Best practice guide

Food and Consumer Goods Packaging: Life Cycle Assessments (LCAs)

Sustainability from IGD

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1 Purpose and context – Why has this guide been developed?

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About this guide

Adopting a Life Cycle Assessment (LCA) approach that measures and reduces the environmental impacts of food and consumer goods packaging, leading to transparent decision–making

Lifecycle assessment (LCA) is used to measure the environmental impacts of a product, service or system across its entire lifecycle, from raw material extraction through to processing, production, use and end-of-life processes.

They are often the first step to understand the impacts of introducing a packaging change.

For food and consumer goods packaging, LCA can be used to analyse and compare the environmental impact of different packaging designs, materials and systems such as single use versus refill and reuse.

LCAs identify impact hotspots and critically inform decisions to reduce impact, without simply moving the problem from one environmental area to another.

IGD has developed this guide in collaboration with the food and consumer goods industry to help the sector undertake packaging LCAs in a standardised way – encouraging transparency and consistency of environmental claims.

It aims to support design decisions that lead to a significant reduction in environmental impacts in line with our shared ambition – to halve the environmental impacts of the UK packaging system by 2030.

Use this guide to help inform, commission, conduct, communicate and act upon lifecycle assessment.

A shared ambition

To **halve** the environmental impacts of all **packaging** systems by **2030** whilst still enhancing the benefits and quality enjoyed of products and their packaging today

The 2030 ambition looks beyond current legislation and addresses all packaging materials. It covers a range of environmental impacts including climate change, water, land use and virgin resource use to tackle this critical industry issue.

The ambition creates a platform for accelerating industry's progress towards a sustainable packaging system.

Achieving this bold ambition will require equally ambitious, evidence-based.

Our 2022 insights report – 'Halving the environmental impact of the UK packaging system: How industry and key stakeholders can work together to drive positive change' found that meeting the 2030 ambition will require a 20% reduction in the amount of packaging put on the market.

This needs to be combined with significant environmental efficiency gains including increased recycled content in packaging and increased material recycled rates.

The report identifies three key levers to change:

1. remove packaging;
2. increase recycled content; and
3. decarbonise existing supply chains.

Removing packaging will have the biggest impact, as it eliminates the full lifecycle impact from production right through to disposal. This includes the adoption of reuse systems.

LCAs provide a robust approach for analysing the scale of change against these levers, and in turn help inform decision-making that leads to maximum environmental impact reductions.

Purpose and value of an industry packaging LCA

LCA can inform decisions that support maximum environmental impact reductions

Purpose:

LCAs provide insight into a diverse range of impacts of a packaging product or system. This guide sets out a standardised packaging LCA methodology for the food and consumers goods industry. This aims to drive comparability and transparency across the industry and deliver environmental impacts in line with the shared ambition.

Value:

- Help meet the shared 2030 ambition: By providing a framework for scaling up LCA outcomes and include change scenarios capable of delivering a 50% impact reduction.
- Support environmental claims and build consumer trust: By ensuring LCAs align with global best practice and anti-greenwash advertising regulations.
- Reduce costs: By minimising the decision-making in the design phase.
- Enhance credibility:By adopting a standardised methodology across industry to provide comparability and transparency.
- Enable future-proof decisions: By undertaking sound environmental analysis and outcomes.

Approach:

This guide follows the framework of a Product Category Rule (PCR) layout and scope.

For the purpose of this guide, we have assumed that all LCAs are performed, as a minimum, to the International Organisation for Standardisation (ISO) 14040/44 standards.

It is important to note that this guide is designed to provide a stand-alone LCA of packaging. A whole system perspective should also be viewed to ensure impacts such as food waste are understood. For example, there are occasions where impacts should be allocated between the packaging and the product inside.

2 LCA overview

2.1 Life Cycle Assessments (LCAs)

2.1 Life Cycle Assessments (LCAs)

Using LCAs can simultaneously provide insight into a diverse range of environmental impacts of packaging across a product's entire lifecycle. This allows practitioners to comprehensively examine a product's impacts and identify any trade-offs occurring between environmental areas of concern. It should be noted that environmental LCAs do not consider non-environmental impacts, such as the aesthetics of packaging and their role in driving consumer sales.

The ISO's 14040/44 standards provide the dominant global framework for LCAs. There are four phases defined by the ISO standards that a practitioner should follow when conducting an LCA:

1. **Goal and scope definition**
   Clearly outlining the goal and scope of an LCA to ensure that it is completed consistently and achieves its intended purpose. This step defines the product (including geographic and temporal factors), determines the functional unit (the unit by which the LCA is quantified) and sets the system boundaries (states what is included and excluded from the LCA, often in diagram and tabular form).

2. **Lifecycle inventory analysis (LCI)**
   Collating all environmental inputs and outputs associated with the chosen functional unit. Inputs include all materials and processes required to create a product, whilst outputs cover the emissions generated from the production of the product and released into the environment (such as GHGs and pollutants).

3. **Lifecycle impact assessment**
   Analysing all the elements from the LCI and relating these to the environmental impact areas chosen for the LCA, such as climate change, virgin resource use, ecotoxicity, and human health.

4. **Interpretation**
   Checking to confirm that the conclusions are supported by the results and methods used within the LCA. Examples of checks include sensitivity analyses and testing of alternative approaches.

3 Packaging LCAs – How can they measure and improve sustainability?

3.1 Packaging and lifecycle assessment

3.1 Packaging and lifecycle assessment

In the Environmental Product Declaration® (EPD) Packaging Product Category Classification Version 1.1 2020, packaging is defined as a "product to be used for the containment, protection, handling, delivery, storage, transport and presentation of goods, from raw materials to processed goods, from the producer to the user or consumer, including processor, assembler or other intermediary" .

Less is better

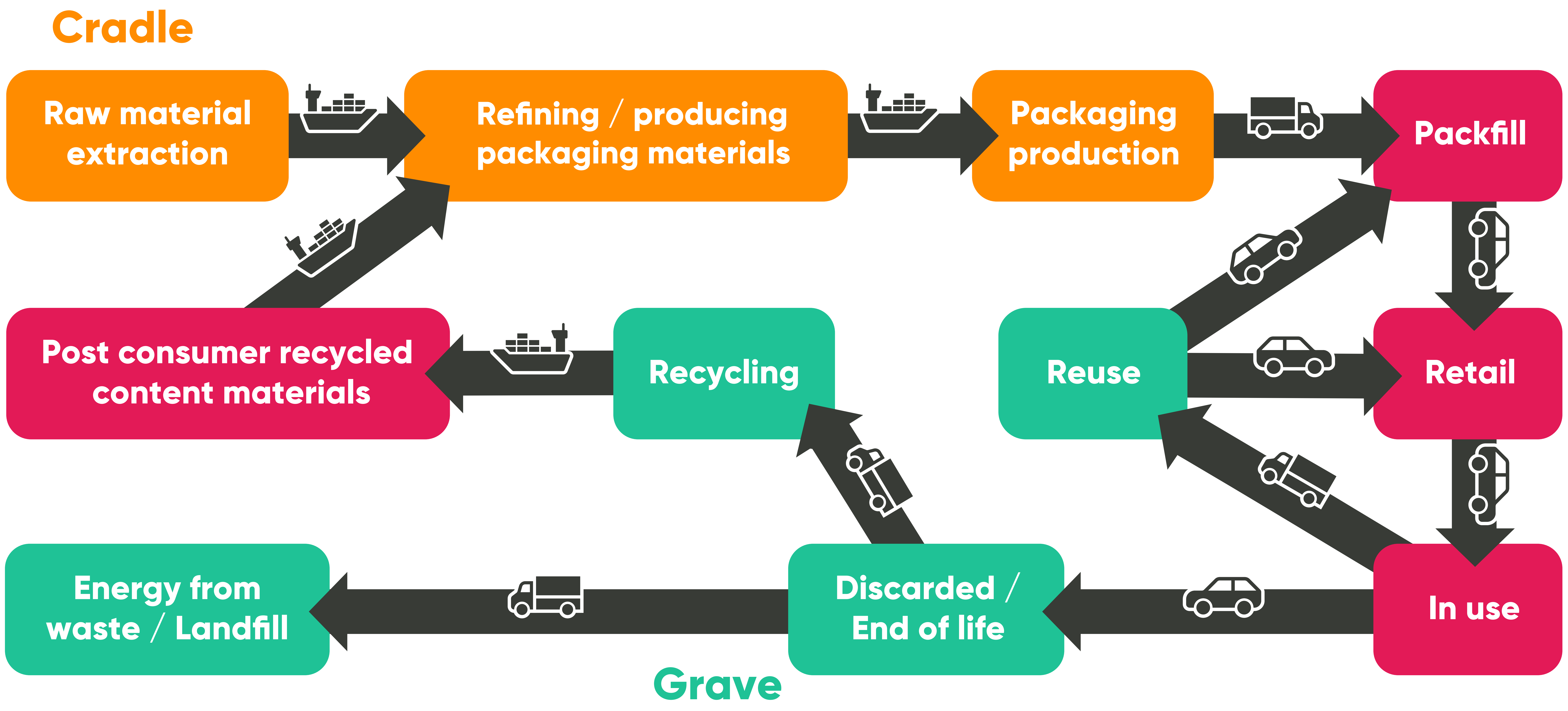
As a general rule, "a comparison of two functionally equivalent packaging designs of the same material and using the same manufacturing process is almost guaranteed to show that the lower-weight design will be associated with lower environmental burdens since it uses less material, consumes fewer resources to transport and shape the material, and leads to less waste (assuming, of course, that the lower-weight design does not compromise product protection and increase product loss)." (UNEP/SETAC Life Cycle Initiative, 2013)

LCA is a critical tool for optimising the environmental performance of packaging. It is often used either as part of a larger product design strategy, or in isolation to allow a practitioner to understand design trade-offs or traits that drive superior environmental performance.

Using LCAs can help to evaluate and compare the environmental performance between packaging designs, materials and systems, such as single use versus refill and reuse.

Conducting an LCA can reveal whether, for example, possible higher burdens within the reuse/recycling processes offset the benefits gained from reusing the packaging or material. This provides an opportunity to avoid any burden shifts ahead of agreeing a new packaging design or system.

Figure 1. Example of food packaging lifecycle from United Nations Environment Programme (UNEP), 2013



With packaging LCAs, it is important to remember the core purpose of the packaging: to protect the product inside. All differences resulting from system or packaging design must be accounted for. These may include, but are not limited to:

- Product losses throughout the product lifecycle (e.g. filling, distribution, retail, consumer etc.)
- Recipe changes caused or enabled by, or requiring, packaging changes (e.g. concentration of liquid detergent resulting in smaller packaging)
- Distribution differences such as:
  - Changes in secondary or tertiary packaging requirements
  - Changes in packing density and transport requirements
  - Change in distribution methods (e.g. mode [road to ship], environment [chilled to ambient]).

These non-LCA elements should therefore be provided alongside the LCA results for context and consideration and reported as outlined in section 5.2.

United Nations (UN) Central Product Classification codes (CPC codes) are used within Europe as a classification system for packaging types and are recommended here as the reference system to be used for classification. Providing a classification code in accordance with a recognised classification system provides an easy method to group, and therefore identify, LCAs of similar packaging types, thus allowing comparison and enabling other professionals to identify possible packaging design modifications to trial.

4 Best practice requirements – How to use this guide alongside LCA standards

4.1 Aligning best practice recommendations with industry standards

4.2 A pragmatic approach to using an LCA

4.3 Requirements

4.1 Aligning best practice recommendations with industry standards

This guide provides a standardised methodology based on ISO14040 standards and is enhanced with requirements and recommendations that support the level of ambition required to 'halve the environmental impacts of packaging systems by 2030'. Where possible, specific data sources and calculations are highlighted. This guide focuses on primary packaging but also covers secondary and tertiary packaging.

Due to constant updates and research into LCA methodology improving accuracy and scope, these guidelines should be reassessed at minimum every three years to account for these improvements and alterations (UNEP/Society of Environmental Toxicology and Chemistry (SETAC) Life Cycle Initiative, 2013).'

4.2 A pragmatic approach to using an LCA

Full scale ISO compliant LCAs are the 'gold standard' for assessing the environmental impacts of packaging. However, they can be time and resource intensive and thus, are not always conducive to rapid, scalable change. Where a significant or high-risk decision is required, there is often a potential for high impacts. An in-depth analysis is therefore strongly advised to draw wider conclusions and focus on impact reduction across a lifecycle.

In other cases, a less data-intensive LCA approach may be appropriate provided its design and application remains consistent with the best practice described in this guide (e.g. how to account for product waste, end of life impacts, different packaging formats, single-use versus reuse etc.). Such 'light-touch' LCAs may be sufficient to make internal decisions where there is a high degree of confidence in a significant finding, but will not comply with ISO standards, and should not be the basis for public claims.

4.3 Requirements

The terms “shall” and “should” are located throughout this guide, and have specific definitions in relation to LCA:

- **Shall**: requirement that must be followed, unless specified within the guide
- **Should**: strongly recommended that the guidance is followed, any exceptions shall be justified with clear evidence
- **May**: light recommendation, and can be overlooked without specific evidence or justification

Following the ‘shall’ requirements will lead to the most robust and aligned LCA approach which in turn will support the shared ambition to halve the impacts of packaging systems by 2030.

5 LCA guidance for food and consumer goods packaging

5.1 Scenario development

5.2 Functional units

5.3 System boundaries

5.4 Key food and consumer goods packaging lifecycle processes

5.5 Cut-off rules

5.6 Allocation rules

5.1 Scenario development

The outputs of any LCA are defined by the scenarios and impact categories chosen by the practitioner. Since a primary aim of this guidance is to support the UK food and consumer goods industry's shared ambition, scenarios cannot be limited to modest, marginal improvement.

Rather, **every packaging LCA should include scenarios designed to achieve the significant lifecycle improvements and resource reductions required to achieve the ambition, including, as a standard component, one or more viable reuse scenarios.**

5.2 Functional units

Functional units are common reference points for comparing the environmental performance of two or more product or service systems. They are defined in terms of the system function: for example, providing a certain number of servings of a product. In the Environmental Product Declarations (EPD) Packaging Product Category Classification Version 1.1 2020, packaging is defined as "for the containment, protection, handling, delivery, storage, transport and presentation of goods, from raw materials to processed goods, from the producer to the user or consumer, including processor, assembler or other intermediary" (EPD, 2021). **In the case of food and consumer goods packaging, the essential function is to preserve, protect and contain the product held within and this therefore should be considered within the chosen functional unit.**

Secondary services such as usability, marketing, branding etc. are not considered to be a fundamental role of product packaging, although in some cases (e.g. displaying ingredient information) they may be a legal requirement. The appropriate functional unit for a packaging LCA is therefore a version of the following:

"Preserve, protect, and contain 1 [volume, mass, units] of [food product], distributed to [geographic location] and preserved until its use, in adherence with relevant legislation on information provision."

where 'use' is considered to be consumption by the consumer (EPD, 2021).

EPD further outlines the following, which are also required by this guide:

"The packaging application (the sector(s) in which the packaging can be used and the types of content it is suitable for) and use (the types of technology that are suitable) shall be clearly declared in the EPD.

The following technical information supports the functional unit definition and shall be reported in the EPD, if applicable:

- Base material of packaging product (e.g. polymer, wood, etc.)
- External dimensions of the packaging product (m)
- Internal volume of the packaging product (l)
- Weight of packaging product (kg)
- Maximum load (kg)
- Compression values (e.g. results of the compression test based on ISO 12048 or equivalent)
- Stacking values (e.g. results of the stacking test based on ISO 12048 or equivalent).

In case a functional unit (cradle-to-grave LCA) is used, the following information shall also be included to increase comparability:

- Number of uses of the reusable packaging during its lifetime
- Maximum transportable load during the lifetime

An optional additional functional unit may be used, taking into consideration the quantity of volume transported in the lifecycle of the packaging and should be declared as total volume or its units. The number of reuses and the total volume considered shall be declared in the EPD." (EPD, 2021)

Alongside the specifications outlined above, users of the guide shall also report:

- Confirmation that packaging meets food standard/safety certifications
- Feasible production line speeds and, in the case of a comparison, changes to these (both for the pack production line and the filling/packing and sealing process)
- Net amount (mass) of material used, excluding material made re-available to the economy through recycling or reuse
- Recognised classification codes appropriate to the packaging.

5.3 System boundaries

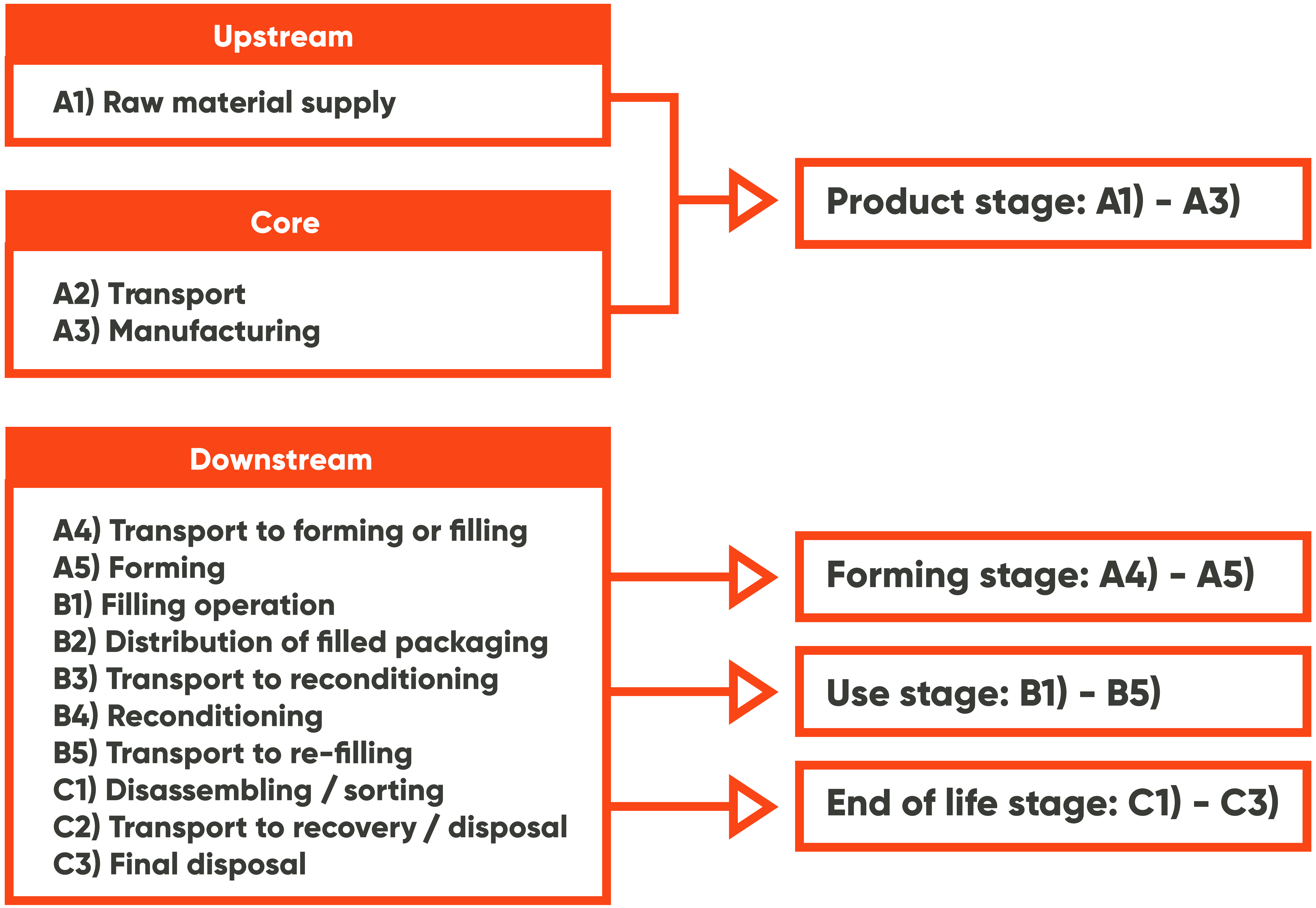
System boundaries outline which lifecycle stages and processes will be included. In the context of this guide, this shall include all upstream, core and downstream processes within the lifecycle for packaging, including accounting for any reuse cycles (section 7.9).

Any changes in product use and/or waste affected by packaging choice are included in the system boundaries. It is acknowledged that not all product loss will be directly related to the packaging choice; however, as the specific amount of loss attributable to the packaging cannot easily be estimated, all shall be included to ensure comparability across packaging scenarios. The system boundaries must be set to include the relevant mass and energy flows through all streams of the lifecycle, for example, raw material supply must include the energy required to extract and transport the raw materials to production.

The system boundaries are split into different stages, covering each part of the manufacturing process and end of life to ensure cradle-to-grave is covered for the functional unit. This can be split into upstream, core and downstream processes as described in Figure 2. Breakdown of lifecycle stages, adapted from EPD Packaging Product Category Rules (PCR) (2020). System boundaries are often displayed in diagram format and clearly highlight which processes are included and excluded from the LCA.

All lifecycle processes shall be included within the packaging LCAs unless there are extenuating circumstances that can be evidenced and justified.

Figure 2. Breakdown of lifecycle stages, adapted from EPD Packaging PCR (2020)



5.4 Key food and consumer goods packaging lifecycle processes

The following lifecycle processes should be considered within packaging LCAs.

5.4.1 Raw material acquisition and pre-processing

This includes water, chemicals, energy and materials usage and transportation of these to site of packaging manufacture.

5.4.2 Manufacturing

Production of primary, secondary, and tertiary packaging and disposal of waste.

5.4.3 Filling/packing and sealing

Transportation of packaging to site of filling/packing and sealing (if required) and filling of the packaging with its contents, including any water, chemicals, energy and auxiliary materials required. Disposal of all waste arising – product, primary packaging and secondary/tertiary packaging – shall also be included.

It is again noted that not all impacts arising from filling and sealing are directly attributable to the packaging format. However, due to the difficulty in accurately allocating impacts between product and packaging, all impacts shall be included.

5.4.4 Distribution

All transportation and storage steps from filling/packing to consumers' homes, including vehicles and fuels, refrigeration (where required) and any wastes arising. This includes both distribution centres and retail sites.

Packaging design can influence how much storage space and/or energy is required per functional unit. For instance, a four-litre bottle of milk requires less fridge space than eight x 500ml bottles.

5.4.5 Consumer use

All activities and products that are required to use the product. Capital goods associated with the preparation, rehydration and consumption of the product shall be excluded as negligible, as shall cooking impacts, although it's acknowledged that packaging design can influence these.

Any waste that is generated from the consumer using the product, such as the packaging waste, is not included at this stage as it is factored into the end-of-life stage. Product and packaging waste arising from damage/spoilage, however, is included.

5.4.6 End-of-life

The preference order of reduce, reuse, recycle and dispose, as set out in the waste management hierarchy, does not always mirror the results from LCA (UNEP/SETAC Life Cycle Initiative, 2013). This hierarchy is not set in stone and there may be trade-offs between environmental impacts like GHG emissions or water consumption and virgin resource consumption (UNEP/SETAC Life Cycle Initiative, 2013).

A cut-off approach (section 5.5) is taken, whereby lifecycle processes are included up to the point of the disposed material transitioning from 'waste' to 'resource'. Therefore, transport to end of life destination, sorting processes, and a subset of treatment emissions are included (see section 7.10).

5.4.7 Reuse

Reuse is defined as "an operation by which packaging is refilled or used for the same purpose for which it was conceived, with or without the support of auxiliary products present on the market enabling the packaging to be refilled" (EPD, 2021). Therefore, reuse and refill scenarios shall include any relevant preparation required for reuse, such as washing, drying and transport. Detail on calculating the reuse rate and integration of this into the earlier lifecycle stages is provided in section 7.9.

The impact of product losses must be accounted for at all stages of the lifecycle.

5.4.8 Excluded processes

- Construction and dismantling of infrastructure, production equipment and other capital goods used throughout the lifecycle (e.g. mines, factories, distribution centres, supermarkets, delivery vehicles, waste treatment facilities etc.).
- Business travel of personnel.
- Travel to and from work by personnel.

The environmental impact of a given piece of infrastructure (e.g. a factory) may be significant; however, the portion that can be attributed to any one unit of packaging is typically unsubstantial and imprecise. Given its likely insignificance, it is excluded.

5.5 Cut-off rules

As many processes as possible shall be included. However, any processes that contribute less than 1% of total category impact across all impact categories may be excluded if satisfactory data is not available within reasonable effort (Product Environmental Footprint (PEF), 2018; EPD, 2020). For example, if the printing of cardboard packaging is expected to comprise only 0.5% of the environmental impact for all the individual impact categories, it should be excluded from the LCA. If, however, this process were to represent 20% of the impact in one category but 0.5% in the others, it should not be excluded.

5.6 Allocation rules

In instances where a lifecycle stage leads to the co-production of energy/materials used outside the system under study, the net impacts of the process must be allocated across these co-outputs in a clear, consistent, and defensible manner (ISO, 2006).

For example: the production of paper can create waste which is suitable for relooping back into manufacturing as an energy source but is also appropriate to be sold as goods to other manufacturing facilities as an energy source or for other use. When considering by-products like these, the impact of the paper production must be allocated across these by-products.

Below are some cases specific to each lifecycle stage:

5.6.1 Raw materials, manufacturing, and filling/packing

- For any materials or energy by-products that are reused within the same process as the packaging of concern, the system boundaries must include all the processes and elements that allow the recirculation of the by-products.
- For any materials or energy by-products used within any other processes or by a third party, allocation shall be conducted according to the economic method between input and output, unless strong justification can be given as to why other methods may be superior.

Losses of packaged food during filling/packing and sealing and at all downstream stages of the lifecycle shall be included in their entirety.

It is acknowledged that not all product losses are attributable to the packaging selection. However, as it is not possible to calculate the 'avoided losses' directly attributable to packaging design (some products cannot be sold without packaging), all product losses in all packaging LCAs shall be included to allow fair, direct comparison between alternative packaging options for like products.

Impacts associated with product loss shall be reported separately throughout the lifecycle and reported as a summed total only in the final, overall impacts for each lifecycle stage.

Balancing product versus packaging LCAs

It is important to note that this guide is designed to provide a stand-alone lifecycle assessment of packaging. There are occasions where impacts should be allocated between the packaging and the product inside, as in the example of food waste, but this split is not easily (or accurately) calculable. Therefore, some impacts are allocated entirely to packaging when in practice they should be split between packaging and product. The results of a packaging LCA cannot therefore be added to a stand-alone food LCA as a portion of these impacts will be double counted.

5.6.2 Distribution

Where information is available, the transportation impacts attributed to the raw materials or unfilled packaging should be set by whichever of mass or volume limits the vehicle loading. It is expected that this information will often be unavailable, and in this case, an assumption of mass limitation shall be taken (PEF, 2016).

The total impacts associated with transportation of filled packaging (product and packaging as a single unit) shall follow the same principle as above. To allocate these impacts between product and packaging respectively, mass allocation shall be used for all ambient products and volume in the case of refrigerated transport (PEF, 2016), unless primary evidence shows otherwise.

For further detail on this section, refer to PEF Legislated Method guidance document section 4.4.3 (PEF, 2016).

5.6.3 Warehousing

Allocated between product and packaging shall be by volume, distinguishing between refrigerated and non-refrigerated, as per PEF Legislated Method document section 4.4.5 (2016).

5.6.4 End-of-life allocation

End-of-life allocation, i.e. attributing the environmental burdens at end-of-life (recycling and disposal), can have a significant impact on the results of a packaging LCA. It is a complex area for calculation as there are two main considerations:

- how to account for, and incentivise, both the use of recycled content in production and recycling at end-of-life; and
- how to account for the environmental impacts of waste treatment when a co-product (e.g. energy) is produced.

There are several allocation methods used in LCA. For packaging LCAs, the 'cut-off' approach, also known as polluter pays principle (PPP), shall be used as the primary allocation method for attributing environmental burdens at end-of-life (including recycling and energy from waste).

This approach takes into account the environmental impacts of disposal up to the point at which the packaging becomes a resource used by a third party. It does not include any of the impacts associated with converting the waste packaging back into a useful product (e.g. recycled material or energy). These impacts are allocated to the user of the packaging waste (e.g. recycling plant; energy from waste plant). This means that emissions from recycling or "waste-to-energy" incineration are outside the system boundaries. In the case of landfill, all impacts are borne by the disposer.

While this 'cut-off' makes sense from a lifecycle perspective, the outcomes of the LCA will not differentiate any environmental impacts of design decisions regarding the likely end use (and/or reprocessing) of their product by a downstream user (i.e. whether the packaging can be fully recycled and is processed into new raw material or whether it is incinerated as EfW). For example, the full process of recycling and EfW have different net environmental impacts and producers of packaging (such as the manufacturers, retailers and brands) play a key role in determining which of those routes are likely to be used – and hence, the impacts. However, with the cut-off approach, impacts of both recycling and EfW are included only up to delivery and initial sorting/cleaning of the waste material, thus have equivalent impacts.

Therefore, to get a complete picture of a packaging's end-of-life impacts, a cradle-to-cradle consideration of downstream impacts and benefits of the packaging design, such as recycled material available for reuse or grid energy displaced, is therefore recommended alongside the LCA impact calculation. This will ensure a fuller perspective to ensure the best overall environmental outcome.

End-of-life impacts which occur beyond the boundaries of the LCA, as well as any avoided impacts arising through displacement (e.g. virgin material manufacture avoidance, grid energy displaced) shall be reported additionally but not included in the expressed impacts. This parallel assessment and reporting is important, as conventional cut-off approaches to energy from waste and recycling can obscure significant net environmental impact differences between the two processes. Net impacts should be accounted for as follows:

A) Recycling

Material reprocessing impacts — avoided raw material impacts

Appropriate and comparable emission factors (same scope, geography, output, ideally source database) shall be used for both material reprocessing and virgin feedstock production of the equivalent output. Waste collection and transport to reprocessing facility is not included in the material reprocessing impacts as it is already included in the cut-off method and so would result in double-counting. The impact to produce an equivalent output quantity of recycled material but from virgin feedstock is subtracted from the reprocessing impact to give a net cost/benefit from recycling.

B) Energy from Waste (EfW)

Combustion impacts — Displaced UK grid impacts

All EfW activity is assumed to occur in the UK at electricity-only facilities, as these are the dominant plant type.

Combustion impacts should be calculated according to the specific packaging material using emission factors as indicated above.

To calculate the displaced UK grid impacts, the total amount of electricity generated from packaging shall be multiplied by the UK marginal grid factor. Global warming impacts shall be taken from the most recent Department for Business, Energy and Industrial Strategy (UK Government) (BEIS) Green Book publication; all other environmental impacts shall be the most recent UK residual grid mix, consumption mix as directed by the PEF Category Rules Guidance Section 4.4.2 (2018). If this dataset is inaccessible, the appropriate UK grid process from the consequential version of Ecoinvent 3.8 may be used instead.

Electricity generation per kg of packaging material should be calculated as follows:

$$\frac{\text{Calorific value of packaging material (MJ/kg)}}{\text{(MJ to kWh conversion factor)}} \times \text{EfW plant efficiency}$$

where the MJ to kWh conversion factor used shall be 3.6 and EfW plant efficiency shall be 22.5%.

Subtracting the displaced UK grid electricity impacts from the combustion impacts gives the net cost/benefit from energy from waste.

6 Data quality and requirements

6.1 Lifecycle and impact data

6.1 Lifecycle and impact data

There are two types of data needed for an LCA:

- Lifecycle data describing the processes at each lifecycle stage (e.g. transport distance by mode), and
- Impact data describing the environmental impacts associated with each process (e.g. GHG emissions associated with a given transport journey).

Specific data (also known as primary data) is preferred for lifecycle and impact data, but not always available. An LCA will therefore almost always rely on some secondary data, but this should be minimised as much as practically possible. Impact data usually comes from secondary datasets, whilst lifecycle data, to the greatest degree possible, should reflect the specific packaging under consideration.

Data should be as temporarily and geographically relevant as possible (i.e. reflecting the current production approaches, energy sources and emission mixes). For lifecycle and impact data more than three years old, justification shall be given with regards to why it can still be considered sufficiently representative.

Where an 'average market mix' of a given input material is used, supplier specific mixes should be used as a priority. If unknown, a market mix shall be calculated using country splits taken from FAOStat Food Balances and Commodity Balances food and fibre raw materials and the geographically appropriate Ecoinvent 3.8 market mix for all unavailable/other inputs.

7 Stage-specific guidance

7.1 Raw material acquisition and pre-processing

7.2 Raw materials: transportation (import of raw materials and internal operations transport)

7.3 Manufacturing

7.4 Manufacturing: transportation (transport from production to filling/packing and sealing)

7.5 Filling/packing and sealing

7.6 Distribution (filling/packing and sealing to retail)

7.7 Retail

7.8 Consumer use

7.9 Reuse

7.10 End-of-life

Here we have provided stage-specific guidance for a packaging LCA. Each of the stages may require sourcing from different LCA databases. There is an order of preference for database selection for each stage and justification must be provided for deviation from these sources.

7.1 Raw material acquisition and pre-processing

This shall include all raw materials and pre-processing steps required for both the primary packaging under study, as well as associated secondary and tertiary packaging throughout the product lifecycle. Shopping bags used in the transport of products from retail to consumer shall be excluded.

Specific lifecycle data shall be used with respect to amounts and sourcing locations. This shall also include all cooling and auxiliary inputs to manufacturing. Where possible, specific data on recycled content should be used. The impact factors for recycled content shall include all production stages downstream of sorted waste feedstock. They shall exclude transport of waste to recycling facility and preliminary sorting, as these are allocated to the producer of the waste feedstock.

Where available, critically reviewed supplier-specific impact data should be requested and used.

Secondary data should be sourced by the following prioritisation:

- PEF-directed data, where not of restricted usage;
- Ecoinvent 3.8 (unless justification can be given regarding why this is unsuitable);
    - For biobased inputs and food waste, World Food LCA Database (WFLDB) is preferred, with the exception of forest-based products where Ecoinvent 3.8 is preferred;
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Preference shall be first for studies that meet PEF criteria, followed by studies that have undergone an independent third-party critical review.

All raw inputs, up to at least a cumulative coverage (by mass) of 99% inputs, shall be included. Where data is available for minor inputs, these shall also be included, as it can be the case that the minor additives are most significant with respect to toxicity impact categories.

7.2 Raw materials: transportation (import of raw materials and internal operations transport)

Specific lifecycle data shall be used with respect to sourcing locations and should be sought for transport routes, modes and load factors. Where unknown, the following model from the PEF Category Rules Guidance 4.4.3.4 should be assumed (PEF, 2018):

"For suppliers located within Europe, if no specific data are available to perform the PEF study, then the default data provided below shall be used.

For packaging materials from manufacturing plants to filler plants (beside glass; values based on Eurostat 201530), the following scenario shall be used:

a) 230 km by truck (>32 t, EURO 4);

b) 280 km by train (average freight train); and

c) 360 km by ship (barge).

For transport of empty bottles, the following scenario shall be used:

a) 350 km by truck (>32 t, EURO 4);

b) 39 km by train (average freight train); and

c) 87 km by ship (barge).

For all other products from supplier to factory (values based on Eurostat 201531), the following scenario shall be used:

a) 130 km by truck (>32 t, EURO 4);

b) 240 km by train (average freight train); and

c) 270 km by ship (barge).

For suppliers located outside Europe, if no specific data are available to perform the PEF study, then the default data provided below shall be used:

a) 1,000 km by truck (>32 t, EURO 4), for the sum distances from harbour/airport to factory outside and inside Europe;

b) 18,000 km by ship (transoceanic container) or 10,000 km by plane (cargo);

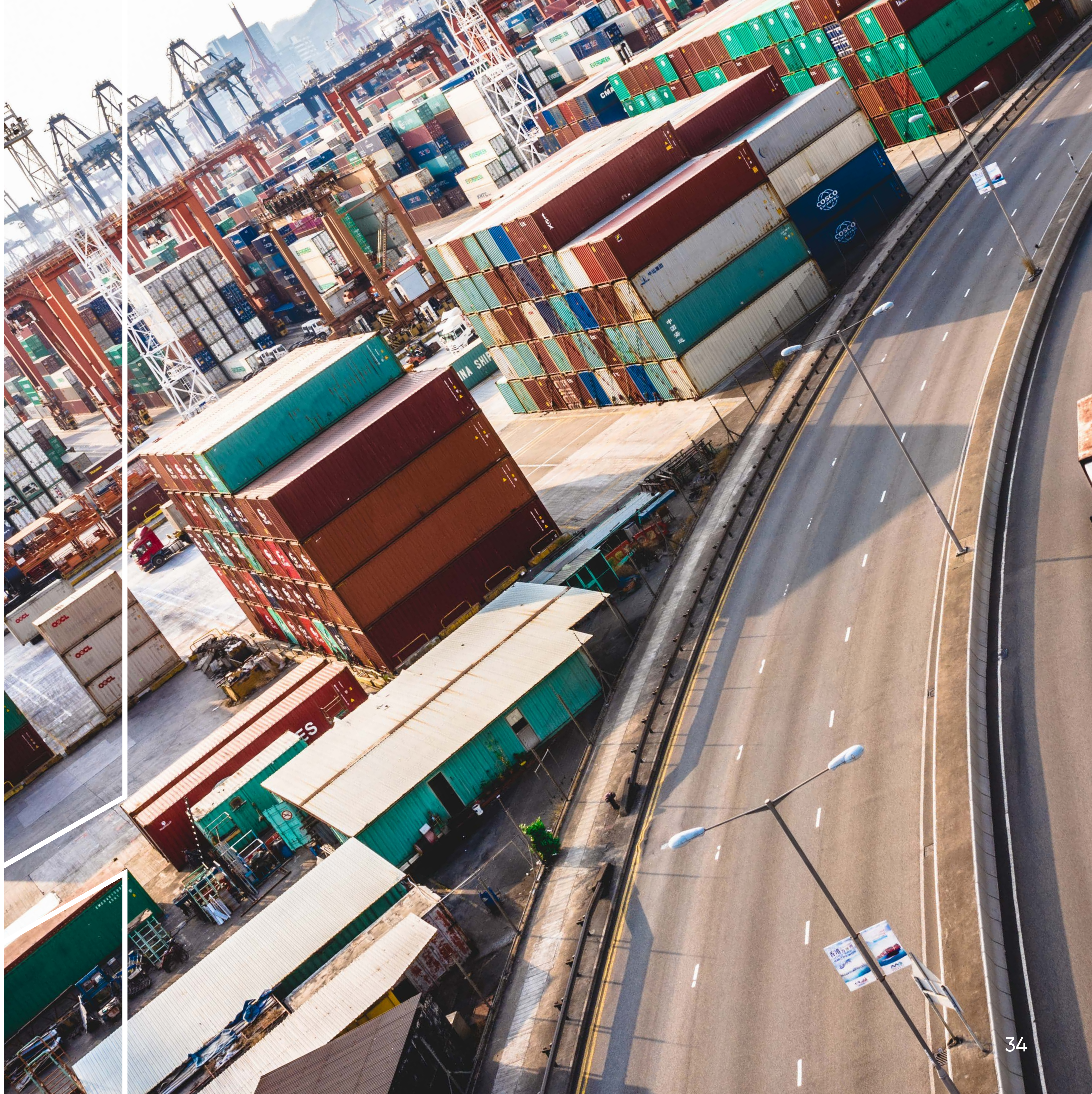
c) if producers' country (origin) is known, the adequate distance for ship and airplane should be determined using specific calculators;

d) in case it is not known whether the supplier is located within or outside Europe, transport shall be modelled as if the supplier was located outside of Europe."

Impact data should be sourced by the following prioritisation:

- PEF-directed data, where not of restricted usage;
- Ecoinvent 3.8 (unless justification can be given regarding why this is unsuitable);
    - For biobased inputs and food waste, WFLDB is preferred, with the exception of forest-based products where Ecoinvent 3.8 is preferred
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Preference shall be first for studies that meet PEF criteria, followed by studies that have undergone an independent third-party critical review.

Where specific loading factors are unknown, assumptions should be made in line with PEF Category Rules Guidance 4.4.3.4.



7.3 Manufacturing

Specific lifecycle data should be requested from suppliers for all packaging components; this should include maintenance, storage/handling, and waste treatment of manufacturing waste. Where there is a possibility that plants operate using different manufacturing approaches, a weighted average of the larger of either:

1. plants covering at least 80% of production, selected in order of production quantity (largest to smallest)

   OR

2. three plants, where any one plant is responsible for more than or equal to 40% of total annual production

shall be used. This shall be considered the minimum; the more that can be included, the better.

If manufacturing is split across multiple plants believed to have similar impact, it should be demonstrated that impacts across all impact categories are within ±10%. This should be done by comparing the larger of:

1. plants covering at least 50% of production, selected in order of production quantity (largest to smallest);
2. three plants.

If it can be demonstrated that impacts are within the allowed range of variance, a weighted average of the plants compared can be scaled up to cover the full manufactured volume. If it is found that this is not the case, the same approach should be taken as for plants possibly operating using different manufacturing approaches.

Electricity shall be accounted for as per the PEF Legislated Method section 4.4.2.1 (2016).

"The following section introduces two types of electricity mixes: (i) the consumption grid mix which reflects the total electricity mix transferred over a defined grid including green claimed or tracked electricity, and (ii) the residual grid mix, consumption mix (also named residual consumption mix), which characterizes the unclaimed, untracked or publicly shared electricity only.

In PEF studies the following electricity mix shall be used, in hierarchical order:

a) Supplier-specific electricity product shall be used if, for a country, there is a 100% tracking system

   in place, or if:

   i. available, and

   ii. the set of minimum criteria to ensure the contractual instruments are reliable is met.

b) The supplier-specific total electricity mix shall be used if:

   i. available, and

   ii. the set of minimum criteria to ensure the contractual instruments are reliable is met.

c) The 'country-specific residual grid mix, consumption mix' shall be used. Country-specific means the country in which the lifecycle stage or activity occurs. This may be an EU or non-EU country. The residual grid mix prevents double counting with the use of supplier-specific electricity mixes in (a) and (b).

d) As a last option, the average EU residual grid mix, consumption mix EU + European Free Trade Association (EFTA), or region representative residual grid mix, consumption mix, shall be used.

The environmental integrity of the use of supplier-specific electricity mix depends on ensuring that contractual instruments (for tracking) are reliable and unique. Without this, the PEF lacks the accuracy and consistency needed to drive product/corporate electricity procurement decisions and accurate consideration of the supplier specific mix by buyers of electricity. Therefore, a set of minimum criteria that relate to the integrity of the contractual instruments as reliable conveyers of environmental footprint information has been identified. They represent the minimum features necessary to use supplier-specific mix within PEF studies. "

Where not covered by the PEF excerpt above, impact data shall be sourced by the following prioritisation:

- PEF-directed data, where not of restricted usage;
- Ecoinvent 3.8 (unless justification can be given regarding why this is unsuitable);
  - For biobased inputs, WFLDB is preferred to Ecoinvent 3.8;
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Preference shall be first for studies that meet PEF criteria, followed by studies that have undergone an independent third-party critical review.

Where manufacturing is split across multiple stages and/or locations, the above approach shall be applied to each stage and intermediate transport stages included.

7.4 Manufacturing: transportation (transport from production to filling/packing and sealing)

Specific lifecycle data shall be used with respect to sourcing locations, and should be sought for transport routes, modes and load factors. Where unknown, the model outlined in the PEF Category Rules Guidance section 4.4.3.4 (2016) should be assumed (outlined in section 7.2).

Impact data should be sourced by the following prioritisation:

- PEF-directed data, where not of restricted usage;
- Ecoinvent 3.8 (unless justification can be given regarding why this is unsuitable);
    - For biobased inputs and food waste, WFLDB is preferred, with the exception of forest-based products where Ecoinvent 3.8 is preferred
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Preference shall be first for studies that meet PEF criteria, followed by studies that have undergone an independent third party critical review.

7.5 Filling/packing and sealing

Specific lifecycle data shall be sought. This shall include:

- Energy and other inputs, including auxiliary inputs, cooling top-ups and sterilisation and cleaning processes;
- Product losses arising during filling/packing and sealing and their disposal pathways;
- Packaging losses arising during forming, filling/packing and sealing and their disposal pathways;
- Secondary/tertiary packaging and palletisation for distribution;
- Storage times and associated energy use at filling/packing and sealing;
- Impact of filling product into packaging type. For example, filling into a carton may have greater/smaller impact than a bottle, which shall be attributed to the packaging.

Only where specific data cannot be sourced shall generic data be used.

Where specific data is unavailable, generic lifecycle data should be selected applying the following prioritisation:

- Critically reviewed industry data for the same packaging-product combination;
- Standard values provided in a PEF Category Rules or EPD PCR for the packaged product in question;
- Manufacturers' specification for the same packaging-product combination;
- Industry data for a similar packaging-product combination, adjusted based on expert guidance;
- Named independent third party without interest in food and consumer goods sector LCA, clearly documented and justified.

Impact data should be sourced by the following prioritisation:

- PEF-directed data, where not of restricted usage;
- Ecoinvent 3.8 (unless justification can be given regarding why this is unsuitable);
  - For biobased inputs and food waste, WFLDB is preferred, with the exception of forest-based products where Ecoinvent 3.8 is preferred
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Preference shall be first for studies that meet PEF criteria, followed by studies that have undergone an independent third-party critical review.

Impact data for the product, losses of which shall be included in the packaging lifecycle impacts from this lifecycle stage onwards, should be sourced in the following order of prioritisation:

- Producer specific, PEF-compliant emission factor;
- Industry emission factor, calculated in line with PEF guidance;
- PEF-directed data, where not of restricted usage;
- WFLDB;
- Ecoinvent 3.8;
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Preference shall be first for studies that meet PEF criteria, followed by studies that have undergone an independent third party critical review.

Impacts associated with product loss shall be reported separately throughout and reported only in the final, overall impacts for each lifecycle stage.

7.6 Distribution (filling/packing and sealing to retail)

This lifecycle stage shall only include distribution from the point at which the product is filled/packed and sealed, to the retailing outlets for the product. For reusable packaging (under a producer refill model), the transport back to the factory will be included within the reuse lifecycle stage (section 7.9). Specific lifecycle data should be sought for transport routes, modes, and load factors. Where unknown, the following model should be assumed:

- PEF Category Rules Guidance 4.4.3.4 (PEF, 2018), see section 7.2

Specific lifecycle data shall be sought for product losses during distribution. Only where this cannot be sourced should secondary data be used in the following prioritisation:

- Standard values provided by in part F of Annex II of the legislated PEF guidance (PEF, 2016);
- Critically reviewed industry data for the same packaging format-product combination;
- Standard values provided by an alternative PCR (e.g. EPD);
- Industry data for a similar packaging-product combination, adjusted based on industry expert guidance.

Impact data should be sourced by the following prioritisation:

- PEF-directed data, where not of restricted usage;
- Ecoinvent 3.8 (unless justification can be given regarding why this is unsuitable);
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Preference shall be first for studies that meet PEF criteria, followed by studies that have undergone an independent third-party critical review.

Where specific loading factors are unknown, the assumptions outlined in the PEF Category Rules Guidance 4.4.3.4 should be followed (as in section 7.2).

7.7 Retail

Storage activities at the retail stage require refrigerant gases and energy, and specific lifecycle data should be sought for these. Retail store overheads (general store energy and water use) shall be excluded. Energy shall be allocated between packaging and contents as per PEF Legislated Method section 4.4.5 (2016):

"Only the portion of the emissions and resources emitted or used at storage systems shall be allocated to the product stored. This allocation shall be based on the space (in m3) and time (in weeks) occupied by the product stored. For this, the total storage capacity of the system shall be known, and the product-specific volume and storage time shall be used to calculate the allocation factor (as the ratio between product-specific volume*time and storage capacity volume*time)."

Specific lifecycle data should be sought for waste secondary and tertiary packaging and the approaches described in the reuse (section 7.9) and disposal/ end-of-life (section 7.10) sections applied. The material quantities reported should be cross checked against those reported to be used in previous stages (i.e. all secondary and tertiary packaging).

Specific lifecycle data shall be sought for product waste due to damage/spoilage, applying the following definitions:

- Unsold product returned to producer shall be treated as food waste.
- Product waste averted via charity donation for human consumption shall be treated as food continuing in the supply stream (i.e. going on to consumer) but with product loss rates at consumer scaled up by a factor of 1.66 [1].
- Product waste averted via diversion for animal feed shall be treated as general product waste and accounted for using the approach described in section 7.10 as the packaging has not achieved its intended function of protecting and preserving the contents for consumption.
- All other product waste shall be accounted for using the approach described in section 7.10.

Where product loss occurs, both packaging and content loss should be considered.

1. The factor of 1.66 has been calculated from a baseline assumed wastage of food via charity donations of 40% ((Alexander and Smaje, 2008)) and a household wastage of 16% (WRAP 2021).

7.8 Consumer use

Consumer use of the product includes all activities and products that are required to use the product. Any waste that is generated from the consumer using the product, such as the packaging waste, is factored into the end-of-life stage (section 7.10) (PEF, 2018).

The following approach shall be taken:

- Capital goods associated with the preparation, rehydration, and consumption of the product shall be excluded as negligible, as shall cooking impacts. This means that preparation and service functions of the packaging, such as replacing the need for a baking tray or tin foil with a 'cook in bag' product, or selling a ready meal in an oven-proof container to avoid the need to transfer to an oven-proof dish, will not be captured. This is on the assumption that the impacts of these savings will be on a par with the impact of other capital goods and negligible in the extent of the LCA.
- Specific lifecycle data shall be sought regarding consumer storage practices (ambient/refrigerated) and duration, for example from market research or similar. Energy shall be allocated between packaging and contents as per PEF Legislated Method section 4.4.5 (2016) (see section 7.7)
- Specific lifecycle data shall be sought for product waste due to damage/spoilage during storage at consumer. All product waste shall be accounted for using the approach described in section 7.10. Where product loss occurs, both the packaging and the contents lost shall be considered.

7.9 Reuse

Packaging may be designed with reuse or refurbishment in mind to reduce environmental impacts. This shall be modelled by making the below adjustments to the above and below lifecycle stages. These adjustments shall be expressed separately to the overall impact of the lifecycle stage as a positive/negative number as necessary, as well as combined to give an overall stage impact.

The reuse rate shall be calculated through PEF Legislated Method 4.4.9.1 (2016). The number of reuses shall be determined as follows:

- Where primary data exists or can be collected, where industry data for the same packaging material and format can be sourced or where standard parameters are provided by a PEF Category Rules or EPD PCR, these data shall be used in the priority order here to calculate an actual number of reuses shall be employed:

$$\text{No. Reuses} = \frac{\text{\# of packaging units filled during packaging lifetime (\#Fi)}}{\text{\# of packaging units at inital stock plus purchased over packaging lifetime (\#B)}}$$

- Where such data is not available, an assumption of an average of one reuse cycle shall be employed (EPD, 2021).

In both cases, sensitivities shall be run for the following scenarios: no reuse, 1 reuse, 10% theoretical reuses, 50% theoretical reuses, 100% theoretical reuses.

Where a comparison between packaging types is being made, the break-even point (number of reuses required for per use impacts to equal that of alternative single use) shall be calculated and reported. For example, if a reusable container is reused 50 times within its lifetime, it shall be compared to the impact of 50 single use containers. The break-even point is critical to determining the viability of reusable packaging options as a means to reduce environmental impact, as it will identify whether the number of reuses required to be 'better' is likely/feasible to be achieved.

Specific lifecycle data shall be sought for secondary/tertiary packaging used in distribution from disposal to reprocessing and reprocessing to filling; all reprocessing inputs; and all waste arising during reprocessing and transit. Specific lifecycle data should also be sought for transport routes, modes, and load factors - disposal to reprocessing, and reprocessing to refilling. This should follow the guidance laid out in the 'Distribution' section 7.6.

Where primary data is unavailable, secondary data may be used for inputs not anticipated to exceed 20% total stage impact in any included lifecycle impact, as indicated by a hotspotting exercise.

Secondary lifecycle data shall be selected applying the following prioritisation:

- Critically reviewed industry data for the same packaging material and form;
- Standard values provided in a PEFCR or EPD PCR for the packaging in question;
- Manufacturers' specification for the same packaging;
- Industry data or PEFCR/EPD PCR values for a similar packaging, adjusted based on expert guidance;
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Preference shall be first for studies that meet PEF criteria, followed by studies that have undergone an independent third-party critical review.

In addition to the lifecycle impacts associated with collection and reprocessing, the following adjustments to other lifecycle stages are to be made, as per PEF Legislated Method 4.4.9.2 (2016):

Raw material acquisition:

- "The reuse rate determines the quantity of packaging material consumed per product sold. The raw material consumption shall be calculated by dividing the actual weight of the packaging by the number of times this packaging is reused, PEF Legislated Method (2016)."
- The impact of reuse will therefore be expressed as the (negative) change in raw material impacts.

Manufacturing: transportation (transport from production to filling/packing and sealing):

- "The reuse rate determines the quantity of transport that is needed per product sold. The transport impact shall be calculated by dividing the one-way trip impact by the number of times the packaging is reused." PEF Legislated Method (2016).
- The impact of reuse will therefore be expressed as the (negative) change in transportation impacts.

Distribution:

- "In addition to the transport needed to go to the client, the return transport shall also be taken into account."

- The impact of reuse will therefore be expressed as an additional distribution impact and will be modelled under PEF Legislated Method 4.4.3 (2016) on modelling transport.

Manufacturing or filling/packing and sealing (as appropriate):

- "Once the empty packaging is returned to the product factory, energy and resource use shall be taken into consideration as regards cleaning, repairing or refilling (if applicable)." PEF Legislated Method (2016).
- The impact of reuse will therefore be expressed as an additional manufacturing and/or filling/packing and sealing impact.

End-of-life:

- "The reuse rate determines the quantity of packaging material (per product sold) to be treated at the end-of-life. The amount of packaging treated at the end-of-life shall be calculated by dividing the actual weight of the packaging by the number of times it was reused."
- The impact of reuse will therefore be expressed as the (negative) change in end-of-life impacts.

7.10 End-of-life

Primary data on consumer use and end-of-life are unlikely to be available, in which case secondary data should be used, reflecting real world outcomes in the relevant geographic region. Specific lifecycle data shall be sought on end-of-life destination (recycling, incineration, landfill) for stages upstream of and including retail.

Where primary data cannot be found, secondary lifecycle data shall be used in the following order of priority. Temporal, material and cultural/infrastructural relevance shall be acknowledged:

- Published annual/biannual national disposal ratios, specific to material (most recent of UK government waste reporting statistics or the appropriate Packflow report);
- Published annual/biannual regional (e.g. European) disposal ratios, specific to material;
- PEF default figures for the Recycling Output Rate (R2), available in Part C of PEF Annex II and applied as instructed in the PEF Legislated Method 4.4.8.9 (2016).

For municipal solid waste, the default values provided in Part C of Annex II of the PEF shall be used for the split between landfill and incineration, unless more up-to-date national (e.g. Environment Agency) or supply chain-specific industry values are available.

Estimated transportation distances for the different waste streams to landfill/incineration/recycling shall be taken from the UK Government Greenhouse Gas emissions (GHG) Conversion Factors for Company Reporting Methodology document. Unless evidenced otherwise, mode of transport/vehicle type shall also be based on the UK Government GHG Conversion Factors for Company Reporting Methodology.

Impact data for transport should be sourced by the following prioritisation:

- PEF-directed data, where not of restricted usage;
- Ecoinvent 3.8 (unless justification can be given regarding why this is unsuitable);
    - For biobased inputs and food waste, WFLDB is preferred, with the exception of forest-based products where Ecoinvent 3.8 is preferred
- Alternative secondary data, drawn from reputable, referenced sources and based on clear and defensible assumptions. Priority shall be given to studies that are PEF compliant and critically reviewed by an independent third-party panel.

8 Measuring impacts

8.1 Enviromental impact areas

8.2 Climate change/ Global warming potential (GWP)

8.3 Ozone depletion potential

8.4 Particulate matter

8.5 Ionising radiation

8.6 Photochemical ozone formation

8.7 Acidification

8.8 Eutrophication potential (kg PO43- eq.)

8.9 Ecotoxicity, freshwater

8.10 Human toxicity, cancer and non-cancer

8.11 Land use

8.12 Water use

8.13 Resource use, fossil fuel

8.14 Resource use, ultimate reserves (minerals and metals)

8.1 Enviromental impact areas

The environmental performance of packaging shall be measured across 13 impact areas: climate change/global warming potential, ozone depletion potential, particulate matter, ionising radiation, photochemical ozone formation, acidification, eutrophication potential (kg PO_4^{3-} eq.), ecotoxicity, freshwater, human toxicity (cancer and non-cancer), land use, water use, resource use (fossil fuel) and resource use (ultimate reserves – minerals and metals).

All these impact categories shall be reported on unless there is clear evidence and justification as to why they can be excluded. The four impact categories used for the baseline and scenario modelling of the industry shared ambition (climate change, land use, water scarcity, and virgin resource consumption – as captured by the two 'resource use' metrics) should be included irrespective of perceived applicability. It is anticipated that there will be very few cases where other impact categories can be excluded

8.2 Climate change/ Global warming potential (GWP)

Four GWP indicators shall be declared:

- GWP-fossil,
- GWP-biogenic,
- GWP-land use and land use change (LULUC), and
- GWP-TOTAL (the sum of the other three GWP indicators).

For climate change and greenhouse gas emissions (GHG) indicators the latest Intergovernmental Panel on Climate Change (IPCC) characterisation factors shall always be used, unless otherwise justified. This assessment shall always include emissions and removals of GHG from fossil sources, biogenic sources and land use/land use change and shall be recorded separately for these three different sources.

If emissions and removals linked to the use phase or end of life stage of the product take place more than ten years after the product's use, then the timing of the emissions and removals will be specified within the reports (EPD, 2021). However, any credits linked to such temporary and permanent carbon storage or delayed emissions shall not be included in the calculation, i.e. there shall be no discounting of emissions and/or removals over time (PEF, 2016). The effect of the timing of GHG emissions and removals can be documented separately within the report if desired.

Carbon sequestration and stored carbon

In some scenarios, carbon may be sequestered or stored by a material over its lifecycle, such as cement, or where it has a biogenic carbon element, such as a wooden product (EPD, 2021)[2].

2. This guidance will require updates in line with Greenhouse Gas Protocol guideline releases.

The carbon storage for these products can only be taken into consideration in the lifecycle if the carbon stored will not be re-emitted within 100 years (EPD, 2021) .

Land management changes, for example in soil or forests, are another area that can cause changes within the stored carbon. Companies should account for this in conformance with the GHG Protocol Land Sector and Removals Guidance (publication expected 2023). In the meantime, however:

- Carbon sequestered by native forests or as soil carbon (through e.g. improved land management or grassland management) will not be included within greenhouse gas quantification, unless within the scope of the primary empirical data outlined below. Estimated soil carbon stock changes may be reported as additional environmental information and, if so, shall be modelled following the PAS 2050:2011 (BSI 2011)/PAS2050-1:2012 (BSI 2012) for horticultural products standard.
- Land use change emissions and wider removals shall be calculated following the PAS 2050:2011 (BSI 2011)/PAS2050-1:2012 (BSI 2012) for horticultural products standards and as outlined in section 4.4.10.3 of Annex I. PEF Legislated Method (2016). Only direct land use change - land use change that happens as a direct result of transforming a type of land into another, possibly affecting stored carbon directly within that area, but not in other systems (e.g. covering forest for agriculture) (PEF, 2016) – shall be included. Indirect land use change – when a change to land use results in a change of land that is not covered within the system boundaries (PEF, 2016) – can be reported within additional information but shall not be included in calculated impacts, due to the current lack of an agreed methodology.

- Where primary evidence of soil carbon change over a minimum of three years and three separate measurements can be provided for all or part of land used, the changes in soil carbon recorded on the measured parcels of land without extrapolation to surrounding land parcels, whether similar or dissimilar, shall be used instead of secondary direct LULUC emission estimates. This shall apply whether the observed changes constitute increases or decreases.

Where carbon sequestration and storage covered by the above is sold as carbon credits or offsets to one or more third parties, the total amount 'sold' must be reported.

Offsetting

Offsetting is the term used to describe third-party emission mitigation schemes and are used to compensate for activities that give rise to emissions. These offsets are calculated to a relative baseline within a hypothetical scenario and will not be used in the climate change indicators. These offsets or purchases of carbon neutral products can be declared separately within the final report of the assessment but shall not be included in the final assessment output.

Aircraft emissions

Greenhouse gas emissions emitted from aircrafts will be included and documented separately to the assessment if found to be significant and can be calculated using ISO 14067 guidance (EPD, 2021).

8.3 Ozone depletion potential

Ozone depletion potential is defined as the degradation of the stratosphere as a result of increased ozone-depleting substances within greenhouse gas emissions, such as chlorofluorocarbons (CFCs).

It shall be reported using the ReCiPe 2016 (H) impact category, known as 'stratosphere ozone depletion', as implemented in the PEF legislated method (PEF, 2016). This method uses the Environmental Development of Industrial Products (EDIP) model based on the Ozone Depleting Potentials of the World Meteorological Organisation (WMO) over an infinite time horizon (WMO 2014 + integrations), kg CFC-11 $_{eq}$ (PEF, 2016). The EDIP model is a normalisation method developed at the Technical University of Demark, as specified within the PEF legislated method (2016).

8.4 Particulate matter

The 'particulate matter' impact category accounts for any adverse impacts to human health caused by particulate matter and its precursors (NO_x, SO_x, NH_3). It shall be reported using the PM model (Fantke et al., 2016 in UNEP 2016) as recommended by the PEF legislation and expressed in 'disease incidence'.

8.5 Ionising radiation

This impact accounts for any adverse impacts to human health resulting from the release of radioactive matter. It shall be modelled, as specified in the PEF legislation and implemented in ReCiPe 2016 (H) as 'Ionising radiation', using the Human health effect model developed by Dreicer et al. 1995 (Frischknecht et al, 2000), reported in kBq $U_{235\ eq}$.

8.6 Photochemical ozone formation

Photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in presence of nitrogen oxides (NOx) and sunlight causes the formation of ozone at the ground level of the troposphere. (PEF, 2016). It was implemented in 2008 by PEF group, and shall be modelled in ReCiPe 2016, and reported in kg NMVOC $_{eq}$.

8.7 Acidification

EDIP describes acidification as adverse reactions caused by sulphur compounds in the lower atmosphere, causing acidification of soils and waters, and impacting the surrounding environment. It shall be specified as accumulated exceedance in PEF, which was developed by Seppälä et al. (2006), and Posch et al. (2008), and shall be reported in mol H^{+}_{eq}. In EDP, it should be specified as acidification potential which is accessible through CML-IA characterisation factors (version January 2016), and was developed by Hauschild and Wenzel (1998).

8.8 Eutrophication potential (kg PO43- eq.)

Spill-off of mainly nitrogen and phosphorus from sewage and farmlands into water sources causes a reduction of available oxygen, due to increased algae and vegetation growth. PEF has divided guidance on reporting eutrophication potential into two areas:

- terrestrial shall be specified as accumulated exceedance (Seppälä et al. 2006, Posch et al, 2008) and shall be reported in mol Neq
- freshwater and marine are modelled by EUTREND, and shall be applied as in ReCiPe 2016, and shall be reported separately, and combined in kg P_{eq}.

8.9 Ecotoxicity, freshwater

Impact of a multitude of toxic materials and by-products which cause damage to species, structure, and function of ecosystems. It shall be reported as specified using USEtox2.1 and shall be reported in CTU_e, which is inline with PEF guidance for ecotoxicity.

8.10 Human toxicity, cancer and non-cancer

A category that covers health impacts on humans that cause cancer and non-cancer related ailment. Cancer and non-cancer shall be reported and implemented separately using USEtox2.1 and reported in CTU_h.

8.11 Land use

Transformation of land resulting in relative species loss in terrestrial ecosystems. It shall be reported as implemented in ReCiPe 2016 as land use (area) and shall be reported as m^2*year annual land converted.

8.12 Water use

Covering the relative available water remaining after demand from humans and aquatic organisms has been met. It shall be reported using the AWARE model, as recommended by PEF and EPD legislation and it shall be reported in m^3.

8.13 Resource use, fossil fuel

Requirement and consumption of non-renewable fossil fuels and shall be reported using CML v6.1 (2016) as recommended by PEF and shall reported in MJ net calorific value.

8.14 Resource use, ultimate reserves (minerals and metals)

Requirement and consumption of non-renewable mineral and metal sources and shall be reported using CML 6.1 (2016) as per PEF guidance and shall be reported in kg Sb_{eq}.

9 Presentation and interpretation of results

9.1 Interpreting results

9.2 Sensitivity analysis

9.3 Results transparency and feedback

9.1 Interpreting results

The results shall be presented to clearly show the impact of the packaging for each of the included impact categories and the main sources of the impact in each. They should also outline any limitations encountered during the assessment, including an evaluation of the data quality, as required within ISO standards, and clear identification of all inclusions/exclusions and assumptions.

Results for each of the environmental impacts shall be presented for the lifecycle of the packaging. After this, the results should show the contribution of each stage for the lifecycle of the packaging. All sources for data and calculations, including references and justification for use, should be transparently included within the report to increase consistency and repeatability of the assessment. All emission factor references should also be provided. It is preferred that the emission factors themselves are also reported, particularly for custom/primary factors. However, it is recognised that in many cases, confidentiality or licence conditions will preclude this.

Careful terminology is required when reporting results from an LCA.

It is important to consider all impact categories, rather than 'cherry picking' a small subset of indicators to effectively inform packaging decisions. This avoids the results being misinterpreted.

For example, undertaking an LCA and reporting on 10 impact categories but only communicating results against four indicators e.g. "packaging type A performed better than type B across four indicators" suggests that the indicators, and scale of impacts, are all equal. This is not generally the case.

In the Figure below, three indicators have been used as an example - carbon (kgCO2e), water scarcity (litres) and land use (m3). If taking the results as stated that packaging B performed better across two (water and land use) indicators, the impression is given that packaging B is better. However, when looking at the results across all indicators, the opposite is a more accurate conclusion to make.

Figure 3. Example of interpreting results between two packaging products

	Packaging A	Packaging B
$kgCO_2e$	0.5	2.0
Litres Water	0.3	0.28
m^3 Land use	0.4	0.2

9.2 Sensitivity analysis

Sensitivity analysis is used to determine which pieces of data hold the most influence on LCAs results, or to assess the potential margin of error in the presented results arising from assumptions and methodological decisions made in the assessment. This is particularly important in cases where data has been used that has high uncertainty or low quality, or assumptions or estimates have had to be made about key lifecycle processes. Inputs like this should be varied within a realistic range to determine the impact of the data on the results; a good method for this is to set a percentage-based target for variation in the result. For example, calculating the change in the data required for a positive or negative variation of 5%, 10% and 20%. Recalculating the lifecycle impacts under alternative possible scenarios is another possible approach.

Completing a sensitivity analysis within a LCAs can future-proof decision-making by testing the sensitivity of findings to future trends with a high likelihood. (e.g. grid and transport decarbonisation).

For food and consumer goods packaging LCAs, practitioners should, as standard practice, apply sensitivity analysis to:

- food product losses across the lifecycle;
- the carbon intensity of electricity;
- the carbon intensity of transport;
- reuse scenarios;
- end-of-life outcome for packaging waste;
- conclusions and recommendations.

9.3 Results transparency and feedback

Improving transparency and knowledge sharing on packaging impacts within the food and consumer goods sector is critical to accelerating and scaling sustainability, and achieving the industry shared ambition to halve the environmental impacts of packaging systems by 2030.

Any LCA which is used to make environmental claims shall, in accordance with ISO standards and advertising requirements, be published to ensure full transparency and accountability. When making environmental claims surrounding products, it is recommended to follow the Governmental and Competition and Market's Authority (CMA) Green Claims Code to avoid risks of greenwashing. Even where environmental claims are not made however, industry stakeholders should share their LCAs in full to maximise their environmental benefit and avoid unnecessary replication.

To encourage best practice and transparency of LCAs across the sector, we would encourage you to continually share your feedback with us so we can review, update and share best practice as appropriate.

Abbreviations

- BEIS - Department for Business, Energy and Industrial Strategy (UK Government)
- CTU - Comparative toxic unit
- EU - European Union
- EFTA – European Free Trade Association
- EfW – Energy from Waste
- EPD – Environmental product declaration
- GHG – Greenhouse Gas emissions
- GWP – Global Warming Potential
- IGD – Institute of Grocery Distribution
- IPCC - Intergovernmental Panel on Climate Change
- ISO – International Organisation for Standardisation
- LCA – Lifecycle assessment
- LCI – Lifecycle inventory
- LULUC – Land use and Land use change
- ODPs - Ozone Depletion Potentials
- PAS – Publicly Available Specification
- PCR – Product Category Rules
- PEF – Product Environmental Footprint
- PPP – Polluter pays principle
- SETAC - Society of Environmental Toxicology and Chemistry
- UN – United Nations
- UN CPC – United Nations Central Product Classification
- UNEP – United Nations Environment Programme
- WFLDB – World Food LCA Database
- WMO - World Meteorological Organisation

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Annex I

Material composition of packaging

Below is the classification system used within Europe for packaging, as used by PEF and EPD. Using CPC codes allows an easy method to compare between LCAs of similar packaging types. EPD provide a framework of categorising packaging types, as outlined in the table, which involves:

- Checking whether the packaging is structural or commercial
- Checking the packaging type
- Checking the packaging material through the available CPC codes

Structural packaging

It can also be defined as distribution packaging or transport packaging (tertiary packaging)

Main function	Type	Applicable CPC codes
Structural	Tanks, reservoirs, and containers	44210 - 364
	Pallets, box pallets and other load boards	317 – 364
	Casks, barrels, vats, and tubs	317 – 364
	Sacks and bags	36410 – 32152
	Packing cases, boxes, crates, drums, and similar packings	317 – 32153 – 364 – 422
	Paper and paper board (tertiary)	3219
	Plates, foils, sheets, films of metals and/or plastics (tertiary)	36390 – 41535 - 36390

Commercial packaging

Includes 2 categories: industrial packaging and consumer packaging (primary and secondary packaging)

Main function	Type	Applicable CPC codes
Commercial	Cartons, boxes, cases, and other packaging	32153 – 364
	Bottles, jars, phials, barrels, tins, cans, tubes, and other containers of a kind used for conveyance or packing of goods	35410 - 32152
	Sacks and bags of paper and plastic	36410 – 32152
	Laboratory, hygienic or pharmaceutical glassware; Ampoules of glass and plastic	37195 – 364
	Paper and paperboard (printed and un-printed)	3219