricity for pre-processing	Electricity, medium voltage / South Africa	ecoinvent UBC processing dataset
Electricity for recycling	Electricity, medium voltage / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Natural gas	Heat, district or industrial, natural gas, market for / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Other heat	Heat, district or industrial, other than natural gas, market for / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset

Emissions to air	ecoinvent dataset applied / Geography	Data source
Casting emissions	Ammonia Chlorine Hydrocarbons, chlorinated Hydrochloric acid Hydrogen fluoride Hydrogen sulfide Particulates, < 2.5 um Particulates, > 10 um Particulates, > 2.5 um, and < 10um Phosphorus Lead Nitrogen dioxide NMVOC, non-methane volatile organic compounds Sulphur dioxide Water/m3	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
Pre-processing waste	Municipal solid waste / South Africa (Doka modelling)	ecoinvent UBC processing dataset
Filter dust	Filter dust from Al electrolysis / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Hazardous waste	Hazardous waste, for underground deposit / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Wastewater	Wastewater, average / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset

Table 16: Inventory inputs for UBC scrap export recycling

Avoided products	ecoinvent dataset applied / Geography	Data source
Avoided aluminium ingot	Aluminium, cast alloy / Global Aluminium, wrought alloy / Global	Split based on world market (69% wrought alloy, 31% cast alloy)
Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Aluminium cast alloy from exported scrap	<i>Aluminium export scrap ingot</i>	<i>See Table 15 above</i>

3.3.4 UBC scrap processed in South Africa (open loop)

Remaining UBC scrap, which amounts to 45% of collected scrap (39% of total UBCs), is collected, pre-processed (e.g. sorted and baled) and recycled by South African recyclers. The final use of this recycled aluminium is unknown, with the cast ingots potentially being used locally for a range of applications (e.g. motor vehicle production, electricity transmission infrastructure, household furniture), whilst currently largely exported. Alongside these long-duration aluminium products, some recycled aluminium is processed into pellets, used as deoxidisers in steel mills, and powders, used in a range of applications, including the production of water treatment chemicals, chemical reagents and military explosives. Besides the production of deoxidiser pellets, it is assumed that the recycling of aluminium to

these other applications is limited in South Africa²². These alternative uses of aluminium are similar to deoxidiser pellet production in that the aluminium is converted into a feedstock that is consumed during further processing/use. Thus, the LCA considers local ingot casting and the production of deoxidiser pellets, with the deoxidiser pellets serving as proxy for all “consumptive” aluminium uses (i.e. uses where recycled aluminium is used as a feedstock and the aluminium is lost from the value chain).

In line with system expansion, the recycled ingot system is credited for avoided “market-average” aluminium ingot use. This “market-average” aluminium ingot has a recycled content of 30%, as recycling is a fundamental component of the global aluminium industry (i.e. the recycling system is credited for 70% avoided virgin aluminium and 30% recycled scrap). In the case of deoxidiser pellet production, the recycling system is credited for avoided ferrosilicon use, as ferrosilicon is a powerful deoxidiser similar to aluminium²³. The datasets used to model aluminium scrap collection and ingot/pellet casting are summarised in Table 17. The resulting datasets used to model UBC scrap ingot recycling and UBC scrap recycling to deoxidiser pellets are summarised in Table 18 and Table 19 respectively.

Table 17: Inventory inputs and outputs for aluminium scrap recycling to ingots or pellets in South Africa

Resources	ecoinvent dataset applied / Geography	Data source
Water	Water, unspecified natural origin / South Africa	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Infrastructure for scrap pre-processing	Waste preparation facility / Global	ecoinvent UBC processing dataset
Inbound transport	Transport, freight, lorry, diesel, unspecified / South Africa	ecoinvent UBC processing dataset
Hardener	Silicon, metallurgical grade / Global Copper, cathode / Global Zinc / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Industrial gases	Argon, liquid / Global Chlorine, liquid / Global Nitrogen, liquid / South Africa	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Processing chemicals	Hydrated lime, packed / Global Hydrochloric acid, without water, in 30% solution state / Global Sodium chloride, powder / Global Sodium hydroxide, without water, in 50% solution state / Global Sulphuric acid / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Lubricants	Light fuel oil / Global Lubricating oil / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Consumables	Cryolite / Global Refractory, fireclay, packed / Global	ecoinvent cast alloy from post-consumer aluminium dataset
Recycling infrastructure	Aluminium casting facility / Global Aluminium melting furnace / Global	ecoinvent cast alloy from post-consumer aluminium dataset

²² Water treatment chemical production may be an exception but typically these are produced from bauxite, not aluminium. Therefore it is believed unlikely that large volumes are utilised for these processes.

²³ Various metals can be utilised as deoxidisers in steel production, with ferromanganese utilised for moderate deoxidation and ferrosilicon used when more powerful deoxidation is required. Aluminium is one of the most powerful deoxidisers available and therefore ferrosilicon is considered the most appropriate equivalent avoided product – See Kreft (2024) Aluminium DeOx (DeOx Al): What It Is and How It's Used. Available at: <https://www.metals-hub.com/en/blog/whats-deox-al-used-for/>

Inputs: Electricity & heat	ecoinvent dataset applied / Geography	Data source
Diesel for scrap pre-processing	Diesel, burned in building machine / South Africa (adapted)	ecoinvent UBC processing dataset
Electricity for pre-processing	Electricity, medium voltage / South Africa	ecoinvent UBC processing dataset
Electricity for recycling	Electricity, medium voltage / South Africa	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Natural gas	Heat, district or industrial, natural gas, market for / South Africa (adapted)	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset <i>As per NCPC report, Zimalco is the largest recycler of scrap aluminium to ingots in South Africa and their energy is supplied from natural gas²⁴</i>
Emissions to air	ecoinvent dataset applied / Geography	Data source
Casting emissions	Ammonia Chlorine Hydrocarbons, chlorinated Hydrochloric acid Hydrogen fluoride Hydrogen sulfide Particulates, < 2.5 µm Particulates, > 10 µm Particulates, > 2.5 µm, and < 10µm Phosphorus Lead Nitrogen dioxide / South Africa NMVOC, non-methane volatile organic compounds / South Africa Sulphur dioxide / South Africa Water/m3 / South Africa	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Outputs: Waste treatment	ecoinvent dataset applied / Geography	Data source
Pre-processing waste	Municipal solid waste / South Africa (Doka/ecoinvent model)	ecoinvent UBC processing dataset
Filter dust	Filter dust from Al electrolysis / Global	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Hazardous waste	Hazardous waste, sanitary landfill / South Africa (Doka/ecoinvent model)	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset
Wastewater	Wastewater, average / South Africa (adapted)	Average of North American aluminium can LCA & ecoinvent cast alloy from post-consumer aluminium dataset

Table 18: Inventory inputs for UBC scrap ingot recycling in South Africa

Avoided products	ecoinvent dataset applied / Geography	Data source
Avoided aluminium ingot	Aluminium, cast alloy / Global Aluminium, wrought alloy / Global	Split based on world market (69% wrought alloy, 31% cast alloy)

²⁴ NCPC (2015) Industrial Energy Efficiency Project in South Africa: Zimalco. Available at: <https://www.industrialefficiency.co.za/wp-content/uploads/2021/05/Zimalco-EnMS-full-Case-Study.pdf>

Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Aluminium cast alloy from scrap	<i>Aluminium scrap ingot</i>	<i>See Table 17 above</i>

Table 19: Inventory inputs for UBC scrap to deoxidiser pellet recycling

Avoided products	ecoinvent dataset applied / Geography	Data source
Avoided deoxidiser	Ferrosilicon / Global	Alternative powerful steel deoxidiser
Inputs: Materials & fuels	ecoinvent dataset applied / Geography	Data source
Aluminium cast alloy from scrap	<i>Aluminium scrap ingot</i>	<i>See Table 17 above</i>

3.4 Employment indicator

The employment-potential of aluminium can production and UBC recycling is modelled using job-intensity factors derived from publicly-available company data (e.g. websites, annual reports etc.) and relevant research reports. The exception is can converters, for which company data was provided for the study. Nonetheless job-intensity factors are also calculated from publicly available data for both local and international can converters for sensitivity.

Data sources and the job-intensity factors derived are given in Table 20. In many cases, the factors are highly variable. The factors employed in the results shown in Figure 18 and Figure 19 is given in bold in Table 20, with the effect of the variability in the factors on the results discussed in Section 4.2.6.

Table 20: Derivation and sources of job- and livelihood- intensity factors for can production and UBC collection and recycling

Value chain stage	Job / livelihood intensity ²⁵		Production		Jobs / livelihoods	Comment	Sources
Primary aluminium production	3.2	jobs-year/ 1,000 tonne (2025)	719,000	tonnes /year	2,300	Direct employees and contractors at South32 Hillside	Company-reported (https://www.engineeringnews.co.za/article/south32-eskom-jointly-exploring-post-2031-power-options-for-hillside-aluminium-2025-12-19)
Semi-fabricated aluminium production	11.1	jobs-year/ 1,000 tonne (2025)	166,528	tonnes /year	1,852	Hulamin. Integrated facility (recycling processing and sheet production). Total group employees.	Company-reported (https://www.hulamin.com/sites/default/files/downloads/Hulamin%20Sustainability%20Report%20for%20the%20year%20ended%2031%20December%202025.pdf)
	39.2	jobs-year/ 1,000 tonne (2022)	30,600	tonnes /year	1,200	Wispeco. Vertically integrated operation, including remelting and casting, extrusion, surface finishing & distribution.	Research report: TIPS (2022) South Africa's aluminium value chain and climate change compatibility (https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/4532-south-africa-s-aluminium-value-chain-and-climate-change-compatibility)
Value chain up to semi-fabricated product	11.5	jobs-year/ 1,000 tonne (2017)	720,000 primary, 289,000 semi-fabricated	tonnes /year	11,600	Older industry-body value providing useful confirmation of company values	Research report: DST & CSIR (2017) The South African Aluminium Industry Roadmap (https://www.afsa.org.za/Downloads/South-African-Aluminium-Industry-Roadmap-2017.pdf)

²⁵ The unit of jobs-year per unit of production is used instead of Full Time Equivalent-year or FTE-year because this more precise unit could not be confirmed from the data sources used in the study (which most often just mentioned employees or jobs).

Value chain stage	Job / livelihood intensity ²⁵		Production		Jobs / livelihoods	Comment	Sources
Beverage can production	16	jobs-year/ 1,000 tonne (2025)				Permanent workers only, can-conversion sites only	Data supplied for study
	23	jobs-year/ 1,000 tonne (2025)				Permanent and temporary workers, including site producing closures	Data supplied for study
	0.24	jobs-year/ million cans (2025)				Permanent workers only, can-conversion sites only	Data supplied for study
	0.26	jobs-year/ million cans (2025)				Permanent and temporary workers, can-conversion sites only	Data supplied for study
	0.35	jobs-year/ million cans (2025)				Permanent and temporary workers, including site producing closures	Data supplied for study
	0.08	jobs-year/ million cans (2015)	1,200	million cans/ year	100	Gayatri: initial production capacity of 1.2 billion two-piece aluminium beverage cans/year; 80–100 employees in the first phase	Project report (https://www.engineeringnews.co.za/article/beverage-can-plant-project-south-africa-2015-10-23)
	0.13	jobs-year/ million cans (2019)	800	million cans/ year	100	Gayatri manufacturing facility (applying effective capacity estimate instead of nameplate capacity)	Industry article (https://www.engineeringnews.co.za/article/nampak-retains-focus-on-reducing-debt-cutting-costs-2019-11-27)
	0.33	jobs-year/ million cans (2023)	3,000	million cans/ year	1,000	GZI group (Nigeria and South Africa) total employees and production capacity (rounded figures)	Industry article (https://www.engineeringnews.co.za/article/affirma-exits-pure-play-beverage-can-gzi-investment-after-ten-years-2023-11-30)
	0.16	jobs-year/ million cans (2011)	750	million cans/ year	120	Nampak Angolata (direct jobs and nameplate capacity)	Company news article (https://www.nampak.com/investors/media-release/2011/nampak-bevcan-opens-160-million-beverage-can)
	0.08	jobs-year/ million cans (2022)	1,000	million cans/ year	80	Crown (Italy), company reporting on new plant	Company report (https://quarterlytics.com/company/crown_cck/annual-report-2022)
	0.17	jobs-year/ million cans (2023)	1,000	million cans/ year	170	Ball Kettering (UK), company report on new plant	Company news article (https://www.biopineoe.com/balls-new-uk-beverage-can-plant-nominated-for-business-awards)
Import and Export	0.06	jobs-year/ 1,000 tonne (2023/24)	156,900	1,000 tonnes/ year	8,991	Average factor for Transnet port terminal handling (imports, exports and transshipments)	Transnet (https://qaweb.site.transnet.net/getFile.ashx?id=3874); Tonnes per year includes bulk cargo, break-bulk cargo, TEU containers and vehicles (average weights applied)
Port handling	0.13	jobs-year/ 1,000 tonne (2023/24)	3,000	1,000 tonnes/ year	398	Average factor break-bulk/general-cargo handling (Durban Ro-Ro/Maydon Wharf cluster)	Transnet (https://www.transnetportterminals.net/Ports/Pages/Durban_MaydonWharf.aspx?)
Road freight	0.14	jobs-year/ 1,000 tonne (2023)	862,523	1,000 tonnes/ year	125,009	Employment from Stats SA, and road-freight payload from Department of Transport	Government statistics (https://www.statssa.gov.za/publications/Report-71-02-01/Report-71-02-012023.pdf); https://www.transport.gov.za/wp-content/uploads/2023/02/Transport-Statistics-Bulletin-2023.pdf)

Value chain stage	Job / livelihood intensity ²⁵		Production		Jobs / livelihoods	Comment	Sources
Landfill disposal	0.10	jobs-year/ 1,000 tonne (2024)				Formal jobs	Research report: Eunomia & UWC (2024) Researching a Deposit Return System for South Africa - Costs and Benefits of Implementing a Mandatory Deposit Return System for Beverage Packaging. <i>October 2024</i> (https://globaldrsplatform.net/wp-content/uploads/2025/05/Study-Report-on-Researching-a-Deposit-Return-System-for-South-Africa.pdf)
UBC informal collection	3109	livelihoods-year/ 1,000 tonne	40733	tonnes /year	126,629	300,000 to 400,000 informal waste pickers, with share attributed to aluminium collection (86%) from aluminium share of total payments for metals to informal reclaimers in SA via buy-back centres in 2017, with UBCs estimated to make up 42% of aluminium	Informal collectors estimate from Recycling Association of South Africa (RASA) (https://www.thedtic.gov.za/wp-content/uploads/RASA.pdf); Estimate of aluminium share from research report: Godfrey L. Quantifying economic activity in the informal recycling sector in South Africa. S Afr J Sci.2021;117(9/10), Art. #8921. https://doi.org/10.17159/sajs.2021/8921 ; Estimate of share of UBCs in total aluminium sold from MetPac-SA data (personal communication); Mass of UBCs collected from MetPac-SA's 2024 MFA.
Informal collectors	3553	livelihoods-year/ 1,000 tonne	40733	tonnes /year	144,719	Upper bound: 400,000 informal waste pickers, with share attributed to aluminium collection (86%) from aluminium share of total payments for metals to informal reclaimers via buy-back centres in 2017	
	438	livelihoods-year/ 1,000 tonne	40733	tonnes /year	17,852	Lower bound: 300,000 informal waste pickers, with share attributed to aluminium collection (14%) from aluminium share of total payments for all materials to informal reclaimers via buy-back centres in 2017	

Value chain stage	Job / livelihood intensity ²⁵		Production		Jobs / livelihoods	Comment	Sources
Scrap metal dealers / buy-back centres	37	jobs-year/1,000 tonne (2024)	40733	tonnes /year	1,492	3,552 registered scrap metal dealers in 2024, each employing an average of 20 employees (RASA). Share attributed to aluminium (5%) based on mass share of aluminium to total metal throughput at dealers	Number of scrap-metal dealers in SA from Recycling Association of South Africa (RASA) quoting data from SAPS (https://www.thedtic.gov.za/wp-content/uploads/RASA.pdf); Estimate of aluminium and UBC shares from MetPac-SA data (personal communication); Mass of UBCs collected from MetPac-SA's 2024 MFA.
	631	jobs-year/1,000 tonne (2024)	40733	tonnes /year	25,702	3,552 registered scrap metal dealers in 2024, each employing an average of 20 employees (RASA). Share attributed to aluminium (86%) estimated from the value share of aluminium in payments for metals to informal reclaimers via buy-back centres in 2017	Number of scrap-metal dealers in SA from Recycling Association of South Africa (RASA) quoting data from SAPS (https://www.thedtic.gov.za/wp-content/uploads/RASA.pdf); Estimate of aluminium share from research report: Godfrey L. Quantifying economic activity in the informal recycling sector in South Africa. S Afr J Sci.2021;117(9/10), Art. #8921. https://doi.org/10.17159/sajs.2021/8921 ; Estimate of UBC shares from MetPac-SA data (personal communication); Mass of UBCs collected from MetPac-SA's 2024 MFA.
UBC formal collection Drivers & loaders	1.5	jobs-year/1,000 tonne (2017)	1,037	tonnes /year	1.6	Estimate of jobs created for collection of separated recyclables at source, with share of UBCs in collected recyclables estimated from share of UBCs in packaging placed on the SA market (7%)	Research report: CSIR (2018) Decision Support Tool for Implementing Municipal Waste Separation at Source: Incorporating Socio-Economic and Environmental Impacts. Kerbside collection scenario (https://wasteroadmap.co.za/wp-content/uploads/2020/03/2_CSIR_Final_Technical_Report.pdf)
Sorting at clean MRF	0.2	jobs-year/1,000 tonne (2017)	1,037	tonnes /year	0.2	Estimate of jobs created for sorting of recyclables collected at source, with share of UBCs in collected recyclables estimated from share of UBCs in packaging placed on the SA market (7%)	Research report: CSIR (2018) Decision Support Tool for Implementing Municipal Waste Separation at Source: Incorporating Socio-Economic and Environmental Impacts. Kerbside collection scenario (https://wasteroadmap.co.za/wp-content/uploads/2020/03/2_CSIR_Final_Technical_Report.pdf)
Sorting at dirty MRF	0.1	jobs-year/1,000 tonne (2017)	5,879	tonnes /year	0.6	Estimate of jobs created for sorting of recyclables collected with MSW, with share of UBCs in MSW (5%) from small-sample, direct-sorting study covering three small towns in 2024	MRF jobs from research report: CSIR (2018) Decision Support Tool for Implementing Municipal Waste Separation at Source: Incorporating Socio-Economic and Environmental Impacts. Kerbside collection scenario (https://wasteroadmap.co.za/wp-content/uploads/2020/03/2_CSIR_Final_Technical_Report.pdf); Share of UBCs in MSW from DFFE-supported Integrated Waste Management Plan for the Central Karoo (https://www.skdm.co.za/sites/default/files/documents/dffe-ckdm-iwmp-draft-report-2024-02.pdf)

Value chain stage	Job / livelihood intensity ²⁵		Production		Jobs / livelihoods	Comment	Sources
Recycling (smelting)	30.8	jobs-year/ 1,000 tonne (2017)				Direct jobs in re-processing of non-ferrous packaging	Research report: CSIR 2017 Table 4, quoted in CSIR (2018) Decision Support Tool for Implementing Municipal Waste Separation at Source: Incorporating Socio-Economic and Environmental Impacts (https://wasteroadmap.co.za/wp-content/uploads/2020/03/2_CSIR_Fin aL_Technical_report.pdf)
	11	jobs-year/ 1,000 tonne (2024)	1,000	tonnes /year	11	Average jobs per 1,000 tonnes UBCs throughput	Eunomia & UWC, <i>Researching a Deposit Return System for South Africa - Costs and Benefits of Implementing a Mandatory Deposit Return System for Beverage Packaging</i> , October 2024 (https://globaldrplatform.net/wp-content/uploads/2025/05/Study-Report-on-Researching-a-Deposit-Return-System-for-South-Africa.pdf)
	12.5	jobs-year/ 1,000 tonne	12,000	tonnes /year	150	Zimalco "capacity in excess of 12,000 ton per year and employing more than 150 people"	Company website (https://zimalco.co.za/)
	17.8	jobs-year/ 1,000 tonne (2022)	9,000	tonnes /year	160	Zimalco, in TIPS research report, with actual production estimated at 30% of smelting capacity	Research report: Trade and Industrial Policy Strategies (TIPS) (2022) <i>South Africa's aluminium value chain and climate change compatibility</i> (https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/4532-south-africa-s-aluminium-value-chain-and-climate-change-compatibility)
	7.5	jobs-year/ 1,000 tonne	6,000	tonnes /year	45	GeT Alloys "current manufacturing capacity is about 500 tons per month of Aluminium alloy ingots"	Company website (https://getalloys.co.za ; naacam.org.za/member/get-alloys-pty-ltd/); number of employees from National Assoc. of Automotive Component & Allied Manufacturers (NAACAM) listing (https://naacam.org.za/member/get-alloys-pty-ltd/)

4 INTERPRETATION

The following section provides the life cycle results, it begins with a presentation of the environmental impacts of producing an aluminium beverage can, including an analysis of the effect of can size on impacts. Following this, the results for five end-of-life management options (disposal, UBC closed loop recycling, scrap export and subsequent overseas ingot recycling, ingot recycling in SA, and deoxidiser pellet production in SA), as well as the current SA "market average", are presented. Discussion is provided with respect to what is making up the environmental impacts of the systems, and how these environmental "hotspots" can be mitigated.

4.1 Aluminium beverage can production

Potential damage to human health and ecosystem quality from the production and end-of-life management of 330 ml aluminium beverage cans on the South African market is presented in Figure 6 (per 1,000 cans or 330 L). The life cycle results include upstream aluminium production (virgin and recycled), aluminium sheet production in South Africa, imported aluminium sheet production and beverage can converting. These results show that over four-fifths (83%) of potential environmental damages relate to climate change (greenhouse gas emissions), with particulate matter emissions (7%) and water availability (water consumption – 2%) being the second and third largest sources of potential damages respectively.

The results also indicate that the **virgin aluminium** produced by South32 at their Hillside operations **is the source of more than half (53%) of potential environmental damages**. Energy consumption, within South Africa, for aluminium sheet rolling and can converting are the next largest source of potential damages, accounting for 12% of human health and ecosystem quality damage each.

It is interesting to note that production of aluminium sheet (virgin & recycled aluminium, as well as sheet rolling inputs & energy) in South Africa is responsible for over two-thirds (69%) of potential damages, while imported aluminium sheet is responsible for a further 11%. South African produced sheets provide 91% of the sheeting used by South African can converters, meaning that the impacts per mass of sheet are lower for South African sheeting than imported sheet. This is linked to the South African sheeting having a higher recycled content than global average aluminium. Together the aluminium sheet inputs for beverage can production therefore account for 80% of the potential environment damages of producing a beverage can.

Imported aluminium cans account for 7% of potential environmental damages, which is in line with them accounting for 7% of the cans placed on the South African market. This suggests that the environmental impacts per can are similar for both locally produced and imported cans.

Greater detail on the impacts per midpoint category and damages per area of protection (AoP) are provided in the sections below.

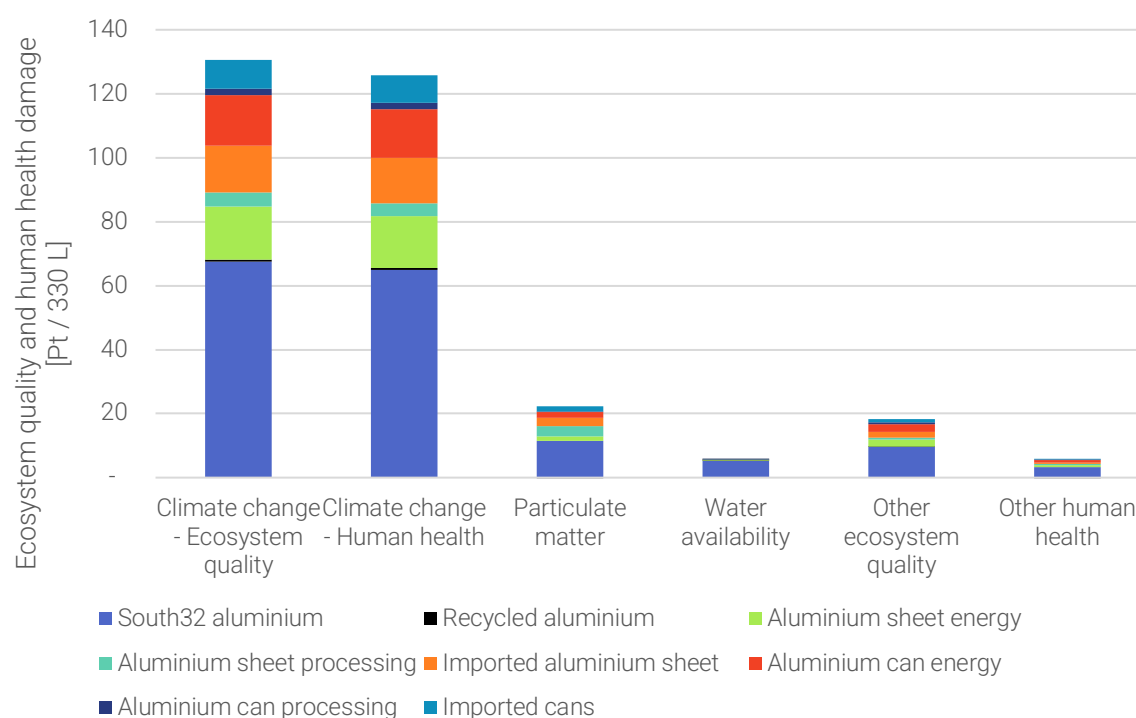


Figure 6: Aggregated potential human health and ecosystem quality damage of 330 ml aluminium beverage cans on the South African market (per 330 L), broken down by life cycle stage and damage category²⁶

²⁶ Unit of Points. The IMPACT World+ methodology includes weighting and normalization for human health and ecosystem impacts, which take these impacts down to a single, common unit (points) and allow for summation of impacts into a "single-score". This single score aggregates all human health and ecosystem quality impact indicators, including climate change, water scarcity, eutrophication, acidification etc. "Other ecosystem quality" and "Other human health" aggregate all contributing impact indicators to that AoP other than climate change. As discussed in Section 2.2.7, this does not include non-renewable resource depletion impacts

The effect of can sizes on the aggregated life cycle potential human health and ecosystem quality damage is presented in Figure 7. South African manufacturing data shows that the total mass of cans required to contain 300 litres of beverage varies from 16.3 kg for 200 ml cans down to 10.0 kg for 500 ml cans. Manufacturing data available did not allow for the differentiation of materials or energy inputs required for different can sizes (i.e. data was mass allocated) and therefore impact results are directly proportional to the can mass required. Therefore, as expected, the **larger can sizes show lower impacts** per 330 litres packaged, as a result of inherent material efficiency of the larger cans. All further results presented below are for 330 ml cans, as this was selected as the focus of the LCA study; however, it should be remembered that impacts will be lower for larger can sizes and higher for smaller cans.

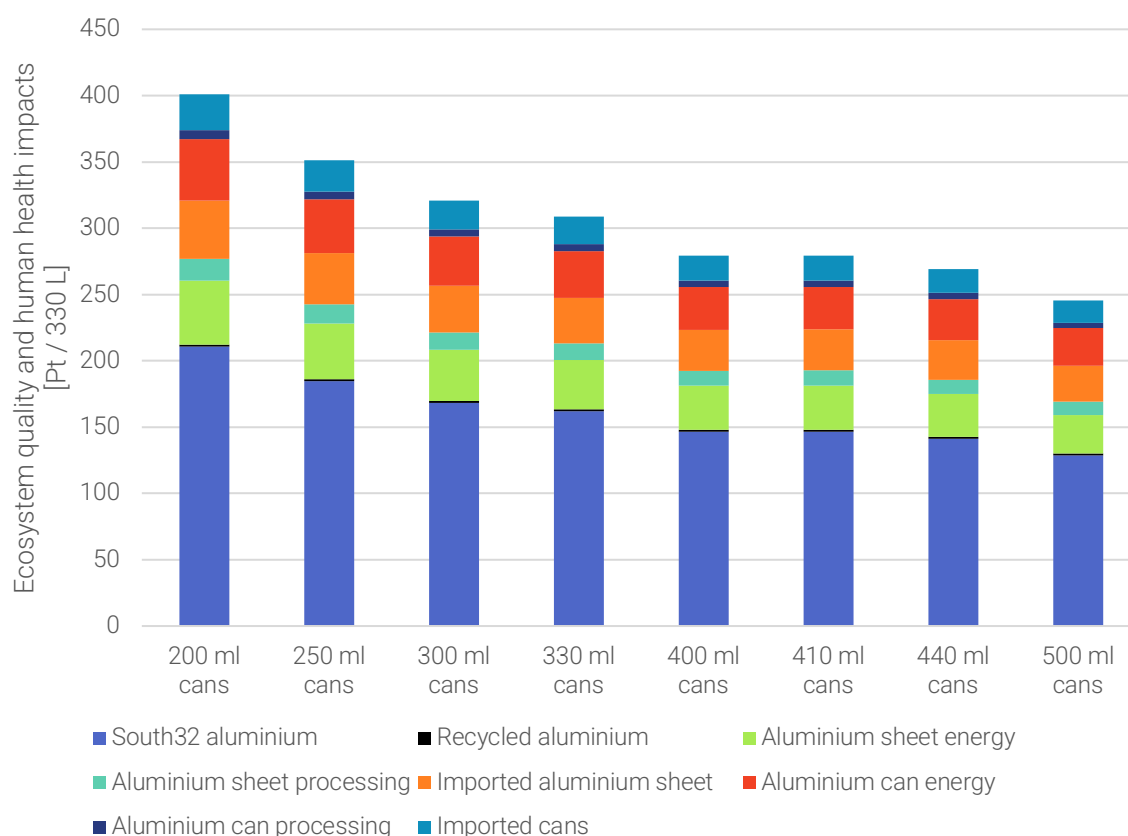


Figure 7: Aggregated potential life cycle human health and ecosystem quality damage of aluminium beverage cans on the South African market, broken down by life cycle stage and can size

4.1.1 Climate change

Climate change impact for South African produced and imported 330 ml cans, as well as the market average (93% SA produced; 7% imported), are shown in Figure 8.

Virgin aluminium is the key source of greenhouse gas emissions, accounting for two-thirds (66%) of emissions for SA-produced cans and 83% of impacts for imported cans. This results in virgin aluminium accounting for more than two-thirds (67%) of GHG emissions for the cans placed on the South African market. This dominance is directly linked to the amount of electricity required for virgin aluminium production from bauxite, as well as the release of fluorinated gases from the smelting process.

Energy consumption within South Africa for **aluminium sheet rolling and can converting** is responsible for over a quarter (27%) of GHG emissions, while for international cans this share drops to 13%. The variance here is due to the carbon intensity of South Africa's energy mix, resulting from the coal-based nature of South Africa's grid electricity and the use of coal-derived fuels (especially Sasol methane-rich gas, produced from coal syngas). Overall, the energy used for sheet production and can converting is a source of more than a quarter (26%) of climate change impact for cans placed on the South African market.

Remaining climate change impact is from lesser processing inputs (industrial gases, lubricants, paints etc.) and recycled aluminium feedstock. The importance of the use of recycled aluminium feedstocks in aluminium can production to reduce the climate change impact may be noted here, with recycled aluminium accounting for around a third of inputs for SA produced aluminium sheeting but correspondingly only being a source of 1% of the GHG emissions. Overall, the carbon intensity of virgin aluminium from South32 is close to 50X greater than recycled aluminium used as feedstock in South Africa, linked to the significant reduction in electricity required and avoidance of fluorinated gas releases.

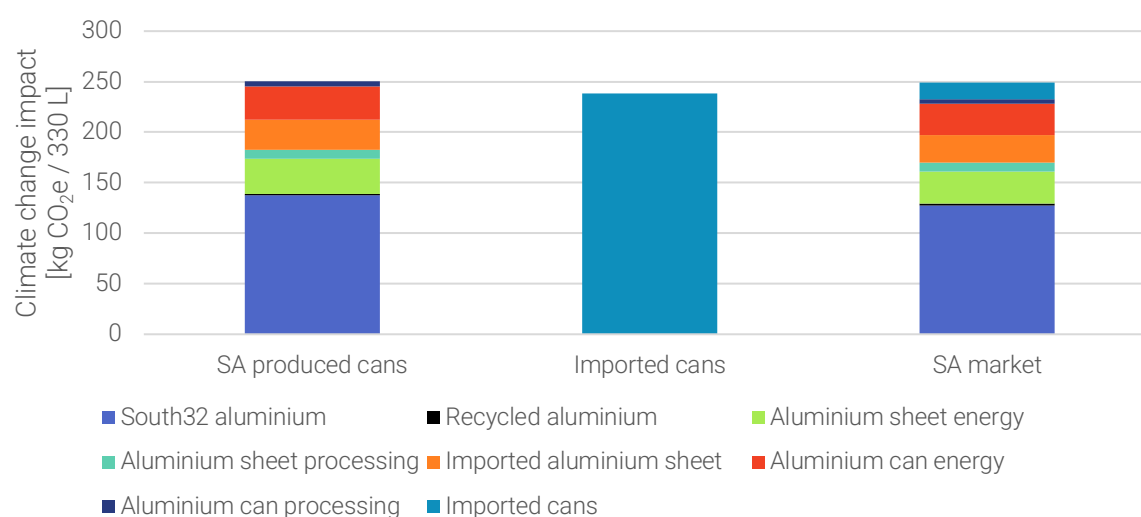


Figure 8: Short-term climate change impacts, broken down by life cycle stage, for South African produced and imported 330 ml cans, as well as the South African market average

4.1.2 Human health

Potential human health damage for South African produced and imported 330 ml cans, as well as the market average are shown in Figure 9.

As with climate change impact, **virgin aluminium is the key source of impacts**, accounting for two-thirds (68%) of human health-related impacts for SA produced cans and 84% of impacts for imported cans. This results in virgin aluminium accounting for 69% of potential human health damage for the cans placed on the South African market. Again, this dominance is directly linked to the electricity required for virgin aluminium production from bauxite and the resulting human health-related impacts from electricity generation, including greenhouse gas and particulate matter emissions to air and the water use in coal-fired power stations.

Energy consumption within South Africa for aluminium sheet rolling and can converting is also responsible for a quarter (24%) of human health-related impacts, while for international cans this share drops to 13%. The variance here is due to the fossil fuel dependence of South Africa's energy mix, including the coal-based nature of South

Africa's grid electricity and the use of coal-derived fuels (especially Sasol methane-rich gas, produced from coal syngas). Overall, the energy used for sheet production and can converting is a source of just under a quarter (23%) of human health-related impacts for cans placed on the South African market.

As for climate change impact, remaining human health-related impacts are from lesser processing inputs (industrial gases, lubricants, paints etc.) and recycled aluminium feedstock. The importance of recycled aluminium feedstocks is again apparent, with recycled aluminium having an impact almost 70X lower than South African-produced virgin aluminium.

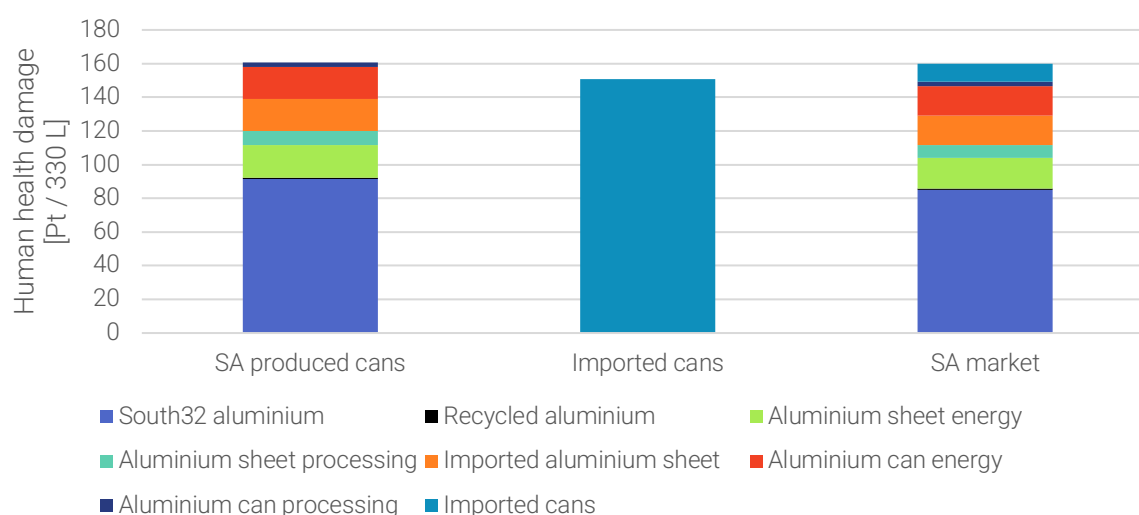


Figure 9: Potential human health damage, broken down by life cycle stage, for South African produced and imported 330 ml cans, as well as the South African market average

4.1.3 Ecosystem quality

Potential damage to ecosystem quality for South African produced and imported 330 ml cans, as well as the market average are shown in Figure 10.

As with climate change and human health-related impacts, **virgin aluminium is the key source of ecosystem-related impacts**, accounting for two-thirds (66%) of impacts for SA produced cans and 84% of impacts for imported cans. This results in virgin aluminium accounting for more than two-thirds (68%) of ecosystem-related impacts for the cans placed on the South African market. This dominance is again tied with the electricity required for virgin aluminium production, including the greenhouse gas, nitrogen-compound and sulphur-compound emissions to air and the water use in coal-fired power stations.

Energy consumption within South Africa for aluminium sheet rolling and can converting is again responsible for more than a quarter (27%) of ecosystem-related impacts, while for international cans this share drops to 13%. The variance here is due to the fossil fuel dependence of South Africa's energy mix, including the coal-based nature of South Africa's grid electricity and the use of coal-derived fuels (especially Sasol methane-rich gas, produced from coal syngas). Overall, the energy used for sheet production and can converting is a source of just over a quarter (25%) of ecosystem-related impacts for cans placed on the South African market.

As seen above, remaining ecosystem-related impacts arise from lesser processing inputs (industrial gases, lubricants, paints etc.) and recycled aluminium feedstock. The importance of recycled aluminium feedstocks is again apparent,

with recycled aluminium having ecosystem-related impacts over 70X lower than South African-produced virgin aluminium.

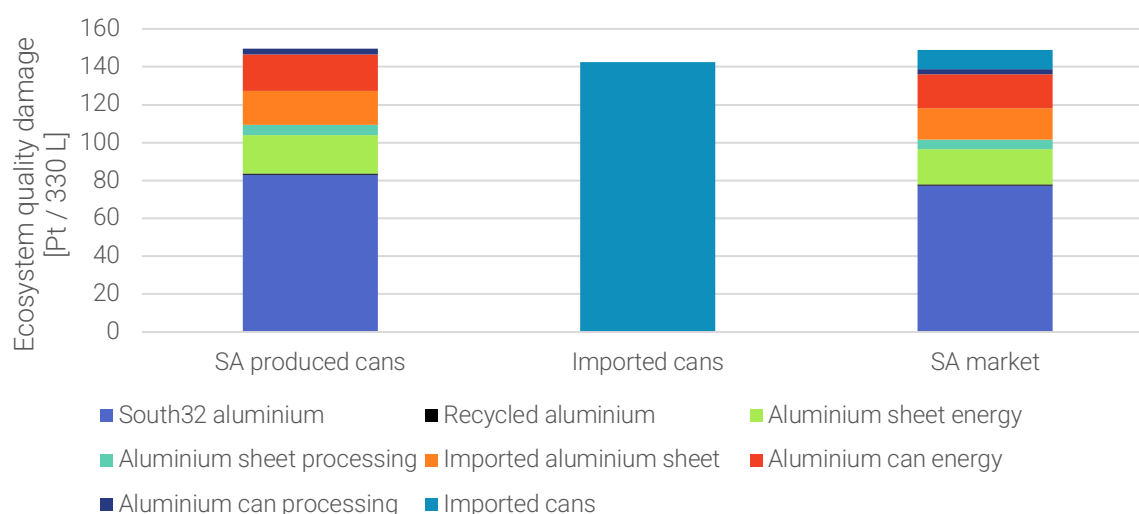


Figure 10: Potential Ecosystem Quality damage, broken down by life cycle stage, for South African produced and imported 330 ml cans, as well as the South African market average

4.1.4 Resources services loss

Socio-economic impacts resulting from the consumption of non-renewable resources, represented by adaptation to resources services loss (i.e. the additional energy required to extract resources due to their lower prevalence and overall dissipation as resources are consumed globally), for South African produced and imported 330 ml cans, as well as the market average, are shown in Figure 11.

As seen with environmental impacts, **virgin aluminium is once again the key source of non-renewable resources services loss**, being responsible for 69% and 84% of impacts for SA-produced and imported cans respectively. For the overall market, virgin aluminium accounts for 70% of non-renewable resources services loss, arising from a combination of the electricity required for bauxite smelting (49% of virgin aluminium impacts) and bauxite extraction (41% of virgin aluminium impacts).

Similar to environmental impacts, energy consumption within South Africa for aluminium sheet rolling and can converting is again responsible for a quarter (25%) of non-renewable resources services loss, while for international cans this share drops to 11%. The variance here is due to the fossil fuel dependence of South Africa's energy mix, including the coal-based nature of South Africa's grid electricity and the use of coal-derived fuels (especially Sasol methane-rich gas, produced from coal syngas), both of which require extraction and depletion of coal reserves. Overall, the energy used for sheet production and can converting is a source of just under a quarter (24%) of non-renewable resources services loss for cans placed on the South African market.

Remaining resources services loss is from lesser processing inputs (industrial gases, lubricants, paints etc.) and recycled aluminium feedstock. The importance of recycled aluminium feedstocks is again apparent, with recycled aluminium having an impact over 100X lower than South African-produced virgin aluminium.

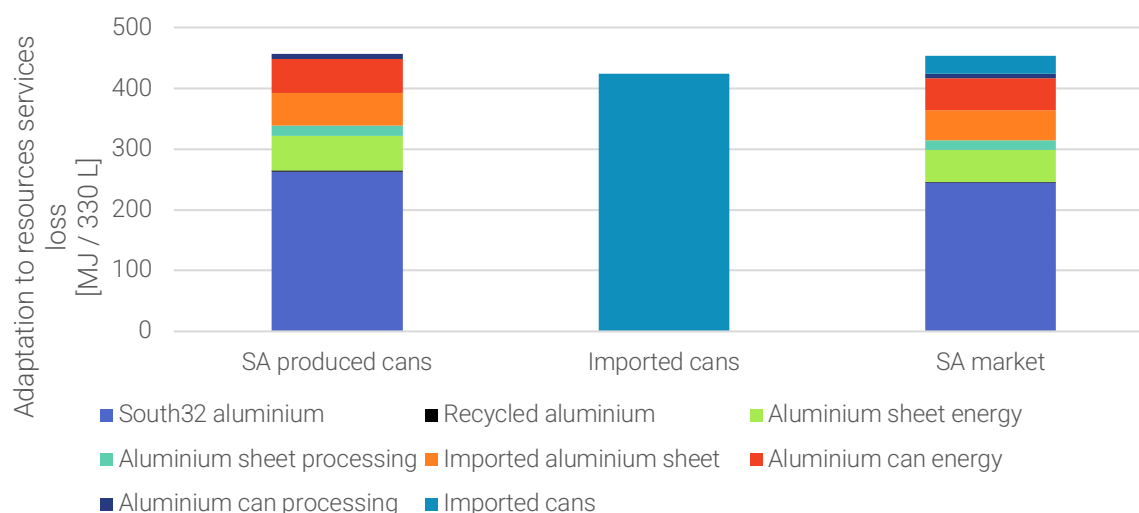


Figure 11: Resources services loss broken down by life cycle stage, for South African produced and imported 330 ml cans, as well as the South African market average

4.2 Used beverage can end-of-life

The aggregated potential life cycle human health and ecosystem quality damage from the end-of-life treatment of 330 ml aluminium beverage cans on the South African market is presented in Figure 12. These damages only represent the end-of-life treatment processes and do not include can production, as presented in Section 4.1.

The market average is according to the known flows of UBCs in South Africa, as summarised in Figure 4. For the share of UBCs known to be collected for recycling but with the processing route unknown, half is assumed to be processed into ingots and the other half used to produce deoxidiser pellets (since no data are available to inform this split). Thus, the SA market average is modelled as follows:

- UBC recycling (UBC to can) - 18%
- SA ingot recycling (UBC to ingot, cast in SA) - 20%
- International ingot recycling (UBC to ingot, cast overseas) - 31%
- Deoxidiser reuse (UBC to deoxidiser pellet) - 20%
- Disposal (UBC to MSW) - 12%

From Figure 12, besides disposal, which has relatively small environmental impacts as aluminium is inert in landfills and dumps, all of the other **end-of-life options have negative potential damage to human health and ecosystem quality**. This is a consequence of system expansion applied in the LCA modelling, meaning that the beverage can's system boundary includes the production of the primary materials displaced when secondary materials are produced (i.e. the burdens associated with producing the **avoided materials**, such as virgin aluminium, are subtracted from the burdens arising from the recycling processes producing the secondary materials). In all the recycling cases, the impacts associated with producing the avoided material (aluminium, ferrosilicon etc.) are higher than the impacts associated with producing the secondary material from UBC scrap, resulting in net-negative life cycle environmental impacts

For the three options where the production of aluminium and virgin aluminium is avoided, more than four-fifths (80%) of avoided environmental impacts are related to avoided greenhouse gas (climate change) emissions. This is a result

of the energy intensive nature of virgin aluminium production. In the case of deoxidiser pellet production, two-thirds (60%) of avoided environmental impacts are linked to greenhouse gas emissions and a third (36%) link to avoided particulate matter emissions.

Greater detail on the environmental impacts per midpoint category and damages to AoPs are provided in the sections below.

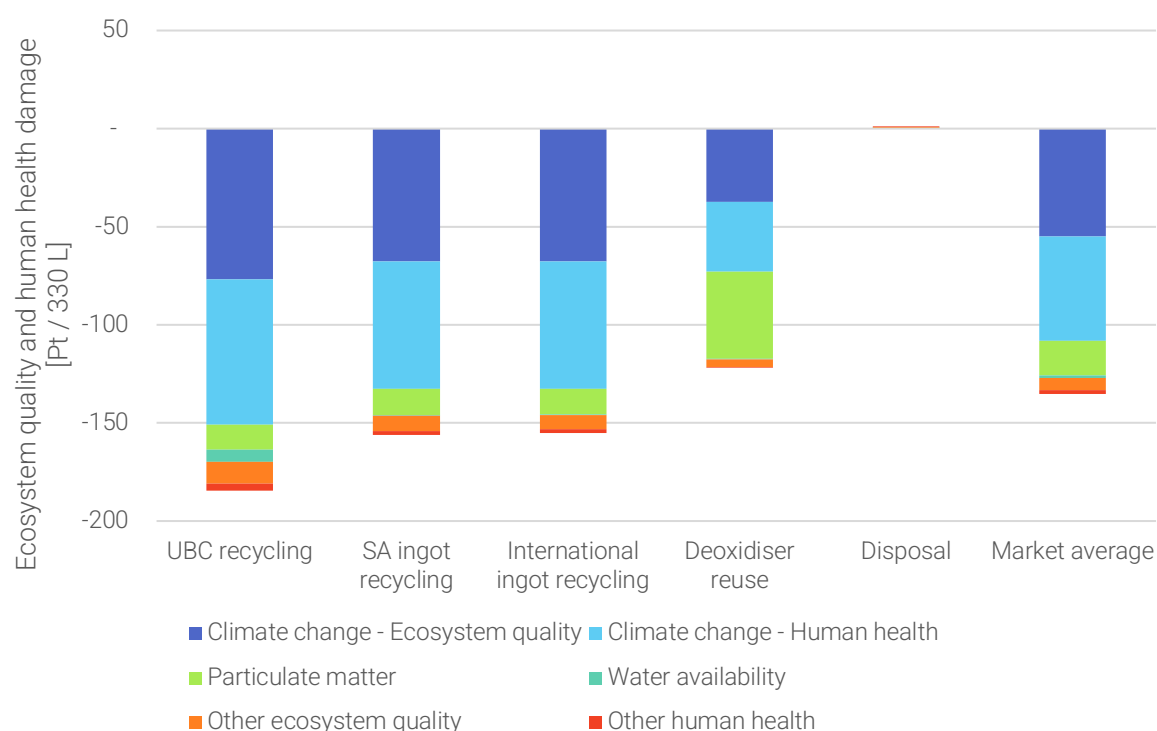


Figure 12: Potential damage to human health and ecosystem quality resulting from the end-of-life treatment of 330 ml aluminium beverage cans on the South African market, broken down by treatment type and damage category

4.2.1 Climate change

Climate change impact for the five end-of-life management options, as well as the market average, are shown in Figure 13. The light green columns represent the climate change impact of can production, as presented above in Section 4.1, that equates to 249 kg CO₂e per thousand 330 ml cans holding 330 litres of packaged beverage.

Disposal impacts are low, at only 1 kg CO₂e per 330 litres, due to the inert nature of aluminium in landfills and open dumps. As such, the majority of emissions from disposal are from fuel and energy used for waste transportation and landfill operations (compacting etc.). The disposal of UBCs does not recover any of their value and therefore no avoided impacts offset the overall system impacts.

Climate change impact relating to collection, pre-processing (e.g. sorting and baling) and recycle processing range from 12 kg CO₂e (international ingot recycling) to 42 kg CO₂e (UBC closed-loop recycling), following the relative amount of energy required for collection, pre-processing and, to a much larger degree, recycle processing. It is for this reason that international ingot recycling has impacts marginally lower than ingot recycling in South Africa, as the extra fuel and energy required for export is more than offset by the lower climate change impact of international grid

electricity (i.e. international grid electricity is less carbon-intensive than South African electricity, which is still heavily coal-based).

For all of the recovery options, avoided climate change impact (represented by the dark blue columns in Figure 13) from avoided production of aluminium/ferrosilicon materials more than offsets the GHG emissions from the recycling process. As such, **all recovery options reduce the overall system GHG emissions**, with UBC to can **closed-loop recycling resulting in the lowest net emissions**. The significant offsets are due to the carbon-intensive nature of aluminium and ferrosilicon production and the fact that aluminium recycling does not result in material quality loss, as seen in most other recycling systems (i.e. recycled aluminium can directly substitute for virgin material).

UBC to can closed-loop recycling directly offsets South32 virgin aluminium, while ingot casting is assumed to offset generic aluminium ingots. As recycling is an inherent part of the aluminium value chain, these ingots contain on average a 30% recycled content (i.e. recycling only offsets 70% virgin material), explaining the lower avoided climate change impact seen between the UBC recycling and ingot recycling systems. Ferrosilicon production, although an impactful process, has less than half the climate change impact of virgin aluminium, as ferro-production does not have the energy demands of aluminium smelting. This explains why avoided climate change impact in the deoxidiser pellet reuse case is less than half that of UBC to can closed-loop recycling.

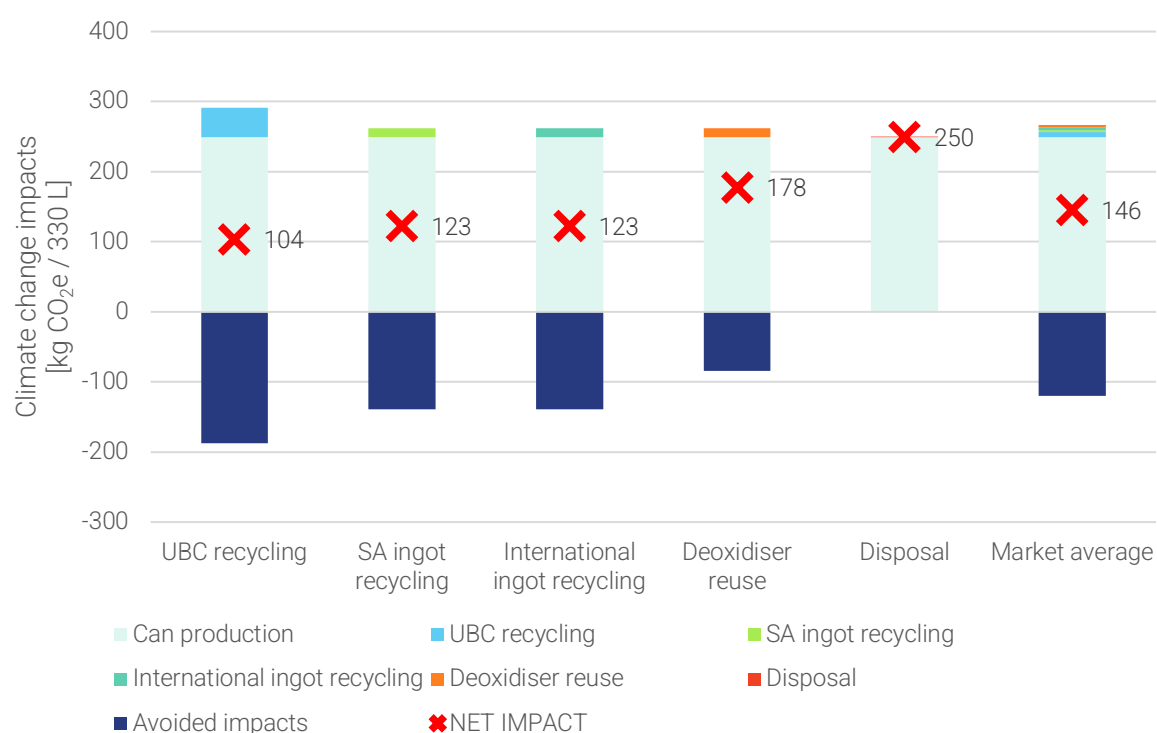


Figure 13: Short-term climate change impact, broken down by life cycle stage, for South African 330 ml UBC end-of-life options (Crosses (X) represent the net climate change impact of each end-of-life option)

4.2.2 Human health

Human health-related impacts for the five end-of-life management options, as well as the market average, are shown in Figure 14. Human health-related impacts of can production (represented by the light green columns in Figure 14, and discussed in Section 4.1) equate to 160 damage-points (0.0022 DALY) per thousand 330 ml cans holding 330 litres of packaged beverage.

Disposal human health-related impacts are relatively low, at only 0.4 Pt per 330 litres, due to the inert nature of aluminium in landfills and open dumps; however, no value is recovered from the system. As with climate change impact, human health-related impacts arise primarily from the energy used for transport and operations.

Human health-related impacts relating to collection, pre-processing (e.g. sorting and baling) and recycle processing range from 8 Pt (SA ingot recycling) to 26 Pt (UBC closed loop recycling), following the relative amounts of energy required for collection, pre-processing and, to a much larger degree, recycle processing. Unlike climate change impact, international ingot recycling (i.e. UBC scrap export and recycling internationally) has higher human health-related impacts than ingot recycling occurring in South Africa. This reversal in trend from climate change impact is primarily related to the human health-related impacts of international shipping, especially particulate matter emissions.

For all of the recovery options, avoided human health-related impacts (represented by the dark blue columns Figure 14) from avoided production of aluminium/ferrosilicon materials more than offset the human health-related impacts from the recycling process. As such, **all recovery options reduce the overall system human health-related impacts**, with UBC to can **closed-loop recycling resulting in the lowest net impacts**. The significant offsets are due to the impactful nature (especially in terms of energy consumption and resulting GHG, particulate and VOC emissions) of aluminium and ferrosilicon production and the fact that aluminium recycling does not result in material quality loss, as seen in most other recycling systems.

Like the climate change impact, the variance in offsets is linked to UBC to can closed-loop recycling offsetting South African-produced virgin aluminium, ingot recycling offsetting “average” aluminium (30% recycled content) and deoxidiser pellet production offsetting lower-impact ferrosilicon production.

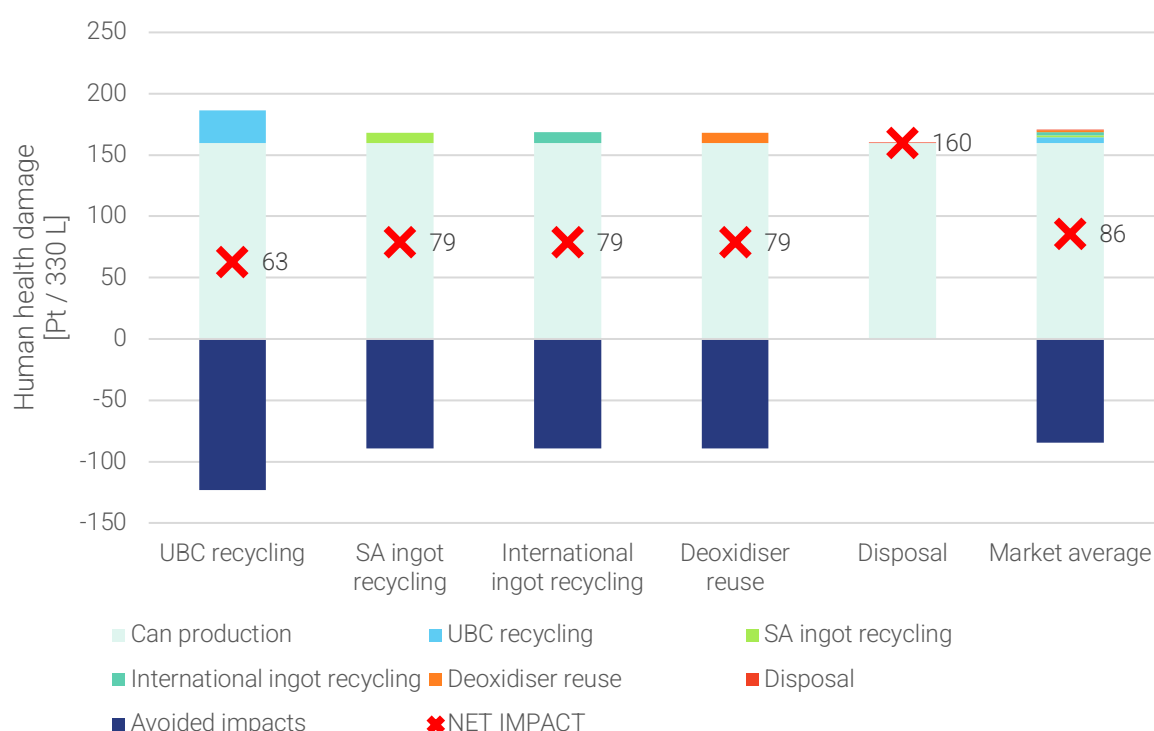


Figure 14: Potential human health damage, broken down by life cycle stage, for South African 330 ml UBC end-of-life options (Crosses (X) represent the net health-related impacts of each end-of-life option)

4.2.3 Ecosystem quality

Potential damage to ecosystem quality for the five end-of-life management options, as well as the market average, are shown in Figure 15. Ecosystem-related impacts of can production (the light green columns Figure 15, as discussed in Section 4.1) equate to 150 damage-points (1,064 PDF.m².year) per thousand 330 ml cans holding 330 litres of packaged beverage.

Ecosystem-related impacts arising from disposal are relatively low, at only 0.7 Pt per 330 litres, due to the inert nature of aluminium in landfills and open dumps; however, no value is recovered from the system. As with climate change and human health-related impacts, ecosystem-related impacts from UBC disposal to MSW arise primarily from the energy used for transport and operations.

Ecosystem-related impacts relating to collection, pre-processing (e.g. sorting and baling) and recycle processing range from 8 Pt (SA ingot recycling) to 25 Pt (UBC closed-loop recycling), following the relative amount of energy required for collection, pre-processing and, to a much larger degree, recycle processing. As seen with human health-related impacts, international ingot recycling (i.e. UBC scrap export, with remelting and casting occurring overseas) has greater ecosystem-related impacts than ingot recycling occurring in South Africa. This difference in trend from climate change impact is primarily related to the ecosystem-related impacts arising from international shipping, especially emissions of nitrogen- and sulphur-compounds.

For all the recovery options, avoided ecosystem-related impacts (represented by the dark blue columns in Figure 15) from avoided production of aluminium/ferrosilicon materials more than offset the ecosystem-related impacts from the recycling process. As such, **all recovery options reduce the overall potential damage to ecosystem quality**, with UBC to can **closed-loop recycling resulting in the lowest net damage**. The significant offsets are due to the impactful nature (especially in terms of energy consumption and resulting GHG, nitrogen-compound and sulphur-compound emissions) of aluminium and ferrosilicon production and the fact that aluminium recycling does not result in material quality loss, as commonly seen in other recycling systems.

Like the other environmental impacts, the variance in offsets is linked to UBC to can closed-loop recycling offsetting virgin aluminium produced in South Africa, ingot recycling offsetting “average” aluminium (30% recycled content) and deoxidiser pellet production offsetting lower-impact ferrosilicon production.

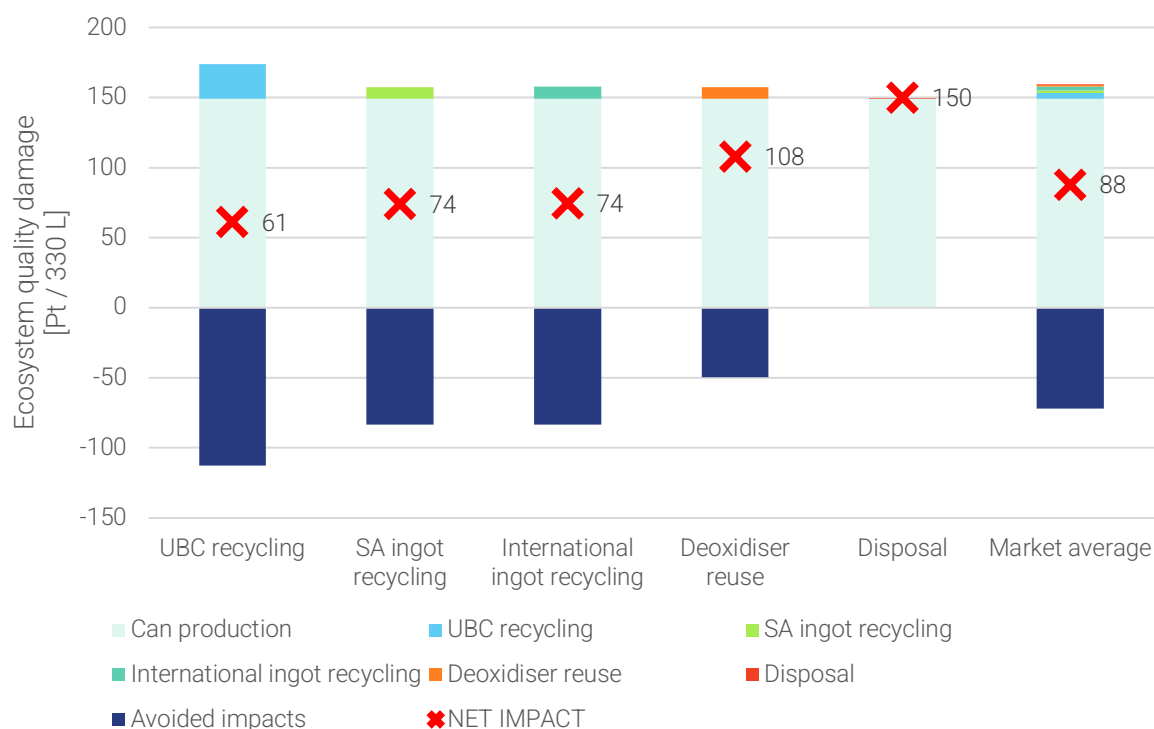


Figure 15: Potential damage to ecosystem quality, broken down by life cycle stage, for South African 330 ml UBC end-of-life options (Crosses (X) represent the net damage of each end-of-life option)

4.2.4 Resources services loss

Socio-economic impacts resulting from the consumption of non-renewable resources, represented by adaptation to resources services loss (i.e. the additional energy required to extract resources due to their lower prevalence and overall dissipation as resources are consumed globally), for the five end-of-life management options, as well as the market average, are shown in Figure 16. The adaptation to resources services loss of can production (the light green columns in Figure 16, as discussed in Section 4.1) equate to 454 MJ per thousand 330 ml cans holding 330 litres of packaged beverage.

Resources services loss from the disposal of UBCs to MSW are relatively low, at only 8 MJ per 330 litres, which is linked to the relatively low input of energy required for UBC collection and landfilling/dumping. However, since this system does not recover any value from the UBCs, no avoided impacts form part of the system.

Resources services loss from the collection, pre-processing (e.g. sorting and baling) and recycle processing range from 25 MJ (international ingot recycling) to 70 MJ (UBC closed-loop recycling), according to the relative amount of energy required for collection, pre-processing and, to a much larger degree, recycle processing. As with climate change impact, international ingot recycling has resources services loss marginally lower than ingot recycling occurring in South Africa, as the extra fuel and energy required for export is offset by the less non-renewable resource intensity of international grid electricity (i.e. international grid electricity uses less fossil fuel inputs than South African electricity, which is still heavily coal-based).

For all the recovery options, avoided use of non-renewable resources (represented by the dark blue columns Figure 16) from avoided production of aluminium/ferrosilicon materials more than offset the non-renewable resource use in the recycling process. As such, **all recovery options reduce the overall system consumption of non-renewable**

resources, with UBC to can closed-loop recycling resulting in the lowest net non-renewable resources services loss. The significant offsets are due to the impactful nature (especially in terms of fossil energy consumption and bauxite/iron ore mineral inputs) of aluminium and ferrosilicon production.

Like the environmental impacts, the variance in offsets is linked to UBC to can closed-loop recycling offsetting virgin South32 aluminium, ingot recycling offsetting “average” aluminium (30% recycled content) and deoxidiser pellet production offsetting lower impact ferrosilicon.

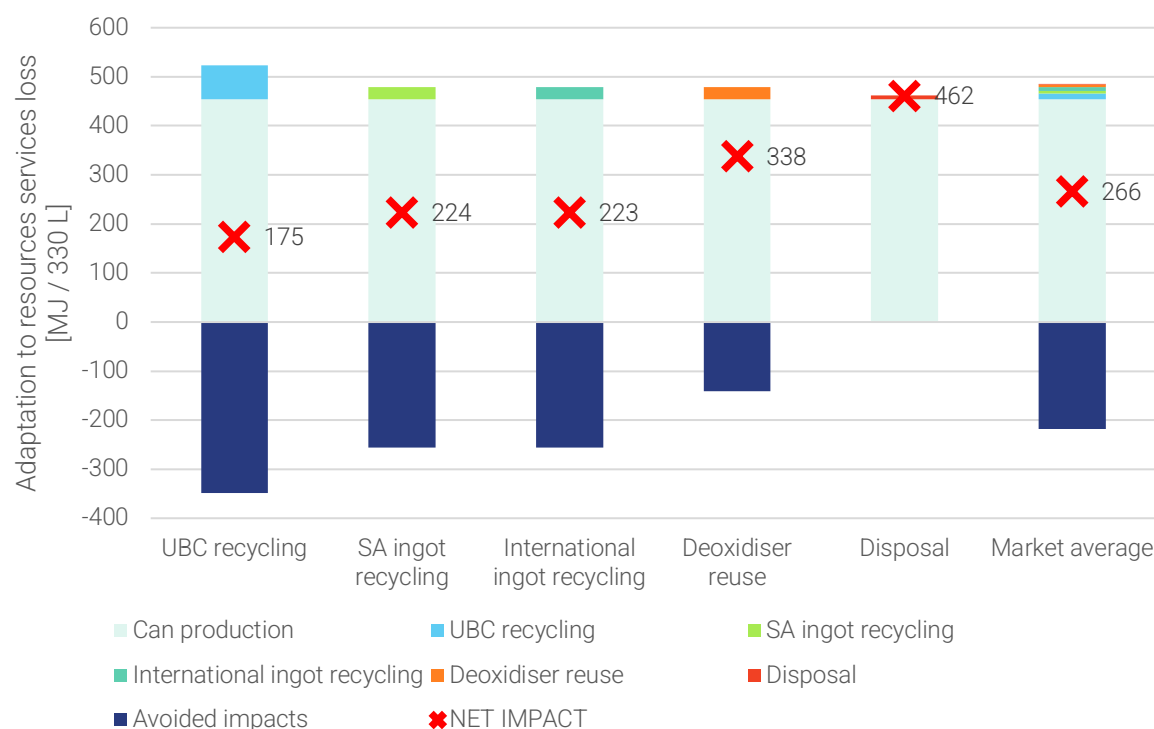


Figure 16: Adaptation to resources services loss, broken down by life cycle stage, for South African 330 ml UBC end-of-life options (Crosses (X) represent the net resources services loss of each end-of-life option)

4.2.5 Material Circularity Indicator (MCI)

The material circularity indicator (MCI) provides a quantitative assessment of the circularity of a system, varying from 0 for a linear system (i.e. virgin input, use and disposal) to 1 for a fully circular system (i.e. 100% recycled input, use and 100% recycling, with no material lost during recycling)²⁷. In this case, two values are presented:

- **Linear Flow Index (LFI):** Measure of the share of material flowing in a linear manner, this includes the fraction of feedstock from virgin sources and the fraction of material sent for disposal at end-of-life
 - *Lower values are preferred, as it indicates that material is not moving linearly through the system*
- **Material Circularity Indicator (MCI):** Measure of the circularity of system, this is calculated from the LFI.
 - *Higher values are preferred, as it indicates that the material is being used in a circular manner (upstream and downstream)*

²⁷ In practice an MCI of 1 is not achievable, as there will always be a degree of wastage from the recycling process.

The MCI results for five UBC disposal scenarios and the SA market average are presented in Figure 17. It should be noted that the upstream production of aluminium cans placed on the market, including those produced in South Africa from local and international sheeting and those imported, includes recycled content, as this is part of the standard aluminium value chain. This recycled content is estimated to be around a third for the cans on the South African market, meaning that all systems have an inherent circularity due to the upstream inclusion of this recycled material (i.e. this is why the disposal system has a linear flow index (LFI) of 0.83).

The three true recycling end-of-life options (UBC to can closed-loop recycling and ingot casting in South Africa or internationally) all have MCIs of around 0.6, as a result of the upstream inclusion of recycled content and the effectively recovery of aluminium through the recycling processing. These values vary slightly due to the recycling efficiency of each system, but the variance is negligible. On the other hand, the use of UBC scrap to produce deoxidiser pellets has the same MCI as disposal, since the aluminium is consumed (i.e. not used in a circular manner to produce new material) and the value of aluminium is permanently lost from the system²⁸. As such, the **three recycling options are clearly the most circular options for UBC end-of-life management**.

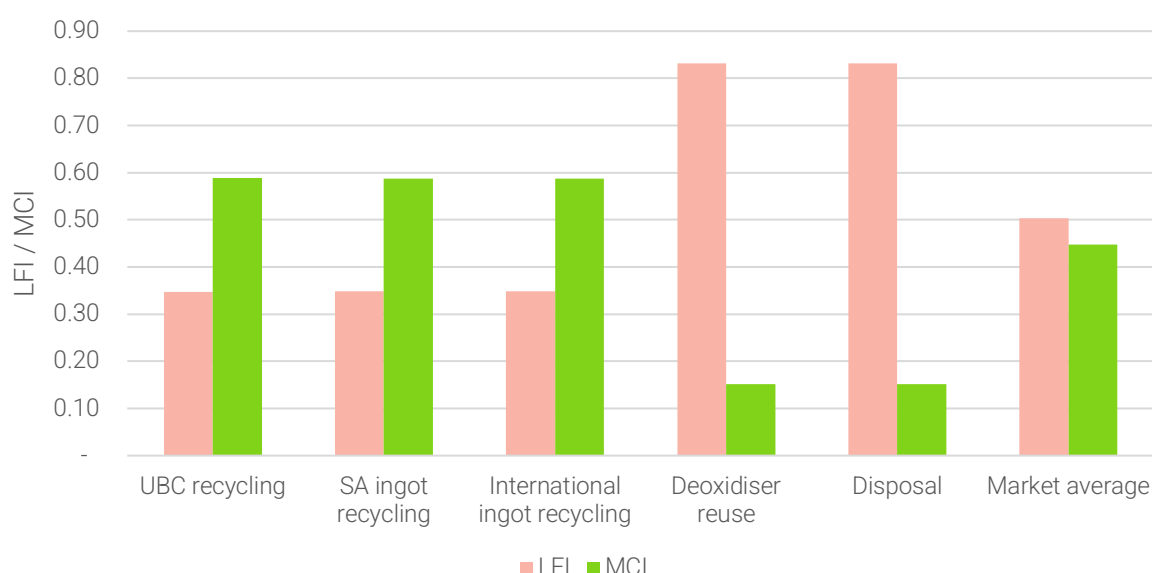


Figure 17: Material Circularity Indicator (MCI) per end-of-life option

4.2.6 Employment indicator

An indication of the socio-economic benefits of producing and recycling beverage cans in South Africa is provided through an estimation of employment (direct jobs) and livelihoods supported. The direct jobs associated with beverage cans placed on the South African market is shown in Figure 18 (cradle-to-gate).

The employment indicator is derived predominantly from highly variable publicly-available data and therefore should be taken as indicative. Nonetheless, it is clear that a **domestically produced can has substantially higher employment potential than an imported can** (noting that the employment indicator includes only jobs occurring in South Africa). Both producing the aluminium sheet and forming the cans are associated with a significant number of jobs.

²⁸ This is similar to energy-from-waste systems, which lose the material value from the system and therefore have low MCIs.

A can produced in South Africa from locally produced aluminium sheet, with the sheet's primary and secondary aluminium content produced in South Africa, has an employment potential of 0.42 jobs per million cans. The **greatest share is from can converting** (57%), followed by sheet production, whilst primary aluminium production contributes a relatively small share (6.6%). The low employment intensity of primary aluminium production (3.2 jobs-year/1,000 tonnes²⁹) accounts for the low employment contribution of primary aluminium despite locally-produced aluminium sheet having a 63% locally-produced virgin aluminium content.

Cans produced from imported sheet have a substantially lower employment potential (0.24 jobs per million cans), whilst fully imported cans have extremely low employment potential. Import (and export) employment potential is modelled from jobs associated with ports and handling (0.13 jobs-year/1,000 t), and also road freight (0.14 jobs-year/1,000 t)³⁰.

Aluminium sheet production is estimated to have a job intensity of 11 jobs-year/1,000 t and contribute 36% to the employment potential of a domestically produced beverage can. This is likely an over-statement when looked at from a can-production perspective as in Figure 18 (i.e. cradle-to-gate, and thus not including can end-of-life). This is because the publicly available company-data on which this number is derived is for the company group total, with the company also undertaking UBC recycling. The job-intensity factor of integrated secondary aluminium and sheet formation is more meaningfully employed when employment is looked at from a full life cycle perspective (as in Figure 19).

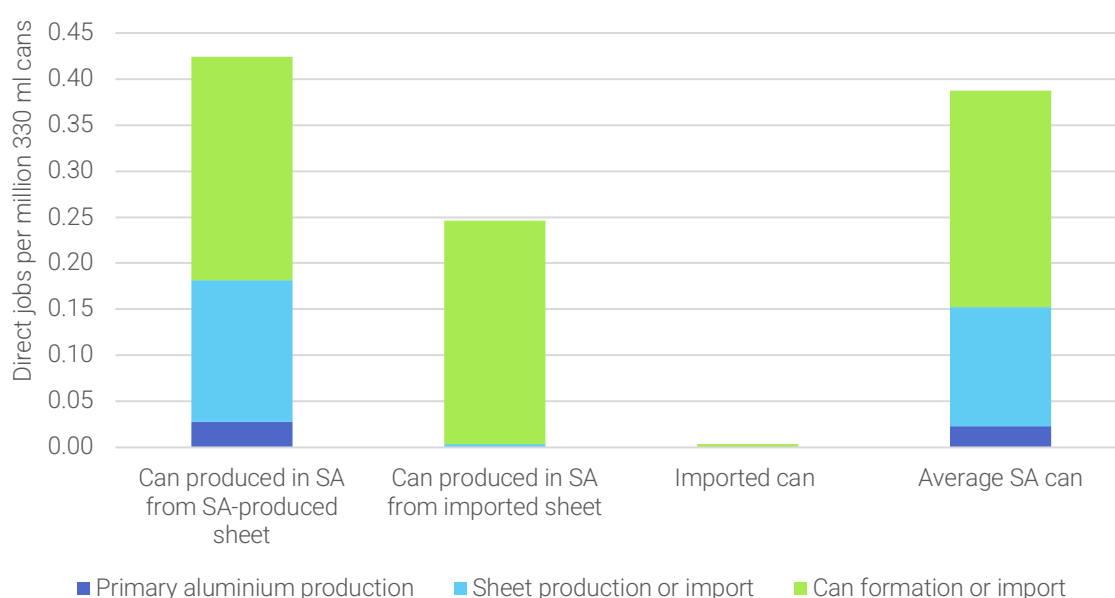


Figure 18: Direct jobs associated with beverage cans on the South African market.

Primary data was obtained only for the can conversion stage (16 jobs-year/1,000 tonnes if can conversion facilities only are considered, and 21 jobs-year/1,000 tonnes if the manufacture of closures is also considered). Including temporary workers further increases the job intensity factors to 17 and 23 jobs-year/1,000 tonnes, respectively, when excluding and including the manufacture of closures in addition to sites manufacturing cans. The industry-provided

²⁹ The unit of jobs-year per unit of production is used instead of Full Time Equivalent-year or FTE-year because this more precise unit could not be confirmed from the data sources used in the study (which most often just mentioned employees or jobs).

³⁰ Jobs associated with transport is not included for the other life cycle stages so including road freight for import/export is arguably over-stating import/export employment potential (however road freight is included as import/export is so extremely small relative to the other life cycle stages already).

data falls on the higher side of the range found in literature (see Table 20) (with values calculated from publicly available sources ranging from 0.08 – 0.35 jobs-year/million cans, with a value of 0.24 jobs-year/million cans applied in the results in Figure 18). The literature factors were found to be especially sensitive to whether installed capacity or actual production was used to calculate the employment intensity, with factors on the lower end from project data (can conversion capacity), whilst factors on the higher end were company-reported totals that also sometimes included wider employment (e.g. head office, logistics etc.). Nonetheless, even if a factor of 0.1 jobs-year/million cans is applied for can conversion, a domestically-produced can has an employment potential of 0.28 and 0.10 jobs per million 330 ml cans produced in SA (from domestically-produced and imported aluminium sheet, respectively), still 30 to 80 times higher than an imported can. Employing the range in can conversion, the **average can on the South African market is found to have an employment potential of between 0.25 and 0.50 jobs per million 330 ml cans.**

The direct jobs associated with beverage cans across their life cycle is shown in Figure 19 for various end-of-life scenarios. These are modelled as discreet hypothetical scenarios to map the decision space. That is, as if all cans follow the specific end-of-life route, when in reality there will always be a share of UBCs that do not reach recycling. Figure 19 includes only direct jobs. That is, it excludes informal collectors, both because the number of informal collector livelihoods that can be said to be supported by UBC collection is highly uncertain, and because the numbers are so high, including collector livelihoods obscures the trends in the other stages.

Employment potential associated with landfill disposal is very low (0.10 jobs-year/1000 tonne waste disposed), which is why the **non-recycled can has the lowest employment potential** across its life cycle. Formal collection (modelled as kerb-side collection in a dedicated truck and sorting at a clean MRF) is also estimated to have low employment potential (1.72 jobs-year/1,000 tonne waste collected³¹), and Figure 19 shows that **informal collection of UBCs has substantially higher employment-potential than formal collection.** This is a result of employment opportunities at scrap metal dealers (buy-back centres). South Africa had 3,552 scrap metal dealers registered with SAPS in 2024, with a reported average of 20 employees per company³². However, how many of these jobs should be allocated to UBCs is highly uncertain (see Figure 20, which compares mass-based allocation (6% of scrap metal dealer-jobs attributed to UBCs) with value-based allocation (36% of scrap metal dealer-jobs attributed to UBCs), noting that in both cases, data are extremely thin on the ground and rely on proxies, see Table 20 for details).

Job intensity of secondary processing of aluminium is found to be in the range of 7.5 to 17.8 jobs-year/1000 tonne (see Table 20), with a value of 11 jobs-year/1,000 tonne applied in Figure 19. The reason open-loop recycling (UBCs recycled to ingots or pellets) shows higher employment-potential than closed-loop recycling (UBCs back into UBCs) is because data on UBC-reprocessing into sheet is included in the sheet processing stage in Figure 19. Data are not available to split out sheet production from recycling processing, but industry data from two integrated aluminium processors indicated a range of 11 to 39 jobs-year/1000 tonne (the lower value is applied in Figure 19). Applying a higher literature value of 30 jobs-year/1,000 tonnes for re-processing non-ferrous packaging³³ gives a **total employment potential of 1.1 direct jobs per million cans across the beverage can life cycle for UBCs recycled back into UBCs.** Thus, with the relative variability in job intensity in integrated re-processing versus separate recycling facilities, it is not possible to say whether closed- or open-loop recycling has the higher employment potential. Nonetheless, it is clear that **re-processing in South Africa has higher local employment potential than exporting UBCs.**

³¹ Derived from case study data in CSIR 2018. https://wasteroadmap.co.za/wp-content/uploads/2020/03/2_CSIR_Final_Technical_report.pdf.

³² Recycling Association of South Africa (RASA) <https://www.thedtic.gov.za/wp-content/uploads/RASA.pdf>

³³ CSIR 2017 Table 4, quoted in CSIR (2018) Decision Support Tool for Implementing Municipal Waste Separation at Source: Incorporating Socio-Economic and Environmental Impacts (https://wasteroadmap.co.za/wp-content/uploads/2020/03/2_CSIR_Final_Technical_report.pdf)

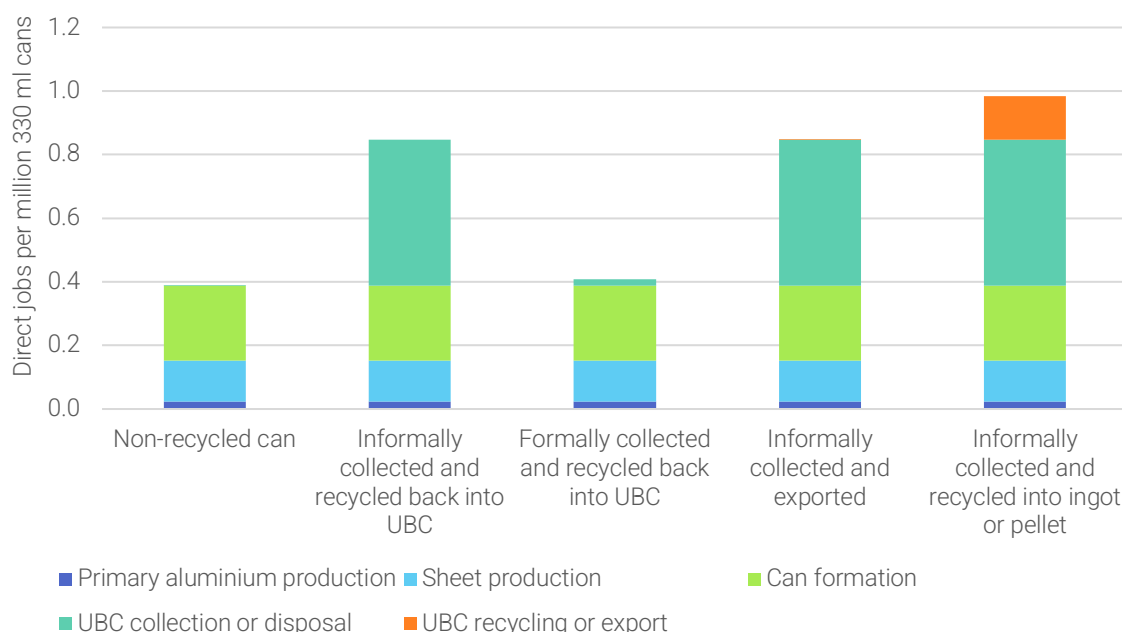


Figure 19: Direct jobs across the beverage can life cycle

The difference between formal and informal collection is even more substantial if informal-collector livelihoods is included along with direct jobs (see Figure 20). That is, if an estimate of the number of informal collectors whose livelihoods are supported by UBC collection is included. Whilst the number of informal collectors is itself uncertain (estimated at 300,000 – 400,000)³⁴, how any of these livelihoods can be attributed to the collection of UBCs adds even more uncertainty. This is shown in Figure 20, which applies a lower bound of 6%, derived from data on payments to informal collectors in 2017³⁵ (with 14% of total money paid to informal waste collectors arising from aluminium, and assuming UBCs account for 42% of aluminium reclaimed), and an upper bound of 36%. Nonetheless, Figure 20 shows that **informal collection very substantially dominates the livelihood/employment-potential across the beverage can life cycle**. Furthermore, even with the lower bound estimate of livelihoods supported (see Table 20), an informally collected and recycled can has an income generating-potential (livelihoods plus jobs) 16 times that of a non-recycled can, and nearly 5 times that of a formally-collected and recycled can.

³⁴ Recycling Association of South Africa (RASA) <https://www.thedtic.gov.za/wp-content/uploads/RASA.pdf>

³⁵ Godfrey L. Quantifying economic activity in the informal recycling sector in South Africa. S Afr J Sci. 2021;117(9/10), Art. #8921. <https://doi.org/10.17159/sajs.2021/8921>

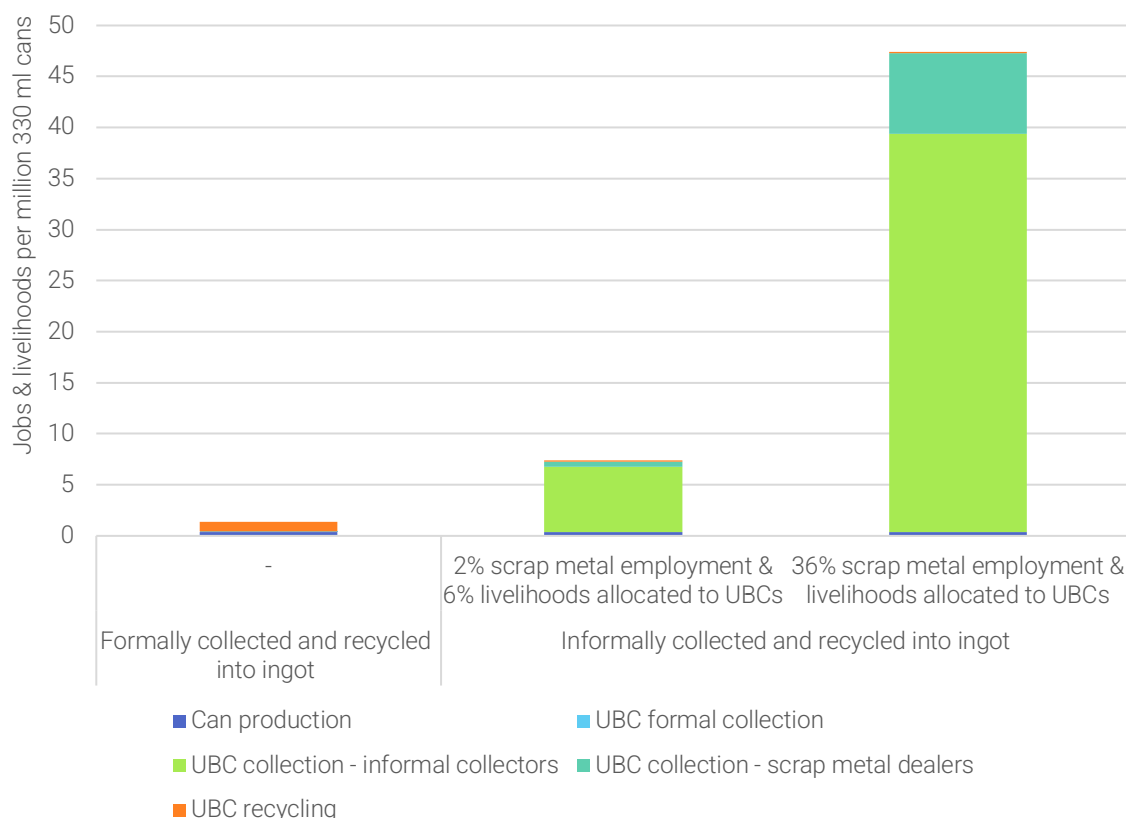


Figure 20: Jobs and livelihoods across the beverage can life cycle, comparing formal and informal collection, and within informal collection, attribution of UBCs to informal collector livelihoods and jobs at buy-back centres.

4.3 Data quality and uncertainty considerations

It is the nature of any LCA study that some data points are uncertain, which translates into uncertainty in the impact assessment results and associated interpretation. This is an important consideration in LCAs comparing different systems, such as different end-of-life management options, to ensure that the systems modelled have the same degree of accuracy and completeness. The current LCA study utilises a mixture of primary data, covering South Africa aluminium sheet production, South African aluminium can converting and South African UBC to can closed loop recycling, and secondary data, covering other value chain systems. This secondary data was sourced from the ecoinvent database and two peer reviewed international LCA studies and is thus deemed high quality. Furthermore, key secondary data inputs were compared with primary data obtained from participating members and were found to align well with the primary South African data (e.g. energy for ingot casting is within 3%, energy for can converting is within 5%).

Nonetheless, the following limitations have been identified in the LCA model that affect the accuracy of the results, and thus the certainty of the life cycle comparison of the end-of-life management options:

- Recycled content of imported aluminium sheet:** The current LCA model assumes the imported aluminium sheet has the global average recycled content of 30%; however, it is possible that the particular sheet is almost exclusively virgin material or has a much higher recycled content. Although this will significantly influence the life cycle environmental impacts of the imported sheet, the overall influence on the LCA results is limited by imported sheet only accounting for 9% of aluminium sheet used by South African can

converters (see sensitivity analysis in Section 4.3.1 below). Furthermore, the upstream (production) impacts are of secondary importance for establishing which end-of-life management option is best for UBCs (the primary focus of the study).

- Recycled content of imported cans:** The current LCA model assumes that imported cans are made from global average aluminium sheeting, with a recycled content of 30%; however, as with the sheeting, it is possible that the specific cans imported are manufactured from aluminium with a much higher virgin or recycled content. Again, this will significantly influence the life cycle environmental impacts of the imported cans; however, the influence on the LCA results is limited by imported cans only accounting for 7% of the cans on the South African market (see sensitivity analysis in Section 4.3.1 below). As with sheet recycled content, the upstream (production) impacts have no bearing on establishing which end-of-life management option is best for UBCs.
- Energy and other inputs for UBC scrap to ingot recycling:** The current LCA model is based on data from the ecoinvent database and North American aluminium can LCA. As a result, the impacts associated with these recycling operations may be over- or understated; however, this is deemed unlikely, as the energy inputs for melting and casting align with available primary data from South Africa. The LCA results also clearly show that, even if impacts linked to recycling increase drastically, avoided aluminium production will still outweigh the recycling impact (i.e. recycling impacts will still show negative impacts). Energy inputs would need to increase over 10X for ingot recycling to not have net positive impacts.
- Material avoided with deoxidiser pellet production:** The current LCA model assumes that aluminium pellet used for deoxidising in steel plants offset the equivalent mass of ferrosilicon. In reality, they may offset other materials, such as ferromanganese, or they may offset a greater mass of ferrosilicon (i.e. more ferrosilicon is required to fulfil the job of 1 kilogram of aluminium). If other materials, such as ferromanganese, are offset, the net impacts of the system would increase, as other ferro-compounds have lower production impacts than ferrosilicon. Conversely, if a greater mass of ferrosilicon is required, the net impacts of the system would decrease, as avoided impacts would be greater. However, this still would result in the material value of aluminium being lost from the system.
- Current end-of-life market split:** It is currently unknown what share of collected UBC scrap is converted to ingots (or where these ingots are utilised or what they are utilised for) and deoxidiser pellets in South Africa. The current LCA model assumes an equal split between these options (i.e. both represent 20% of UBC scrap), which influences the market average results presented. However, this does not influence the comparison of different end-of-life options, as is the focus of the LCA, and therefore does not compromise establishing which end-of-life management option is best for UBCs.

4.3.1 Recycled content sensitivity

The recycled content of both imported aluminium sheet utilised by can converters and the imported aluminium cans is unknown and may vary with importer. The current LCA model is based on the global average of 30% recycled content; however, some of MetPac-SA's member report higher values. As such the effect of the recycled content of both imported aluminium sheet and imported cans on the can life cycle impacts was tested in a sensitivity analysis, as shown in Figure 21.

The climate change impact of South African produced aluminium cans vary by 15% depending on whether the imported aluminium sheet has a recycled content of 0% (i.e. 100% virgin) or 100% (i.e. 100% recycled, which is not

technically possible³⁶). As such, it is possible that the average South African produced aluminium can could have, at most, impacts 10% lower than reported (if the imported aluminium sheeting is 100% recycled aluminium).

The climate change impacts of imported aluminium cans vary greatly depending on recycled content of the cans, showing climate change impacts of almost 320 kg CO₂e when cans are fully virgin, down to 50 kg CO₂e for 100% recycled content cans. This much greater variance for imported cans relative to South Africa-produced cans is because the unknown component of South African-produced cans is only 9% of the aluminium (i.e. 91% of the can is formed from aluminium sheet with a known recycled content).

Overall, if the imported aluminium sheet and cans both had 100% recycled content (not technically possible), the climate change impact of cans on the market would drop 15% from the results presented in the study above. In reality, recycled content is unlikely to exceed 75% and therefore climate change impacts would be at most 10% lower than the current study results. Furthermore, irrespective of the recycled content of the imported aluminium, the assessment around end-of-life options and the finding that closed-loop recycling is the most sustainable approach is not influenced by this change. All other environmental impacts follow a similar trend to the climate change impact shown.

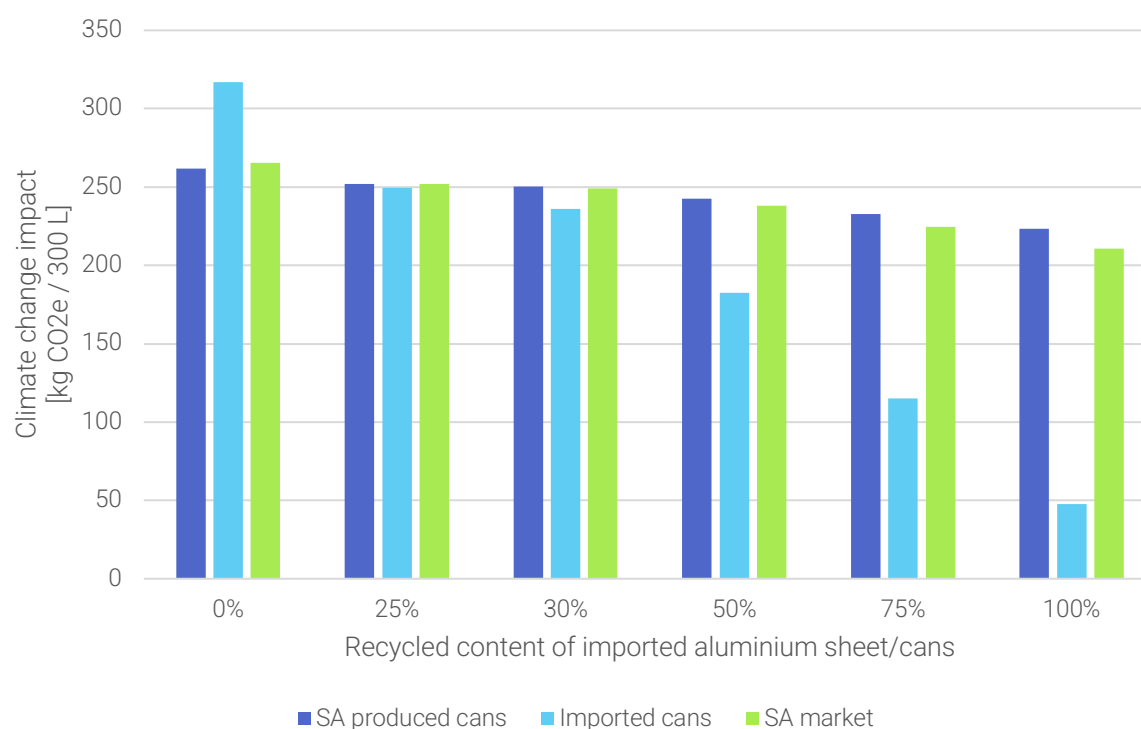


Figure 21: Sensitivity of aluminium beverage can production climate change impact to recycled content of imported aluminium sheet and cans – Study baseline is 30% recycled content for imported material

³⁶ The IAI estimates that, without major alloy redesign of the existing two-alloy system, an "optimum" global system could reach about 68% UBC content in the body and 36% in the lid, or about 62% for the complete can. <https://international-aluminium.org/wp-content/uploads/2025/09/Can-to-can-recycling-factsheet-FINAL.pdf>

5 CONCLUSIONS

The aluminium beverage can market is dominated by cans produced in South Africa, using South African produced can body (3104 alloy) and can end (5182 alloy) sheets. However, some internationally produced sheeting (9% of input to can converters) and cans (7% of cans on market) also forms part of the market mix. After use, the majority (88%) of used beverage cans (UBCs) are collected and sent for recycling within the country or internationally.

The **environmental impacts of aluminium can production is dominated by virgin aluminium production**, especially at South Africa's South32 Hillside smelter, with energy inputs for the sheet rolling and can converting stages also being significant sources of climate change impact, and impacts affecting human health and ecosystem quality, along with non-renewable resource consumption.

In line with the EPR requirements, potential UBC management options are studied in the LCA to determine the most sustainable management option. In line with ISO 14044:2006, system expansion is applied to avoid end-of-life allocation choices. This is also deemed the most appropriate approach for identifying the environmentally preferred end-of-life management option for UBCs.

The LCA results demonstrate that **all forms of UBC recycling have significant environmental benefits**, resulting from the avoidance of primary aluminium or conventional deoxidiser production. These benefits are seen across all life cycle environmental impact categories. The **benefits are greatest for UBC to can closed-loop recycling**, followed by recycling to ingots that are utilised for varying applications (open-loop recycling). The production of deoxidiser pellets has the least environmental benefits, although this is still significantly more beneficial than losing the value of the aluminium entirely as is the case with landfill disposal.

Alongside this, the **recycling of UBCs in open- or closed-loop processes align with circular-economy principals** and ensure the value of aluminium is not lost from the economy, ensuring that less resources must be extracted and less aluminium enters the natural environment as waste. The production of deoxidiser pellets does not align with circular-economy principals as the value of the aluminium is lost, although it avoids the production of other metallic compounds.

Producing and recycling aluminium beverage cans in South Africa is associated with significant employment potential. Locally producing cans, especially if from locally produced sheet, has 70 to 120 times the employment potential of importing cans, at around 0.4 direct jobs per million cans produced. Collecting and recycling cans in South Africa adds a further 0.5 direct jobs per million cans placed on the market, showing a very strong socio-economic benefit of recycling cans relative to landfill disposal or export. This number increases very substantially to around 7 income opportunities (jobs and livelihoods) per million cans if informal collector livelihoods are included (and as high as 47 income opportunities per million cans depending on the assumed extent to which UBCs contribute to informal collector livelihoods relative to other materials collected).

These results also show the **importance of designing aluminium beverage cans for recycling**, even if this means material use increases, as the circularity, environmental and social benefits of recycling outweigh any minor impacts of the additional material. This is key for UBC closed-loop recycling, where currently can end and can body alloy differences limit the overall share of recycled UBCs that can be incorporated into can sheeting. Internationally work is underway to align these alloys and ensure full closed-loop recycling is possible, although it is acknowledged this alignment may hamper further lightweighting. However, this study demonstrates that such industry moves align with sustainability goals.