HORIZON-CL6-2021-CIRCBIO-01
Innovative solutions to over-packaging and single-use plastics, and related microplastic pollution (IA)

BUDDIE-PACK

Business-driven systemic solutions for sustainable plastic packaging reuse schemes in mass market applications
Starting date of the project: 01/09/2022
Duration: 42 months

= Deliverable: D7.1 =

Definition of goal & scope, assessment methodology

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AUTHORS

Author	Institution	Contact (e-mail, phone)
Justine GLOZ	IPC	justine.gloz@ct-ipc.com
Ewen RONDON	IPC	ewen.rondon@ct-ipc.com
Rachael ROTHMAN	USFD	r.rothman@sheffield.ac.uk
Mathieu LIONS	IPC	mathieu.lions@ct-ipc.com
Maoli COMPAY	IPC	maoli.compay@ct-ipc.com

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Reviewers		Validation date
Work Package Leader	Justine GLOZ	24/02/2023
Scientific advisor	Catherine COLIN	01/03/2023
Coordinator	Marie-Alix BERTHET	09/03/2023
Work Package Leader	Justine GLOZ	16/07/2024

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Point of Contact	Name: Justine Gloz Partner: IPC Address: 2 rue Pierre & Marie Curie 01100 BELLIGNAT - France Phone: +33 (0)4 74 81 92 62 E-mail: Justine.gloz@ct-ipc.com
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Acronym description

ADEME	Agence De l'Environnement et de la Maîtrise de l'Energie
CFF	Circular Footprint Formula
CSR	Corporate Social Responsibilities
EC	European Commission
EoL	End-of-Life
EPD	Environmental Product Declaration
EPLCA	European Platform for Life Cycle Assessment
GA	Grant Agreement
ILCD	International Reference Life Cycle Data System
JRC	Joint Research Center
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
SLCA	Social Life Cycle Assessment
NGO	Non-Governmental Organisation
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
RPC	Reusable Plastic Container
SIA	Social Impact Assessment
UC	Use-Case
WP	Work Package

Executive Summary

The aim of the deliverable D7.1 is to identify the methodologies and data available for the screening LCAs, LCCs and SLCAs, to perform the six use-cases full circularity assessment. It will present the WP7 projects steps to go from the screening studies with methodological and data uncertainties to a harmonized overall methodology.

In the first part, a literature review is performed to identify the existing methodologies and studies, preferably specific to the use-cases, to reusable packaging or to packaging in general. For LCA, some studies with a robust enough methodology were found on scenarios close to the Buddie-Pack use-cases. Two main methodologies are identified, the PEF and the ADEME methodologies, but each with their defaults for reusable packaging modelling. For LCCs, one study was found on the economic impacts of a reusable packaging, and the other ones are on an expanded perimeter of circular economy in general. There are existing methods but no specific one for packaging and reusable packaging modelling. For SLCAs, they are not many studies in general. Therefore, specific studies on reusable packaging were not found, two studies on packaging have been selected and the other ones are not in the same industrial sector but are interesting for their methodology. For the methodologies benchmark, general guidelines have been found but they don't give specific indications for packaging systems.

In the second part, the methodology chosen for the screening studies and the full circularity assessment are chosen. As it has been seen in the precedent part, LCA is the assessment with the most advanced work on methodology, and the goal of the screenings will be mainly to create a harmonized method, creating a sort of PEFCR with the inputs of the ADEME methodology. The screenings and full assessment will use the Simapro software. For LCC, the work on methodology will be mainly based on IPC experience, using a method already designed and applied in a previous EU project (H2020 CIMPA). A Life Cycle Cost screening based on the data collected in the LCA screening, combined with a Total Cost of Ownership analysis, will lead to deploy properly financial indicators to measure the profitability of the whole system and progressively integrate externalities. The screening will help develop a specific assessment tool. The most work on methodology will be on the SLCA part, considering that both partners will have to develop an expertise, based on guidelines documents and use-case leaders Corporate Social Responsibilities. It will use the online Risk Mapping Tool of the Social Hotspots DataBase.

Finally, the goal and scope written for the screening studies, and the potential changes for the full assessment, are presented for each use-case. The goal is general to all the use-cases, as they all aim to identify the hotspots, the thresholds to make a reusable packaging better than its single use version, and challenge the methodological choices for the full circularity assessment. Then the scope for each use-case screening study is shown, with the steps included in the perimeter and the excluded ones, both for the single-use and the reusable packaging. The sources used and remaining uncertainties are given to explain what assumptions could change during the screening steps. Eventually it is explained that the steps excluded from the screening studies for various reasons will be included in the full assessment.

In conclusion, the work done with this task identified a methodology for each planned assessment. The screening studies will apply these methodologies. When relevant, the project team expect to adapt and change some methodological choices during the project execution. Indeed, this deliverable has been written in the early stage of Buddie-Pack, before key choices from the other work packages. Moreover, the screening phase is an iterative process destined to challenge the methodological choices made in this deliverable.

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1. Introduction

The aim of the deliverable D7.1 is to identify the methodologies and data available for the screening LCAs, LCCs and SLCAs, and to plan how the screening studies will answer the remaining methodological uncertainties for the full assessment phase.

Life Cycle Assessment (LCA) is a multi-criteria environmental evaluation method for a product or service. It quantifies the impact of the product over its entire life cycle, i.e., from the extraction of raw materials to the end of its life, based on several impact categories. The LCA records all the material and energy flows reported for each phase of the life cycle, in order to convert them into environmental impacts such as climate change, depletion of fossil resources, human toxicity, etc.
In the case of reusable plastic packaging, the LCA can be used to assess whether the identified reuse scenarios provide environmental benefits other than saving raw materials, or whether they cause impact transfers. Indeed, other environmental issues than plastic wastes, such as greenhouse gas emissions or air pollutants, are currently or will be regulated. It is therefore important to carry out LCAs to identify key design aspects that will lead to globally virtuous reuse scenario.
Currently, there are general LCA standards and methodologies, but few sector-specific benchmarks for plastic packaging or reuse. As a consequence, the existing LCAs on reusable packaging lack harmonisation and do not allow conclusions to be drawn on the environmental superiority or not of reusable packaging compared to single-use packaging. The aim of this deliverable will be to review the existing methodologies and studies to draw ideas to harmonize reusable packaging LCAs: which life cycle steps must be studied, how to model them, which impact indicators to choose…

The objective of the life cycle cost (LCC) is to serve as a decision support tool for future investment while taking into account the many parameters seen by a product along its life (e.g., environmental assessment, end-of-life assessment, regulatory compliance assessment, etc.). The details of the boundaries, cost categories, and cost carriers that are included in the analysis, as well as how they are quantified and aggregated, will determine the LCC method and approach to be applied, as well as the interpretation of the results. Hence, in the present deliverable, several methods regularly used for LCC analysis will be presented (ABC method, TCO method, etc.). The idea is to identify which methods answer partially or completely to the project needs. Based on our experience, a hybrid methodology will be favoured for the BUDDIE-PACK project. This method will be described in the document and its objectives highlighted.

Social Impact Assessment (SIA) is a methodology dedicated to the review of social consequences of an organisation or of infrastructure projects. Social Life Cycle Assessment (SLCA) is a method that can be applied to evaluate the social aspects of products, their real and potential positive and negative impacts throughout the life cycle. Even if SLCA methodology is still under development, it complements environmental LCA and LCC and can be applied on the same life cycle stages, alone or in combination with the other 2 techniques. Social impacts are assessed by stakeholder categories (Workers, Consumers, Local Community, Society, Value Chain Actors, …). Those categories are then broken down into subcategories (Fair Wages, Health and Safety, Discrimination, …). The challenge is to determine the subcategories and the appropriate indicators within these subcategories. SLCA uses generic and site-specific data, it can be quantitative, semi-quantitative or qualitative, collected with questionnaires, interviews, organization documents, NGOs reports, and so on. It involves many stakeholders, along complex value chains, and data collection can be very tricky. For this project, the aim of the Social Impact Assessment study will be to identify the social hotspots linked to reusable packaging. We will review and use the existing methodological frameworks to initiate our study, but we aim to adapt the existing frameworks to a packaging-specific methodology.

To do so, the report is divided as follows. In the first part, a literature review is performed to identify the existing methodologies and studies, preferably specific to the use-cases, to reusable packaging or to packaging in general. In a second part, the methodologies and tools to perform the comparative studies between a single-use and reusable packaging are chosen. Finally, the goal and scope written for the screening studies and the projects steps to obtain a full circular assessment of the reusable packaging are presented for each use-case.

2. Literature review on Reusable Plastic Packaging

2.1. Life Cycle Assessment

2.1.1. Benchmark of the existing methodologies

As it can be seen on Figure 1 below, there are several levels of LCA methodologies, going from the most reproducible (standards) to the most specific (tools). The aim of the benchmark performed in this task is to overview what methodologies are available and applicable to reusable packaging or packaging in general, and what methodological guidelines are particularly interesting to apply for our use-cases' LCAs.

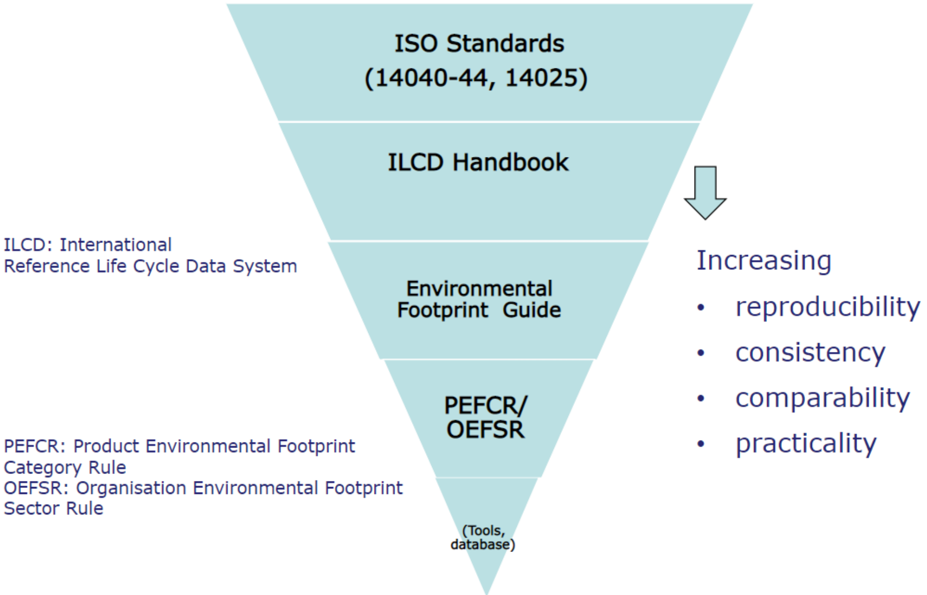


Figure 1: Overview of existing LCA methodologies (Source: Galatola M., European Commission[46])

For this benchmark, six methodologies were reviewed to determine the relevance of their guidance for conducting LCAs of reusable packaging. The detail of this benchmark is available in Annex 1 and the summary in the Table 1 below.

Table 1: Summary of LCA methodologies benchmark

Methodology	ISO 14044	PEF	FD CEN/TR 13910	ADEME methodology	EPD Packaging CR	KIDV tool
General information						
Last publication year	2006	2021	2010	2022	2019	2020
Type	General norm on LCA	Guidelines for european eco-labelling	Guidelines for LCA	Guidelines for comparative LCA	Guidelines for eco-labelling	Simplified tool
Follow ISO 14044	/	Yes	Yes	Yes	Yes	No
Specific to packaging	No	No	Yes	Yes	Yes	Yes
Methodological guidelines						
Reuse rate	/	2 formulas: for a marketed package & for a package under development	/	2 formulas: for a marketed package & for a package under development	/	/

Transport allocation	/	Utilisation ratio (real load/payload)+empty return rate	/	Utilisation ratio (real load/payload)+empty return rate	/	Tons.km
EoL allocation	/	CFF using JRC reference values	/	CFF with French reference values	100:0	CFF with JRC reference values
Results presentation	Characterisation	Characterisation/Normalisation/ Weighting	Characterisation	Characterisation	Characterisation	Characterisation
Characterisation Impact categories	/	16 from ILCD (Characterisation)+ Restricted choice from Normalisation/ Weighting	16 from ILCD	16 from ILCD + Restricted choice imposed	13 from EPD general framework	Climate change
Inventory categories	/	/	/	/	Use of resources, Waste and output flows	Total cost

2.1.2. Information drawn from the literature review

As the aim of the methodology definition in this deliverable is to harmonise as much as possible LCAs for reusable packaging, it is important to analyse the methods most used in existing studies to see if there is a consensus among them.

There are already existing literature reviews on comparative LCAs between single-use plastic packaging and their alternatives. The decision has been made to make the literature review based on the following reviews made by governmental agencies or NGOs:

- Gueudet, A., Guiot, M., Pasquier, S., Parisot, F., 2021. Réemploi des emballages et alternatives aux emballages plastiques à usage unique - Revue bibliographique des ACV sur les emballages et contenants pour la restauration.
- United Nations Environment Programme, 2020. Single-use plastic take-away food packaging and its alternatives - Recommendations from Life Cycle Assessments.
- United Nations Environment Programme, 2021. Single-use plastic tableware and its alternatives – Recommendations from Life Cycle Assessments.
- Zero Waste Europe, Reloop, 2020. Reusable vs single-use packaging - A review of environmental impacts.

The criteria used to select the studies from the previous documents are the following ones:

- The study provides an environmental impact comparison between reusable and single-use packaging alternatives aimed for applications as close as possible to the studied use-cases in Buddie-Pack ;
- The study follows the LCA methodology according to ISO 14040- 14044 standards;
- The study was published between the year 2000 and the actual year.

In the end, eight LCAs were selected and analysed in Annex 2.

2.2. Life Cycle Cost

2.2.1. Benchmark of the existing methodologies

In order to "measure" the sustainability of a project, technology or product it is important to analyse the three axes: environmental, economic and social. The objective of LCC assessment methods is to quantify the life cycle cost to serve as a decision support tool, the analysis draws on data from other assessments (e.g., environmental assessment, end-of-life assessment, regulatory compliance assessment, etc.). The details of the

boundaries, cost categories, and cost carriers that are included in the analysis, as well as how they are quantified and aggregated, will determine the LCC method and approach to be applied, as well as the interpretation of the results.
In the following sections, we will describe a number of existing economic analysis methods and finally describe the method used for this project and the reasons for this choice.

ABC Method

The activity-based costing (ABC) methodology was developed by Cooper and Kaplan as a way to address the problem of the increasing share that indirect fixed costs have on a product's cost structure, derived from the process of industrialization and automatization of the production processes.
ABC costing systems estimate the costs of resources used or spent in a given process, consisting of a set of activities, to produce products or services. In this system, it is assumed that resources are consumed by the activities needed to produce the products or services.
The ABC method can be defined as follows: the cost objects (products, customers...) consume activities which, themselves, consume resources. This method allows to analyse the costs by activity, using cost drivers.

- A **cost driver (or activity driver)** measures how cost objects consume activities. They allow to allocate the cost of the activity according to the number of drivers consumed by the cost objects: products, processes, projects, customers. Example: number of manipulations, number of adjustments, number of hours of production work...

What is the objective of the ABC method?
The objective of the ABC method is to model expenses by activity in order to better manage them. It allows to analyse which activity is the most profitable and which is the least profitable. The objective is therefore to identify the real cost factors and potential savings in order to improve the profitability of products and customers.

This method would allow us to compare the profitability of two solutions, which is an incomplete answer to the questions asked in Buddie-Pack. For this reason, we do not use this method.

Material flow cost accounting, MFCA Method

Material flow cost accounting (MFCA) aims to calculate the "cost" of waste. It takes into consideration the obvious costs related to waste management (e.g., waste container rental, disposal fees, gasoline surcharge, etc.) as well as hidden costs (e.g., purchase of materials, energy expenses, labor costs, capital costs, depreciation of certain equipment, etc.). This approach, which originated in Germany and is widely used in Japan, is now the subject of standard ISO 14051 :2011.

The objective of this approach is to identify and measure the real costs associated with waste. It is therefore the sum of three types of costs: material costs, system costs and waste management costs.

Once this analysis is completed, managers can better assess the economic impacts associated with waste and consider improvement measures such as input substitution, process modification, internal recycling or by-product sales. Among other things, the data from an MFCA can be used to calculate internal rates of return (IRRs) related to process modifications or equipment purchases.

To determine whether a cost should be included in the analysis, it is necessary to understand its behaviour. The following Table 2 helps to differentiate between types of costs. For the remainder of the study, we will use these cost definitions.

Table 2: Definition of different types of cost

Cost type	Definition	Examples
Cost behaviour		
Fixed	Does not vary according to the production volume of the the organization	• Fixed assets • Equipment
Variable	Changes according to the production volume of the the organization	• Raw materials • Manufacturing labor manufacturing
Direct/Indirect		
Direct	Being attributable to a particular product	• Raw materials • Manufacturing labor manufacturing
Indirect	Concerning the whole organization and that can hardly be attributed to a particular product in particular	• Fixed assets • Administrative administrative
Avoidable/Unavoidable		
Avoidable	Future costs that may change as a result of a decision	• Raw materials • Energy
Unavoidable	Costs that cannot be avoided or reduced regardless of whatever decision is made	• Fixed assets • Equipment

In management accounting, relevant costs refer to the set of costs that can be affected by a decision. It is the context that dictates whether a cost is relevant or not. In the context of a MFCA, a cost is relevant if it can be changed as a result of the implementation of reduction, reuse or recycling measures. Relevant costs usually relate to future, variable and/or avoidable expenditures.

The MFCA approach is limited to measuring waste flows and costs. These data are therefore insufficient because it only concerns the end of life of products, which is why we do not favour this method.

"Direct" LCC method or LCC screening

LCC analysis covers a defined list of costs over the physical, technical, economic or functional life of an asset, often on a cradle to cradle or cradle to grave basis, thus encompassing the entire life cycle. LCC analysis can also be part of a strategic review of supply pathways or objectives (such as improving sustainability or functionality).
Practice may vary among users as to whether only the costs incurred by the client of the analysis are considered, or whether client/company costs, etc. are also included.
The following cost elements should be considered when calculating the life cycle costs of a particular procurement item:

- Acquisition costs: for example, purchase price or lease costs.
- Transportation costs (if not already included in the purchase cost).
- Installation costs: for example, for heating and lighting systems.

- Operation and maintenance costs: these include, for example, energy costs (electricity, gasoline, diesel), costs of potable water supply and sanitation (e.g., for cleaning services), costs of consumables (toner cartridges, lubricants, cleaning products), taxes, insurance costs, training costs, maintenance and service costs, repair costs (spare parts, man-hours), costs of necessary accessories.
- Disposal costs: transportation to the disposal company and cost of treatment and disposal
- Residual value: revenue from the sale of the product after the end of the period of use and the value of the object after the end of the useful life of the life cycle cost calculation, if it can still be used in the future.

LCC screening or “Direct LCC method” are LCC tools allowing to add on a given perimeter a financial analysis over a more or less extended period of time.

TCO Method

Total Cost of Ownership (TCO) is a similar concept that complements the LCC method. It comes from the business sector, and determines the total costs (direct and indirect) throughout the life cycle of a product or service, up to the preparation of the facilities for the next economic use.
TCO complements the classic LCC in its approach to indirect costs, notably with the addition of labor costs and the integration of an equipment commission/discount component in the fixed asset analysis. The integration of residual values of equipment (income from the sale of equipment before the end of the depreciation period) is then accessible.
Finally, the Discounted Cash Flow (DCF) method is used on the TCO fixed assets analysis to determine the revenues that the asset will bring in (we speak of future cash flows) and to discount them to indicate the value of the asset at a given date "t".

The JRC published a technical report on Safe and Sustainable by Design chemicals and materials[1]. Within this report was described the economic dimension of this approach together with different methodologies.
Hence, the indicators to account for the economic dimension in the reviewed frameworks were grouped into four aspects: product cost, profitability, life cycle cost (and externality cost) and market-related criteria.
The methodology developed by IPC for the project was inspired by those four aspects.

> In a nutshell, the objectives of the cost studies carried on a life cycle are to compare the additional costs of a new technology (or a product) to a reference technology (or product).
> The LCC screening methods will collect all costs and especially the costs that come additionally to the baseline. Externalities of eternal costs are also collected. The use of tools such as TCO and DCF will bring an extra level of analysis by putting these additional costs structure in a time perspective in a foreseen business horizon (e.g. 25years).
> Hence, the LCC screening combine with the TCO/DCF methods will then allow the deployment of financial indicators to assess the system profitability (see below in the document).

2.2.2. Information drawn from the literature review

In the literature, the subject of LCC in the field of packaging is quite small, this is even more the case for LCC in the field of reusable packaging, indeed the majority of the literature on LCC is in the field of building.
This is why in this bibliography we will remain general and open to other types of economic performance tools.
A good bibliographic base has already been constituted at IPC during the projects carried out, we will thus rely on it by seeking more current and more targeted sources.

[1] JRC technical report “Safe and Sustainable by Design chemicals and materials” 2022

The keywords used are: "Packaging", "LCC", "Economical", "Reusable packaging" on the following websites:

- Google Scholar
- SpringerLink
- Science Direct
- KB Platform (IPC intelligence platform)

2.3. Social Life Cycle Assessment

2.3.1. Benchmark of the existing methodologies

The UNEP/SETAC Guidelines

The first guidelines for Social Life Cycle Assessment (SLCA) were published in 2009 by the UNEP/SETAC Life Cycle Initiative and an update was published in 2020. Since it came out, the first version was the main reference for SLCA. The update aims to expand the audience, focus on capability development, capture methodological developments, recognize the plurality of established approaches and position SLCA in the current context.

Just like the ISO 14040 standard for Life Cycle Assessment, SLCA is an iterative methodology that consists of four phases: Definition of the objectives and scope of the study, Life Cycle (Social) Inventory (LCSI), Social Impact Assessment and Interpretation. These phases are illustrated in Figure 2.

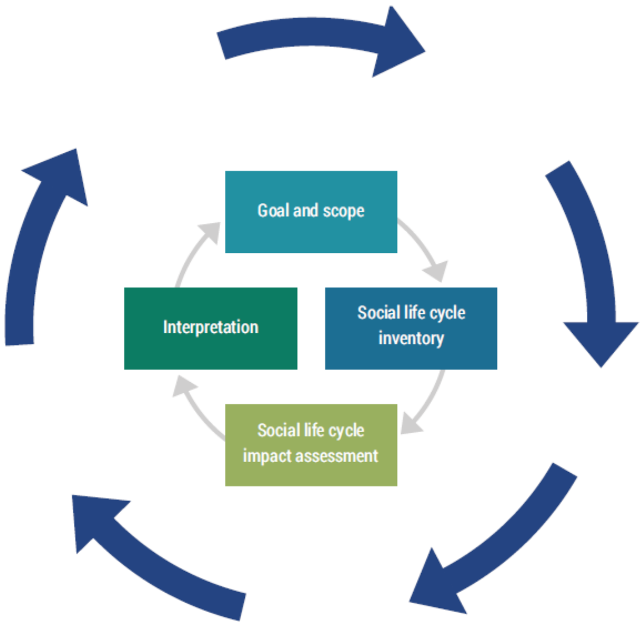


Figure 2 : The four phases of SLCA (Source: UNEP/SETAC Guidelines 2020)

The SLCA framework uses a stakeholder approach in which the potential impacts on different categories of stakeholders are taken into account. This reflects the fact that social sustainability is about identifying and managing impacts, both positive and negative, on people (stakeholders). In this framework, the stakeholder categories are workers, local communities, value chain actors (e.g. suppliers), consumers, society and the newest category: children.

Linked to the stakeholder categories are the impact subcategories, which cover themes or characteristics that are important to society. These guidelines present 40 subcategories, linked to the 17 Sustainable Development Goals (SDG,) but the list should not be seen as exhaustive: it is possible to add/remove subcategories if it's justified.

These subcategories are assessed using impact indicators whose inventory indicators are directly linked to the product life cycle inventory. Several indicators can be used to assess each of the sub-categories. These indicators may vary depending on the context of the study.

The proposed stakeholders and subcategories are listed in the Table 3**Erreur ! Source du renvoi introuvable.** below.

Table 3: List of stakeholder categories and impact subcategories (Source: UNEP/SETAC Guidelines 2020)

Stakeholder categories	Worker	Local community	Value chain actors	Consumer	Society	Children
Subcategories	Freedom of association and collective bargaining Child labour Fair salary Working hours Forced labour Equal opportunities/ discrimination Health and safety Social benefits/ social security Employment relationship Sexual harassment Smallholders including farmers	Access to material resources Access to immaterial resources Delocalization and migration Cultural heritage Safe and healthy living conditions Respect of indigenous rights Community engagement Local employment Secure living conditions	Fair competition Promoting social responsibility Supplier relationships Respect of intellectual property rights Wealth distribution	Health and safety Feedback mechanism Consumer privacy Transparency End-of-life responsibility	Public commitments to sustainability issues Contribution to economic development Prevention and mitigation of armed conflicts Technology development Corruption Ethical treatment of animals Poverty alleviation	Education provided in the local community Health issues for children as consumers Children concerns regarding marketing practices

To facilitate the enforcement of the UNEP/SETAC guidelines, a complementary document intitled "Methodological sheets for subcategories in social life cycle assessment" was published in 2010 and updated in 2021. For each stakeholder subcategory, this document gives: definition, objective, link to SDGs, measurement/information tools, examples of indicators with associated sources but also the limits of the subcategory. The main purpose of those methodological sheets is to provide a comprehensive open resource for SLCA.

There are two main families of impact assessment approaches for SLCA:

- The reference scale approach (type I), to evaluate social risk or performance.
- The impact pathway approach (type II), to evaluate consequential social impacts through a cause-effect chain characterization

Philosophically, the impact pathway approach is closer to environmental LCA, but the reference scale approach is simpler and more developed and therefore more used. The type I approach compares social data to a baseline to determine whether a product has a positive or negative social impact.

The Reader's guide of the UNEP/SETAC guidelines summarizes the methodology like the following:

Step 1: Goal and Scope or "question to be answered by the SLCA"
Specify the goal of the study, identify the affected stakeholders, set the system boundaries and a functional unit, select an impact assessment method.

Step 2: Inventory data collection
For the identified stakeholders, select relevant subcategories and impact indicators, collect data through databases, software and on-site interviews/questionnaires.

Step 3: Translate collected data into social impact
Benchmark of impact indicators to determine a reference scale, compare collected data to the reference to obtain social performance/hotspots results.

Step 4: Result interpretation
Verify hotspots by using site-specific data instead of using secondary data from databases or literature.

Step 5: Result communication

Step 6: Consider limitations and future research

The Handbook for Product Social Impact Assessment (PSIA)

The PSIA was first published in 2013 and Version 4 of the handbook was published in November 2018. Whilst based on UNEP/SETAC guidelines, a key difference is the strong focus on applicability and business relevance. The methodology focuses on assessing social impacts of products and services rather than on the impact of a company as a whole. The handbook describes a consensus-based methodology to assess positive and negative social impacts of products and services on four stakeholder groups: workers, local communities, small-scale entrepreneurs, and users.

The four key elements of the methodology are:

1. Stakeholder group
2. Social topics
3. Performance indicators
4. Impact assessment method

24 social topics are identified, split across the four user groups:

Social topics for workers	Social topics for local communities
1.1 Health and safety 1.2 Remuneration 1.3 Child labour 1.4 Forced labour 1.5 Discrimination 1.6 Freedom of association and collective bargaining 1.7 Work-life balance	3.1 Health and safety 3.2 Access to tangible resources 3.3 Community engagement 3.4 Employment
Social topics for users	**Social topics for small-scale entrepreneurs**
2.1 Health 2.2 Product safety 2.3 Responsible communication 2.4 Privacy 2.5 Inclusiveness 2.6 Effectiveness and comfort	4.1 Meeting basic needs 4.2 Access to services and inputs 4.3 Women's empowerment 4.4 Child labour 4.5 Health and safety 4.6 Land rights 4.7 Fair trading relationships

Figure 3 : Social topics per stakeholder group (Source: Handbook for Product Social Impact Assessment)

Before each product social impact assessment, a number of preparation steps should be undertaken:

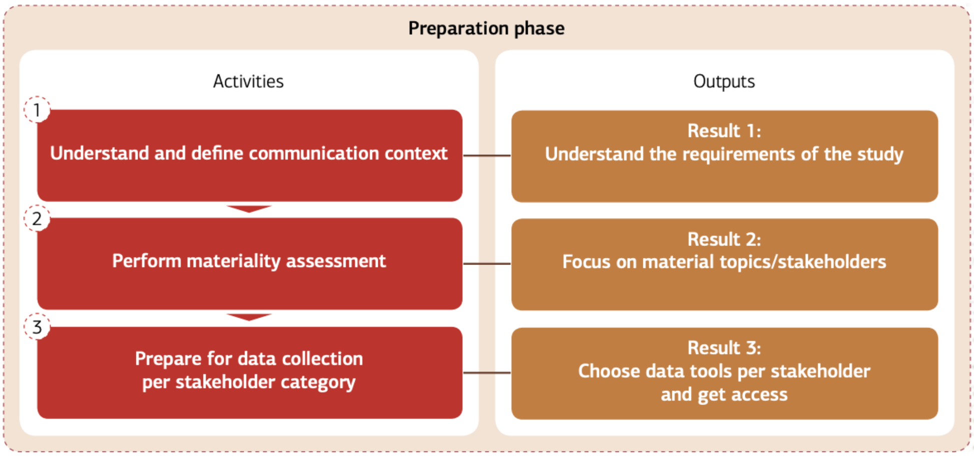


Figure 4 : Overview of Preparation phase (Source: Handbook for Product Social Impact Assessment)

These preparation stages give outputs that then define the goal and scope:

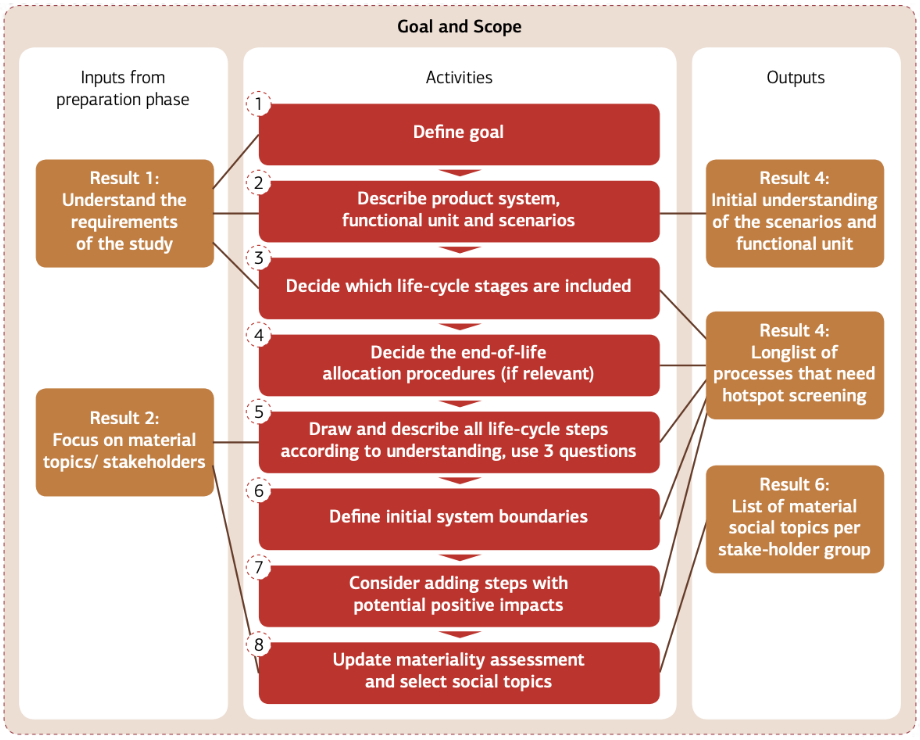


Figure 5 : Overview of the goal and scope definition phase (Source: Handbook for Product Social Impact Assessment)

A circular economy study can then be conducted to distinguish between strategies aimed at closing the loop and optimising use, although this is not obligatory, and its use depends on the company strategy. This module links circular economy inspired strategies to impacts related to recycling, refurbishment and reuse and impacts due to additional services needed when moving to a circular economy. These strategies do not influence users but will have impact on the worker categories.

Hotspot identification is used to identify which value-chain actors may have significant positive or negative social impacts. The short list produced then undergoes impact assessment, considering the impacts of workers, small-scale entrepreneurs and local communities. Each module is given a score between -2 and +2, by using performance indicators and reference scales.

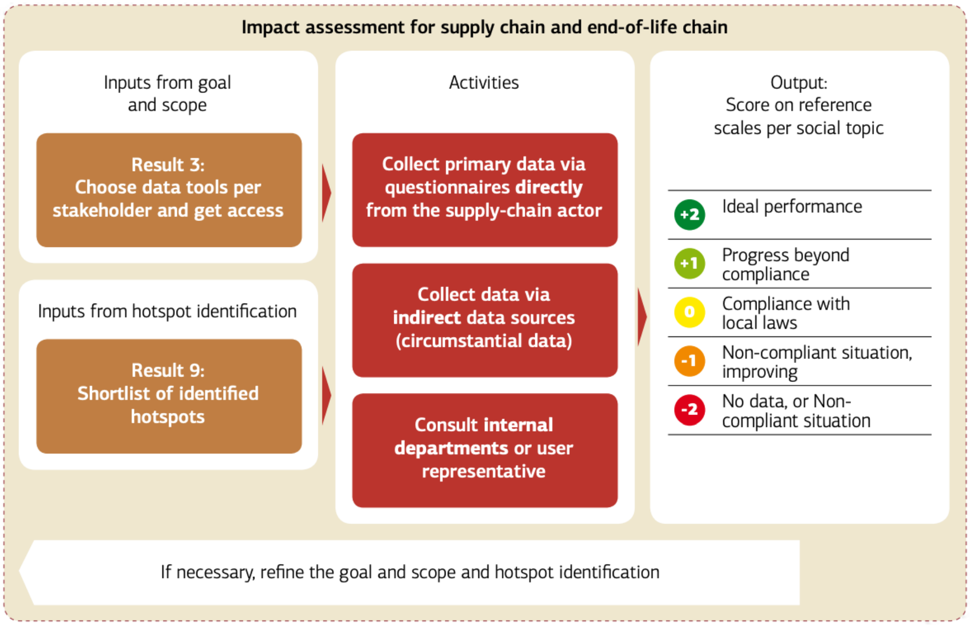


Figure 6 : Illustration of PSIA process (Source: Handbook for Product Social Impact Assessment)

Finally, the impact on users is assessed. Different types of users can be defined, for example professional users and direct and indirect users of the product. Again, hotspots are allocated a score between -2 and +2.

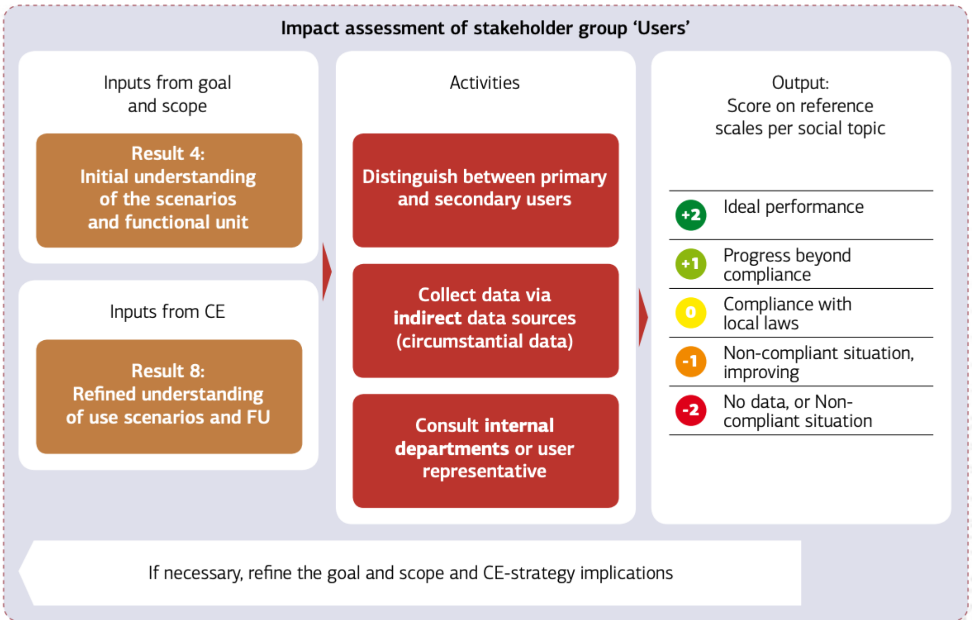


Figure 7 : Overview of impact assessment for users (Source: Handbook for Product Social Impact Assessment)

Studies aimed at external communication must provide a transparent description of data collection, data quality, limitations and data gaps along with study limitations and uncertainties.

The Social Life Cycle Metrics for Chemical Products (WBCSD)

Chemical industry is involved in the life cycle of most products. Therefore, the World Business Council for Sustainable Development (WBCSD) is committed on the sustainability performance of chemical products. The Social Life Cycle Metrics for Chemical Products (2016) is the fourth publication by the WBCSD. This guidance aims to provide a methodology framework to enable credible assessment and communication on social impacts and benefits. It has been greatly inspired by the 2009 UNEP/SETAC guidelines and by the 2014 version of the Handbook for Product Social Metrics.

In the WBCSD, 3 stakeholder groups were targeted: workers, consumers and local communities. The first two are identical to the UNEP/SETAC guidelines. The stakeholder "local communities" is the merger of "community" and "society" stakeholders. The stakeholder "value chain actors" is considered included in the 3 targeted groups because they are addressed at each step of the value chain.

Along with the 3 stakeholder categories are 11 mandatory social topics (impact subcategories) and 14 non-mandatory social topics.

The 25 social topics can be regrouped into 5 social areas: Basic rights & needs, Employment, Health & Safety, Skills and Knowledge and Well-Being. The Figure 8 below summarizes all of it.

OVERARCHING SOCIAL TOPICS	STAKEHOLDERS		
	Workers	Local communities	Consumers
SOCIAL AREAS	Social Topics		
Bacis rights & needs	• Fair wages • Appropriate working hours • Freedom of association, collective bargaining and labor relations • No child labor • No forced labor, human trafficking and slavery • No discrimination • Social/employer security and benefits	• Access to basic needs for human rights and dignity (healthcare, clean water & sanitation, healthy food, shelter) • Respect for indigenous rights	• Direct impact on basic needs (healthcare, clean water, healthy food, shelter, education)
Employment	• Management of reorganization	• Job creation	
Health & Safety	• Workers' occupational health risks • Management of workers' individual health • Safety management system for workers	• Health and safety of local community's living conditions	• Impact on consumer health and safety
Skills & Knowledge	• Skills, knowledge and employability	• Promotion of skills and knowledge	• Promotion of skills & knowledge
Well-Being	• Job satisfaction	• Access to basic needs for sustainable development (infrastructure, ICT, modern energy) • Nuisance reduction • Developing relationship with local communities	• Consumer's product experience

Legend
Mandatory social topics
Additional social topics to be selected by a practitioner

Figure 8 : The 11 mandatory and 14 non-mandatory social topics (Source: The Social Life Cycle Metrics for Chemical Products)

For each of the 25 social topics, at least one mandatory impact indicator was developed. They combine the checking of processes in place and the assessment of their impact. It is also possible to use one or more optional "advanced indicators". These indicators are usually quantitative and not required for the assessment. Every indicator is explicit and normalized to a 5-point scale (-2 the worst social impact, +2 greatest social benefit) to facilitate interpretation, comparability and usage.

Since all the indicators are defined on this 5-point scale, the impact assessment method used in this framework is the reference scale approach. The use of this approach ensures that a topic is handled the same way by different users of the guide. They were built with a chemical industry's benchmark.

Listed below are the core steps of the methodology. Many requirements, for each step, are quoted in the document but we won't describe them all.

Step 1: Goal and Scope
Clear definition of the goal is critical for results and expectations alignment. Clear definition of the scope is critical to focus the analysis on the intended goal. Must be consistent with the ISO 14040 & ISO 14044 standards.

Step 2: Functional unit
Clear definition of the functional unit is critical to allow comparison of the social impact between two or products.

Step 3: Selection of social topics for a specific product assessment
Non-mandatory social topics are selected based on their relevance to the studied system.

Step 4: Choice of indicators and advanced indicators
For the advanced indicators, since not mandatory, they can either be assessed in numerical format (-2,+2) or they may be published in quantitative format only.

Step 5: Setting up reference scales (when needed)
All indicators (advanced or not) have at least a generic reference scale. When a given advanced indicator needs a specific reference scale, the guide refers to the PSIA document (p13-16). A specific reference scale can be based on expert investigations or average sector levels.

Step 6: boundary setting
To avoid complex, time-consuming studies with little relevance, it is critical to set proper boundaries. To select key life cycle stages, questions such as "Is there evidence of social violations and risk situations at this stage of the value chain?" will be addressed to an industry expert. Depending on the answers, the life cycle stages will be included/excluded from the perimeter. An example is given in Appendix 8.4.

Step 7: Data collection
Must be defined: type of data sources (origin) & gathering level of data (location), depending on information availability and the scope of the study. An example is given in Appendix 8.4.

Step 8: Data quality assessment
To ensure transparency and clarity, data quality should be assessed and provided on criteria inspired by Life Cycle Assessment. The quality ratings are given in Appendix 8.4.

2.3.2. Information drawn from the literature review

For the Buddie Pack project, the focus is on the plastics industry in the broadest sense, and the packaging sector more specifically, all in Europe. Our literature searches have shown that Social Life Cycle Assessment suffers from a lack of case studies, compared to Life Cycle Costing and Life Cycle Assessment. This low number of studies is reflected in the publications selected for the literature review.

The UNEP/SETAC guidelines are the common basis for all these selected studies. Indeed, this document has been used as the main methodological reference since 2009. Nevertheless, there is a global lack of methodological framework. Many of the reviewed studies listed in appendix 8.3 were about developing such frameworks and to facilitate the application of the UNEP/SETAC guidelines.

According to the literature, the major difficulties about SLCA are to relate social indicators to the functional unit, to select and quantify said indicators among a large quantity, to obtain regionalized data and to properly measure the impacts.

Since one of the main challenges in SLCA is to select relevant indicators, we analysed the subcategories present in our literature review. The result of the inventory is in the Appendix 8.4 “Impact subcategories in literature review”. On average, 18 indicators are selected. Some of them can be qualified as “must-have”, since they are used in 6 or more case studies: Equal Opportunities & discrimination (W), Health and Safety (W), Safe and healthy living conditions (Lc), Local employment (Lc) and Contribution to economic development (S).

Among the three axes of the Life Cycle Sustainability Assessment, the Social Life Cycle Analysis is the least developed. Very few case studies are available and, to the best of our knowledge, there is no specific S-LCA case study on reusable plastic packaging. For that reason, our literature review focuses on the applied methodology rather than the subject of the study.

We used the key words “Social Life Cycle Assessment”, “Packaging” and “Plastic sector” on the sources:

- Science Direct
- SpringerLink
- Google Scholar

We also used the references in the following document:

- United Nations Environment Program, 2020. Guidelines for Social Life Cycle Assessment of Products and Organizations 2020

The selected studies were chosen on the following criteria:

- The study applies, at least partially, the 2009 UNEP Guidelines.
- The study was published between 2010 and 2022.
- The results of the study are classified by stakeholder categories.

3. Assessment Methodology

3.1. Life Cycle Assessment

3.1.1. Experience of the partners

IPC

IPC is working on packaging LCA, for consulting services, but also on the LCA work packages of numerous research projects, at national or European level. The industrial technical centre refers to the methodology of the Product Environmental Footprint (PEF) Guide, recommended and written by the European Commission. These LCA studies also comply with the ISO 14040 and ISO 14044 standards. The environmental assessments are performed on SIMAPRO software, using the EcoInvent 3.9 database and the EF 3.0 calculation method. Several projects performed by IPC are described below:

- Comparative LCA on four multilayer flexible packages (2022)
- Comparative LCA between a single-use pump bottle versus and a rechargeable solution for the cosmetic sector (2022)
- Comparative LCA between plastic and cardboard for fresh fruits and fresh fish packaging (2021)

Other projects were conducted to improve the technical centre's methodology for reusable packaging LCA:

- ACV REEMPLOI (REUSE LCA, 2022)

On this project, IPC worked with the LNE and CTCPA to apply the ADEME reference framework for comparative LCAs of packaging solutions (2022) on a single use VS reused plastic packaging. The use case studied was a home-delivered meal in a single-use polypropylene packaging with a polypropylene lid compared to a reusable polypropylene packaging with a polypropylene film.

USFD

USFD has worked on life cycle assessment of plastic packaging for the last 5 years. Over recent years the focus has been on reusable plastic packaging, with current funding through the UK government for "Many Happy Returns", a project starting in 2020 which aims to find ways to make reuse mainstream. LCA studies conducted include:

- Comparative LCA of takeaway food packaging
- Comparative LCA of milk packaging
- Comparative LCA of the Vytal reuse scheme, as used in a trial in University cafes as part of the Many Happy Returns project (2022, not yet published).
- Comparative LCA of carrier bags, including plastic, plastic bags for life of different types and paper bags.

The LCA was carried out in accordance with the Product Environmental Footprint (PEF) method (2012) as well as ISO 14040 and ISO 14044 guidelines. The LCA was carried out using SimaPro9.0 software.

3.1.2. Choice of methodology for the LCA studies

Norm, methodology chosen

The Grant Agreement of Buddie-Pack project states that the PEF will be applied for LCA studies. However, it has been seen in the benchmark study that the PEF methodology does not fully apply ISO 14040/44 standards and does not have a packaging category rule, meaning that comparative assessments between packaging solutions made with the PEF should not be published.

On the other hand, the ADEME methodology for packaging comparative LCAs is specific to packaging environmental assessments following ISO 14040/44 standards, with methodological choices following the PEF recommendations (e.g. transport allocation, CFF formula). However, the reference data developed are only applicable to a French case study.

If the PEF must be applied, the aim of the screening studies is then to create a method similar to the PEFCRs for packaging analyses, including methods to model reusable packaging. Therefore, the work performed in WP7 is quite similar to the steps recommended by the PEFCR Guidance [47] for PEFCR development, shown in Figure 9.

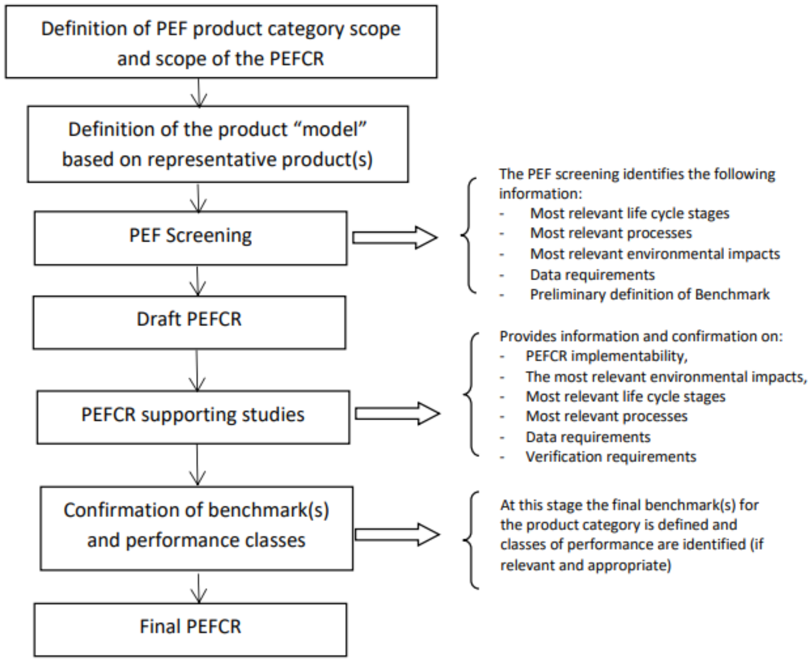


Figure 9: Steps to be followed for the development of PEFCRs (Source: PEFCR Guidance, European Commission [47])

The screening phase will aim to identify the most relevant life cycle stages, processes and environmental impacts as well as the data quality requirements.
They will also give the opportunity to compare the existing methodologies on the methodological points shown in Table 4.

Table 4: Methodological points tackled in the screenings and justification

Methodological point	Sources	Choice	Justification
Freight transport allocation	PEF		The two methodologies give the same formula (with reference values for French packaging for ADEME) to model the allocation of fuel consumption of road transports to one FU, but not for other elementary flows like air emissions. The ecoinvent transport data model all the elementary flows, but the allocation in t.km is less precise than the formula given by the methodologies. At first, generic data with t.km allocation will be used to see the potential impact of all elementary flows.
	ADEME		
	Ecoinvent data	x	
Consumer transport allocation	PEF	x	Consumer transport allocation is only addressed in the PEF. However, this method does not take into account if the trip is made to get or give back the packaging, or if the impacts have to be shared with another activity. The PEF method will be used but the consumer

			behaviour allocation will be subject to a sensitivity analysis on the extreme scenarios.
Packaging uses number	ADEME		The calculation methods given by the methods are too elaborated to be used when the packaging is at such an immature design stage and no large-scale test has been performed. Therefore, the aimed number of uses given by the use-case leaders will be used at first and subject to a sensitivity analysis in the screening studies.
	PEF		
	Industrial data	x	
Reuse infrastructures	ADEME		The ADEME suggests including in the perimeter infrastructures necessary to a reuse model, like washing facilities automated packaging recovery machines, with generic or specific data. Databases do not have the data deemed sufficiently representative, and the screening phase is too short to gather the necessary information. Thus, reuse infrastructures will not be in the screening studies perimeter.

When the justification is a lack of primary data to apply the methods, one of them will be applied for the full assessment. Indeed, as the aim is to create a harmonized LCA methodology, it will use as much as possible the existing work. For example, the formula to calculate the number of uses for a reusable packaging are not the same in the PEF and in the ADEME methodology. When more data will be available from other WPs, the screenings will give the opportunity to assess which one is more suitable.

When the justification is that the modelling problems associated with reusable packaging are not tackled by the PEF and the ADEME methodology (or not sufficiently), the screening studies will be taken as an opportunity to develop methodology on those points. For example, transports fuel consumption allocation is the same in the PEF and the ADEME methodology, but do not tackle the other elementary flows. The screenings will try to understand why and see if any improvement can be brought.

Impact categories chosen

At first, all impact categories recommended by the PEF will be assessed during the screening phase. The screening studies will enable a choice of most relevant impact categories for packaging LCAs, and see if it is aligned with the restricted choice of indicators suggested by the ADEME methodology.

Table 5: Chosen impact categories and methods for the screening studies

Impact categories assessed	Characterisation methods
Climate change	IPCC 2013 100y
Particulate matter	RiskPoll model & Greco et al 2007
Ozone depletion	WMO 1999
Ionizing radiations	Human health effect model (CML, ReCiPe, Ecoindicator99 & Impact 2002+)
Acidification	Accumulated exceedance
Eutrophication, terrestrial	Accumulated exceedance
Eutrophication, freshwater	EUTREND (ReCiPe)
Eutrophication, marine	EUTREND (ReCiPe)

Photochemical ozone formation	LOTOS-EUROS (ReCiPe)
Resource use, fossils	CML 2002
Resource use, minerals & metals	CML 2002
Human toxicity, cancer	USEtox
Human toxicity, non-cancer	USEtox
Ecotoxicity, freshwater	USEtox
Water use	Swiss Ecoscarcity
Land use	SOM model

As USFD has done it on Many Happy Returns, the guidelines to make the reusable packaging more environmentally friendly than a single-use one will be especially based on results interpretations on climate change, fossil resource use and water use indicators.

For the full assessment, only the chosen indicators will be analysed in the results interpretation part, but the results for all indicators will be available in the report annex.
Moreover, as it is a circularity assessment, other indicators will be used in the last task:

- Circularity indicators developed in deliverable D7.3. They will be based as much as possible on existed tools, such as the Material Circularity Indicator[48], developed by The Ellen MacArthur Foundation and ANSYS Granta, measuring how restorative and regenerative the material flows of a product are, with complementary indicators that take into account additonal impacts and risks (e.g. Energy and water usage, Supply chain risks…).
- Inventory categories, like total energy demand or total waste generation, if they are not already implemented in the above-mentioned indicators.

Sensitivity analyses

The screening studies are performed before some big milestones of the Buddie-Pack project described below:

- WP1: Technical and economic specifications of reusable plastic packaging (D1.3, M9);
- WP2: Report describing how consumers interact with reuse systems (D2.1, M24);
- WP3: Production of reusable packaging following sets of design rules (D3.2, M30);
- WP4: Refined business models for the 6 reusable packaging studied (D4.3, M36);
- WP5: Decontamination equipment and technologies (D5.1, M24);
- WP6: Report about demonstration results for all use-cases (D6.1 to D6.6, M42).

Therefore, some of the parameters that are needed for life cycle analyses won't be defined before the screening studies and will require performing iterative studies on the following parameters:

- Packaging: packaging capacity and mass, materials and additives;
- Finishing processes;
- Tracking system: none, RFID, QR code…;
- Transports: type and distance;
- Washing: on site or made by a third party, water, electricity, detergent, rinsing agent, salt consumptions;
- End-of-life: packaging recyclability.

These analyses will vary from one use-case to another, depending on the information available and the parameters that are still not defined by the use-case leaders.

The aim of the screening studies is to identify the main contributors to give eco-design guidelines to the WP 2 to 5 partners to make the reusable packaging better than the single-use plastic packaging. As a consequence, sensitivity analyses will be performed using extreme scenarios for the following parameters:

- Packaging: packaging mass and capacity, chosen in accordance with the use-case leaders;
- Freight transports: type (thermic or electric truck), distance multiplication factor from 1 to 5;
- Consumer transport, if there is one: type (thermic or electric vehicle), distance, type of allocation (volume allocation from 0% to 100%);
- Washing: consumptions, with or without a first wash by the consumer;
- Energy mix: country specific or renewable;
- End-of-life (country specific municipal scenario for plastic packaging, 100% recycled, 100% incineration, 100% landfill).

The full impact assessment will be performed after the screening analyses from month 19 to month 42. Therefore, most of the uncertainties about design choices and methodology will be resolved. During the full assessment, the aim of sensitivity analyses will be to make the conclusion on the environmental performance of the Buddie-Pack solutions more robust, considering the possible changes in the following years on:

- Technological development;
- Collection and sorting rates;
- Consumer acceptance and behaviour;
- Packaging durability;
- Material quality requirements;
- Energy scenarios;
- Policy developments.

Moreover, some sensitivity analyses will be performed to correspond to ADEME requirements:

- Number of uses: calculation of the break-even point for every indicators chosen;
- End-of-life: variation of the A and R_3 factor in CFF, consider the packaging non-recyclable if the compatibility between its components is not perfect, substituted heat energy mix;
- Transports: other secondary and tertiary packaging solutions;
- Infrastructures: comparison with or without their integration.

Tools and software

To conduct the LCAs, as set of documents will be created on Excel:

- The first document that will be useful for conducting the LCAs is a steering document explaining the global methodology for all the LCA studies, for example which secondary data will be used for each elementary flow that could not be collected from the project partners, or the impact categories chosen;
- One document per use-case, with different tabs:
  - Iterations history;
  - Scope of the study (Functional unit, reference flows, perimeters);
  - Data collection for the single-use packaging and reusable packaging;
  - Calculations used for the single-use packaging and reusable packaging;
  - Life Cycle Inventory for the single-use packaging and reusable packaging;
  - LCA results (Comparison, Contributors, Sensitvity analyses)

The software used to perform the LCAs will be Simapro v9.5 using the ecoinvent v3.9.1 database.

3.2. Life Cycle Cost Assessment

3.2.1. Experience of the partners

IPC

Method used in the project H2020-CIMPA :

The purpose of the LCC analysis used in the frame of CIMPA project (Project start: 1 June 2021) was to obtain and ultimately detail all costs items that were incurred by the products during its life cycle. Based on the LCA approach developed in the previous project task, all selected cost items were identified by the industrial partners.

The LCC study was executed on a simple multilayer packaging film that was recycled mechanically or physically. This multilayer product is composed of a layer of PET laminated to a layer of LDPE. During its life cycle, the products was produced, transformed, trashed and ultimately recycled.

The system boundaries were chosen to include only the steps that add costs to the products compare to state-of-the-art steps. Steps that will be in any case included in the value chain such as the production of the initial multilayers, the use by the consumers, etc., are excluded of the present LCC. In other words, the project proposes novel technology and novel path to valorise the multilayers waste and only those new steps are subjected to the LCC analysis. Those costs are compared to other regular routes such as for example incineration. To include those costs in a state-of-the-art value chain, transfer prices are used.
In the CIMPA project, a LCC screening methodology was followed. Hence, an identification and collection of all costs incurred by the product during its life cycle was performed. Nonetheless, the externalities were collected in a second task that is still ongoing when this deliverable is written. The following is a description of the costs considered:

- Raw materials and manufacturing:
  - Use of transfer prices for the production of LDPE/PET raw materials
- Distribution:
  - Use of transfer prices for the manufacture of multilayers.
- Use:
  - Use of transfer prices for the production of bale of sorted multilayers waste.
- End of life (including recycling):
  - the variable cost related to the transformation of the products (OPEX)
  - the fixed cost related to the work force and the maintenance (OPEX)
  - the immobilized assets such as equipment (CAPEX)

The main methodology that was used in CIMPA was based on a LCC screening completed by a TCO analysis. Here, two value chains are compared, on a common perimeter, on the CIMPA project only the steps that differ from the value chains have been taken into account so a cost structure is identified and overheads are calculated. This methodology will be used for the Buddie-Pack project.

3.2.2. Choice of methodology for the LCC studies

Description

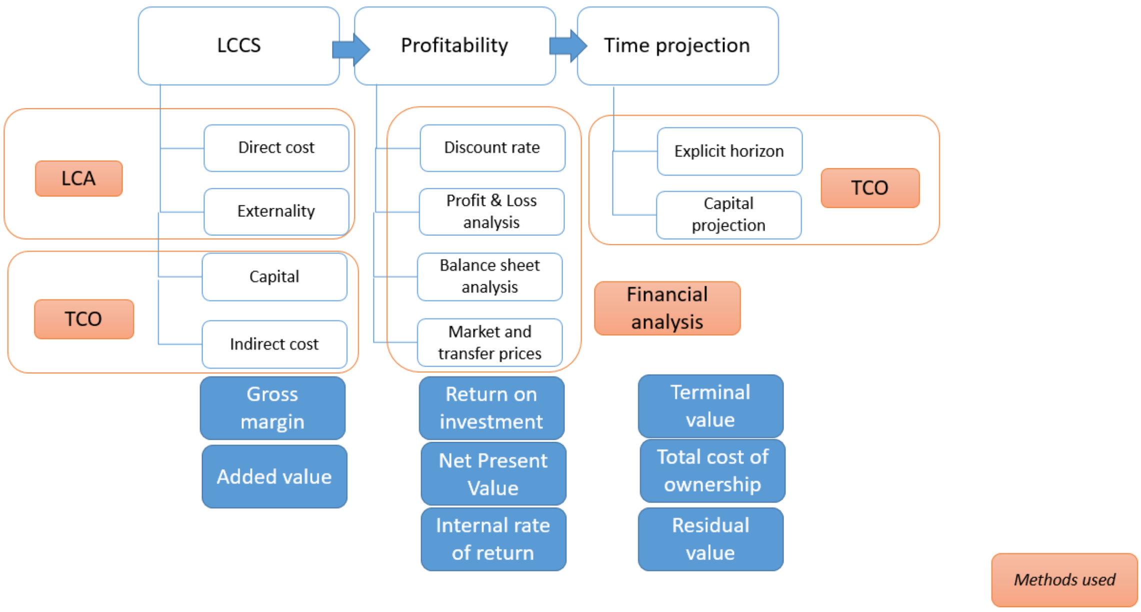
When considering the development or use of an economical life cycle assessment methodology, once shall considerer obviously the economic dimension that is linked to achieving sustainable growth. The inclusion of environmental and societal dimension being included as criterion of sustainability.

Hence, greener products need as well to generate profits for the business activity and provide the functions needed by society. However, there is no shared definition of economic sustainability[2]. Economic indicators can be linked to different costs linked to the production of a product e.g., capital or operating costs but also societal or environmental costs.

For this reason, no standardize methodology emerged for the LCC assessment. To our experience, the choice to include profitability indicators, or at least taking into account criterion used in financial analysis is a prerequisite to any economical assessment that at the end could favour one novel technology over another. As described in the JRC technical report, indicators to account for the economic dimension can be grouped into four aspects: product cost, profitability, life cycle cost (and externality cost) and market-related criteria.

The methodology designed by IPC for the project is summarised in the Figure 10 below. The idea of the **methodology is to couple a screening of the costs along the value chain (often described in the literature as LCC) together with a TCO analysis that will add the project capital costs over a longer period of time (i.e. 25 years).** This combination of detailed costs together with a deeper analysis of the present and future capital expenditure costs will allow the deployment of financial indicators linked to the asset's profitability analysis, commonly seen in business planning.

In addition, considering the reuse of food packing concept of the Buddie-pack project and more generally other circular business models, different hypothesis are considered and integrated in the final LCC model under “market & transfer prices”. For example, the market prices of regular food packaging, the cost of the food it will protect are data that are integrated in the financial analysis to assess return on investment.



[2] JRC technical report: Safe and Sustainable by Design chemicals and materials, 2022

Figure 10: LCC methodology designed by IPC

Hence, the objectives and outcomes of this methodology are to:

- Described the cost incurred by the product including the externalities that influence its business model (see Figure 11 below);
- Described the costs related to the structure or the system that will produce the product (see Figure 11 below);
- Deploy financial indicators describing the profitability of the product (NPV, IRR, etc.[3]);
- Assess the total cost of owning the technology/product over a defined period.

LCCA steps

The LCC methodology chosen for the project will follow these main steps:

1. Use case identification: Perimeters for each process steps will be identical to the one chosen for the LCA. Most probably, the functional unit will be kept.
2. Direct data collection: data will be collected during the LCA phase. The LCC screening will use the collected data to gather the main additional cost bear by the product
3. TCO/ DCM setting up to obtain the first level of financial analysis that will lead to global ownership cost over time.
4. Finacial analysis: Profit and loss as well as Balance sheet will be constructed to set the financial indicators

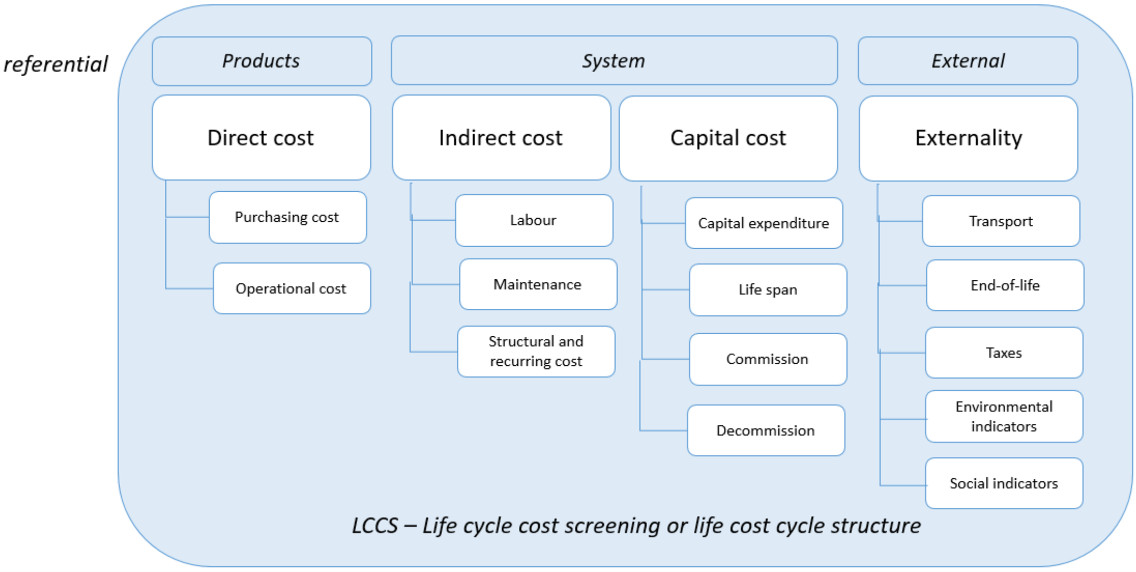


Figure 11: Description of the Life Cycle Cost Screening (LCCS) items

Tools and software

The following tools will be used to perform the LCCs:

[3] Net Present Value vs. Internal Rate of Return

- Data collection template: based on a LCA data collection sheet, all inputs and outputs are identified and their costs translation collected. Financial items are also collected such as CAPEX, discount rate, depreciation period, insurance, etc.
- Business planning tools: a tool design to integrate LCA/LCC excel sheets that will compile all cost data leading to a P&L/Balance sheet analysis ultimately deploying financial indicators such as NPV or IRR.

3.3. Social Life Cycle Assessment

3.3.1. Experience of the partners

IPC

The contribution of IPC to the literature review and the benchmark of the existing methodologies can be considered as a first experience in SLCA but so far, IPC never conducted SLCA studies. To offset this lack of experience, IPC contacted SLCA experts from EVEA & AFNOR, that participated in the redaction of the UNEP/SETAC guidelines and are currently working on an ISO standard for SLCA. A training session with one of these experts will take place before month 12 to enable IPC's participation in the SLCA study.

USFD

Colleagues at USFD developed the Triple Helix approach for combined LCC-LCA-SLCA in a paper published in 2021 [29]. This creates a basis to study all three analyses using the same system boundaries, thereby allowing a comparison between economic, environmental and social indicators. The SLCA part is based on the UNEP/SETAC guidelines and discusses in great detail the choice of indicators when conducting this type of analysis for carbon dioxide utilisation processes. Even though the subject under study in the Triple Helix article is quite different from the use-cases in the Buddie-Pack project, there is a lot of overlap in the types of supply chain and similar indicators that will be relevant for Buddie-Pack.

3.3.2. Choice of methodology for the SLCA studies

Norm, methodology chosen

So far, the published SLCA methodological frameworks were following the principles of the ISO:14040 2006. In 2024, a new ISO standard, specific to SLCA, will be published. This new standard should follow the UNEP/SETAC methodology. Since the literature review indicates that most studies are following the UNEP/SETAC guidelines and since a new standard in accordance with these guidelines is coming out, it makes sense to try and follow this methodology.

However, the UNEP/SETAC guidelines lacks some executive information. The PSIA handbook and WBSCD methodological guides, which are inspired by the UNEP/SETAC guidelines, try to remedy this shortcoming by making it easier to carry out SLCA. It is especially true for the WBSCD guidelines, which is tightly framed, with pre-defined reference scales and mandatory impact indicators. The three guides are compatible, with differences and similarities (as shown in Annex 7 of the BBSD), particularly on the number of social topics and their definition.

Since we can be considered as beginners in terms of SLCA, we need to work towards the simplest methodology, at least for the screening studies. We will follow the WBSCD guidelines and adapt it as much as we can to our specific case studies, while remaining within the framework of the UNEP/SETAC guidelines.

Impact categories chosen

Our literature review indicates that on average, there are 18 impact subcategories selected for a Social Life Cycle Assessment case study. There 40 categories in the UNEP/SETAC guidelines, 24 in the PSIA handbook and 25 (11 mandatory) in the WBCSD.

Since we plan to follow the WBSCD, we will select the 11 mandatory subcategories/social topics: Fair Wages, Freedom of association, collective bargaining and labour relations, Child labour, Forced labour, human trafficking and slavery, Access to basic needs for human rights and dignity, Job creation, Workers occupational health risks, Safety management system for workers, Health and safety of local community's living conditions, Impact on consumer health and safety, Skills, knowledge and employability.

These 11 indicators already have defined reference scales, impact indicators and data sources, they should be simple to assess. When necessary and/or relevant, we will use the proposed social topics and impact indicators in the other 2 guidelines.

We will select more indicators, based on our literature review and on relevance to our case studies (geographical relevance, data availability, bibliography validation …), such as Equal Opportunities & discrimination, Contribution to economic development and End-of-Life Responsibility. The challenge will be to develop relevant reference scales and impact indicators. It is important to do this work to sharpen our skill in SLCA.

We also wish to conduct a materiality analysis by submitting a questionnaire to the stakeholders (mostly the consortium partners), in which they will rank pre-selected subcategories according to their perceived relevance. The objective is to include the stakeholders in the early stages of the SLCA.

Tools and software

To assist us in the definition of the perimeter and of the impact categories, we will use the online Risk Mapping Tool of the Social Hotspots DataBase. This tool helps you identify where the social risks are the highest (country, sector, life cycle stage, …) and which issues are the most concerning (impact categories). This tool will be useful in the early stages of the screening studies. It can also help us complete the data collection with "generic data".

For the data collection, our main tools will be surveys (most likely in a Word document format or a google Form) and interviews (to assist the filling of the survey). The answers will then be compiled in an Excel format for the assessment of the social impacts.

Project steps and conclusion

As a summary of our methodological choices for the SLCA studies, we can define the following main project steps:

- Identification of the relevant social topics (impact categories), based on the methodological frameworks, the literature review and the help of the Risk Mapping Tool.
- Definition of the impact indicators and of the reference scales. Construction of the questionnaires (structure, content, filling procedures, ...).
- Data collection through interviews and questionnaires. In order to complete the data collection, it is possible to use sources such as the Social Hotspots Data Base or the International Labour Organisation (ILO).
- Evaluation of the impacts based on the answers/data (scoring, analysis, aggregation methods, …)
- Interpretation of the results

3.4. Results interpretation and trade-offs

For the full circularity assessment, the results interpretation (comparison, contributor analysis, sensitivity analysis) will associate the results of LCA, LCCA and SLCA to draw general conclusions on the developed packaging durability. Results interpretation may differ in their conclusion from on type of assessment to another. If SLCA

results are in a different format, trade-offs between LCA and LCCA results have been identified as one of the risks of WP7 contingency plan.
The aim is in priority to have the lowest environmental and economic Break-Even Points possible, but also reduce the gap between them. The results interpretation will put forward the conclusions that enables to do so, even if it means that it can make one of the two BEP a little bit higher.
As it is difficult to anticipate for which impact, life cycle step or hypothesis the trade-off will be, this risk mitigation measure must be further elaborated after the preliminary results from the screening task.

4. Definition of goal & scope

This part follows the requirements for the first step of a LCA, according to the ISO 14044 standard. Usually, the LCC takes the elementary flows quantified by LCA and converts them into financial flows. The scope will then most likely be the same. For the S-LCA, the perimeter will be the same, but because it is an evaluation of a system in general, the life cycle steps will not be as precise.

4.1. Goal of the screening studies

Unlike the scope definition, which is specific to each use-case, the goal is general to the screening studies phase. The goals of the screening studies are then to:

- Collect the available data from WP1 to WP5;
- Identify the environmental, economic and social hotspots of every use case scenario;
- Identify the threshold, the break-even point, for the environmental and economic impacts of a reusable packaging vs its single use version;
- Provide reusable system improvement guidelines to WP2 to WP5 (e.g. material change impact to WP3, cleaning technology impact to WP5);
- Challenge the methodological choices for the full circularity assessment.

4.2. Vytal use-case

This use-case is a 3-compartment reusable food tray for take-away restaurants. This B2C solution will be tested in Germany and France.

4.2.1. Sources to initiate the description of the screening study

For this use-case, the work has mainly been based on the experience of USFD developed in "Many Happy Returns", which scope is visible in Figure 12.

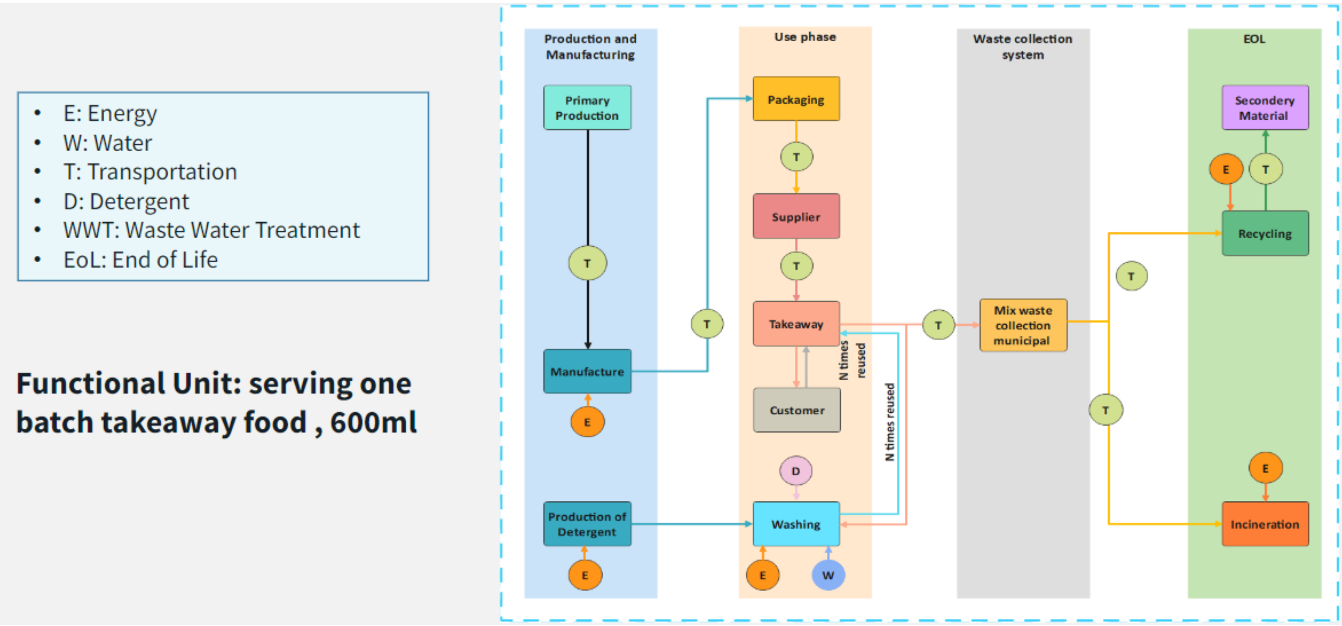


Figure 12: Many Happy Returns goal & scope

The scope of the following study remains quite the same, except that the consumer is most likely transporting the packaged meal to another place by car and has to retrieve it the same way. The design also changes considering it will be a 3-compartment tray.

The participation to the use-case meeting on 17/01/2023 also helped gathering information. However, the functional unit may change considering the container capacity hasn't been decided yet. This parameter can be very critical on flows such as food waste, and can totally change the conclusion of the comparative study. Defining it is a priority during the screening studies.

4.2.2. Scope of the screening studies

Functional unit & reference flow

A first description of the functional unit for this system is: **"Contain, allow serving in a take-away in France of 1000mL of a 3-side prepared dish"**.

To perform this functional unit, the two systems studied are:

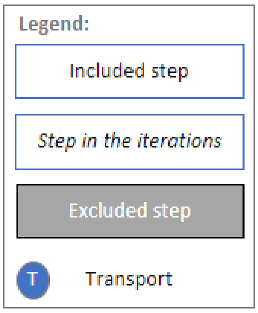
- Baseline: One single use PP container with a single-use PP lid;
- Case study: One use of a reusable PP container with a PP/TPE reusable lib, assuming the container is used 50 times.

System boundaries

The steps included in the screening studies' perimeter are the:

- Raw material extraction and production:
  - PP for both types of primary packaging
  - TPE for the reusable packaging
  - PBT for the reuse iterations
  - Additives for both iterations
- Production of primary packaging:
  - Injection moulding
  - Film extrusion for the single-use packaging and for the reuse iterations
  - Coating for the reuse iterations
  - QR code printing for the reuse iterations
- Cleaning of reusable packaging in restaurant
- End of life:
  - Treatment of waste generated during the life cycle (recycling, energy recovery, landfill)
- Transport: distribution of raw materials and components to the manufacturing plant, empty packaging from the plant to the restaurant, car transport of the full packaging to consumption spot, return car travel of the reusable packaging to a collection point, transport for reuse treatment, collection and transport of production and post-consumer waste to waste treatment facilities.

These steps are presented in the perimeters described in Figure 13 for the single-use packaging and Figure 14 for the reusable packaging according to the legend below.



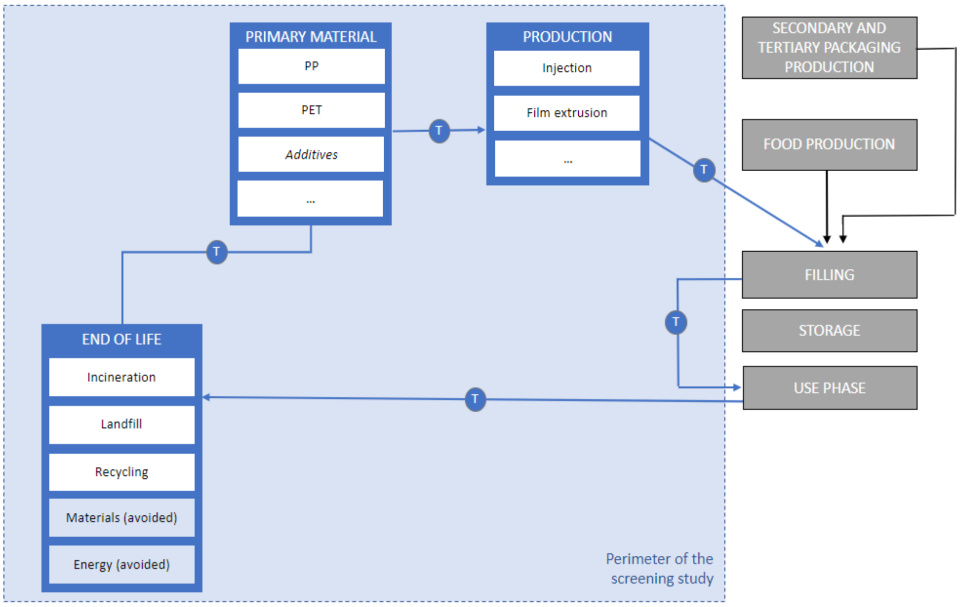


Figure 13: System boundaries for the Vytal UC single-use packaging life cycle

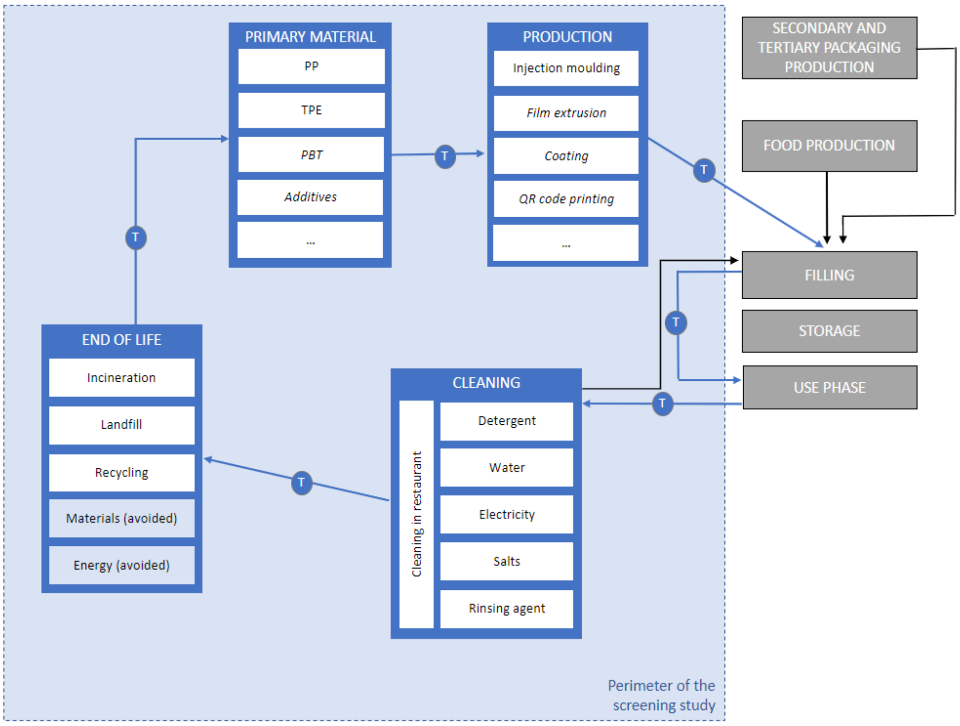


Figure 14: System boundaries for the Vytal UC reusable packaging life cycle

The following steps, associated with the packaged product, can be impacted by the packaging choice. However, they will be excluded from the screening study perimeter, as recommended by the ADEME methodology.

- Food production and processing;
- Package filling;
- Use phase (refrigeration or heating).

Moreover, the storage steps are also excluded from the perimeter because they are considered equivalent in both systems, and will not change the conclusion.

The secondary and tertiary packaging production will be excluded in the first screening study to focus on the primary packaging eco-design.

As explained in the LCA methodology part, the reuse infrastructures are not included in the perimeter, as no data is considered relevant enough.

4.3. Asevi/Smurfit-Kappa use-case

Use-case 2 is a refillable rigid bottle for laundry detergent. This B2C solution will be tested in Spain and France. Use-case 6 is a Bag-in-Box packaging for liquid loose goods in supermarkets. This B2B solution will be tested in Spain and France. The use-cases 2 and 6 are part of the same reuse system. The decision is then made to make one study evaluating the impact of the whole system. Thus, the scope of the study for a refill & reusable packaging for detergents includes the life cycle of the refillable bottle and the Bag-in-Box.

4.3.1. Sources to initiate the description of the screening study

During the two use-case meeting we attended, it was clear that defining the scope for this use-case would be the most challenging, considering LCA results were expected to decide on the final design and reuse system of the reusable packaging. The scope presented is then the most likely to happen to our opinion, but may be subject to major changes. Some of the information has been extracted from the answer of SK and ASEVI to the questionnaire for the Use-case leaders. The work done on task 1.4 on value-chain definition to define the return scheme was also used. The functional unit was discussed during the last meeting, because different sizes of Bag-in-Box exist, but it seemed the most practical for us to model. The iterative process of the study may give an answer on which Bag-in-Box size is better and change the final functional unit.

4.3.2. Scope of the screening studies

Functional unit & reference flow

A first description of the functional unit for this system is: **"Contain and distribute 20L of detergent product in Spain for large scale retail trade."**.

To perform this functional unit, the two systems studied are:

- Baseline: 28 single-use 720mL rigid plastic bottles;
- Case study: 28 uses of a reusable 720mL rigid plastic bottle (reused 5 times) & one 20L Bag-In-Box.

System boundaries

The steps included in the screening studies' perimeter are the:

- Raw material extraction and production:
    - PP, PET, PE for the single-use and refillable bottles
    - PE, EVOH, PP and carboard for the Bag-in-Box
    - HDPE/Copolyester for the bottle body and Bag-in-Box tap iterations
    - Additives for both bottles iterations
- Production of primary packaging:
    - Injection and blow mouldin, film extrusion and printing for the bottles
    - Coextrusion, lamination, welding and printing for the Bag-in-Box
- Cleaning of reusable packaging
- End of life:
    - Treatment of waste generated during the life cycle (recycling, energy recovery, landfill)
- Transport: distribution of raw materials and components to the manufacturing plant, empty packaging from the plant to the filler, full packaging from the filler to the supermarket, empty reusable bottle from the plant to the supermarket, return scheme of the reusable bottle, consumer transport from and to the

supermarket to retrieve the reusable bottle, collection and transport of production and post-consumer waste to waste treatment facilities.

These steps are presented in the perimeters described in Figure 15 for the single-use packaging and Figure 16 for the reusable packaging.

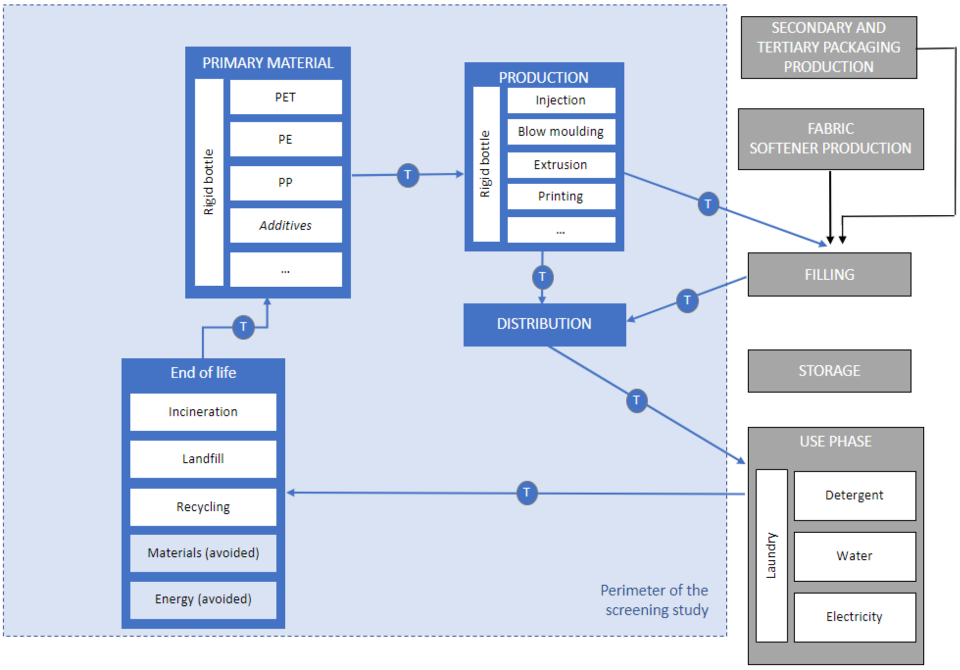


Figure 15: System boundaries for the Asevi UC single-use packaging life cycle

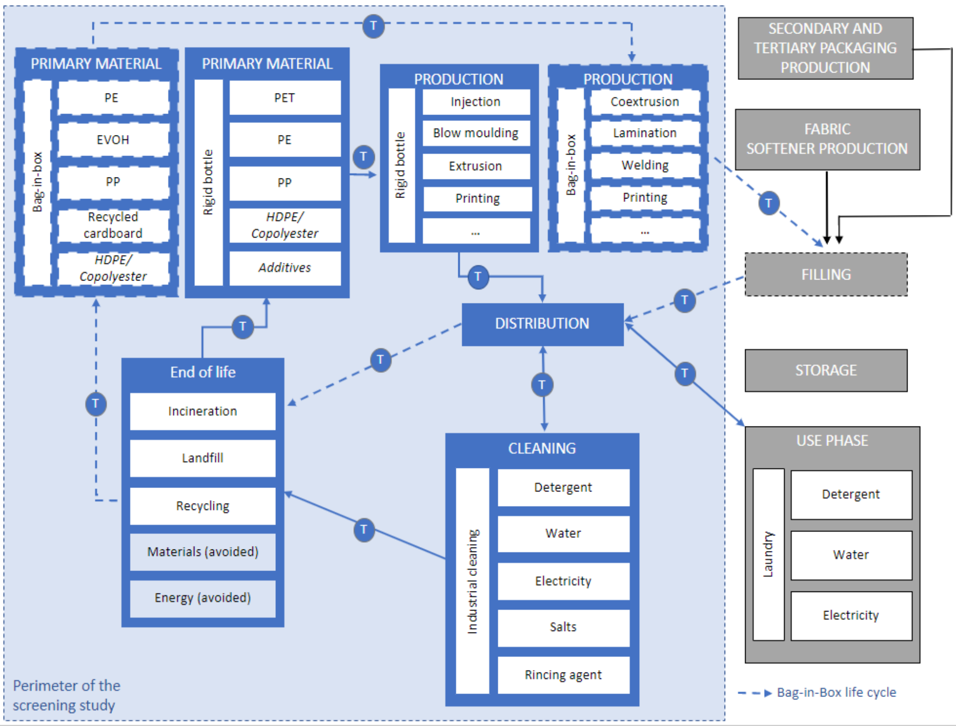


Figure 16: System boundaries for the Asevi/Smurfit-Kappa UC reusable packaging life cycle

The following steps, associated with the packaged product, can be impacted by the packaging choice. However, they will be excluded from the screening study perimeter, as recommended by the ADEME methodology.

- Fabric softener production;
- Package filling (single-use bottle or Bag-in-Box);
- Use phase (consumptions of the washing machine using the softener).

Moreover, the storage steps are also excluded from the perimeter because they are considered equivalent in both systems, and will not change the conclusion.
The secondary and tertiary packaging production will be excluded in the first screening study to focus on the primary packaging eco-design.

As explained in the LCA methodology part, the reuse infrastructures are not included in the perimeter, as no data is considered relevant enough.

4.4. Ausolan use-case

This use-case is a semi-rigid catering tray used in schools and nursing homes. This B2B solution will be tested in Spain.

4.4.1. Sources to initiate the description of the screening study

The information for the following scope was mostly based on the work performed in WP1, with T1.4 specifications sheets and T1.2 Value chain. Two types of trays are considered for this use-case: one multiportion tray for B2B schemes and one single-portion tray for B2C schemes. Hence four container types were considered during this use-case: The reusable stainless steel tray and reusable plastic tray, and the reusable and single-use single-portion plastic containers, which each contain a single-portion. Three comparisons were undertaken:

- steel trays vs reusable plastic trays;
- single-use single-portion plastic containers vs reusable single-portion plastic containers;
- steel trays and single-use single-portion plastic containers (the current system) vs plastic trays and reusable single-portion plastic containers (the fully reusable plastic system).

4.4.2. Scope of the screening studies

Functional unit & reference flow

In the tray case, the selected functional unit was "the containment during heating, transport and serving of 40 meals from a central kitchen to a school in the Gipuzkoa, Bizkaia, or Araba region of Spain". The corresponding reference flows are:

- One reusable stainless steel tray per use (with a lifetime of 100 cycles);
- Five reusable plastic trays per use (with a lifetime of 50 cycles each).

In the container case, the selected functional unit was "the containment during heating, transport and serving of one meal from a central kitchen to a school in the Gipuzkoa, Bizkaia, or Araba region of Spain". The corresponding reference flows are:

- One single-use plastic containers per use
- One reusable plastic container (with a lifetime of 50 cycles)

System boundaries

These steps are presented in the perimeters described in Figure 17 and Figure 18 for the single-use and stainless steel baseline packaging and Figure 19 for the reusable plastic packaging.

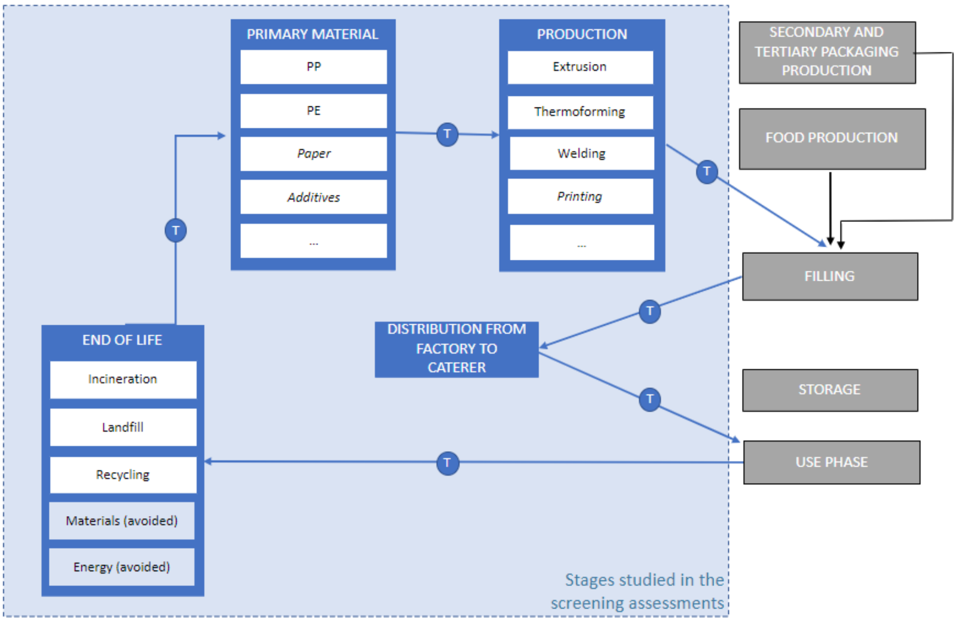


Figure 17: System boundaries for the Ausolan UC single-use packaging life cycle

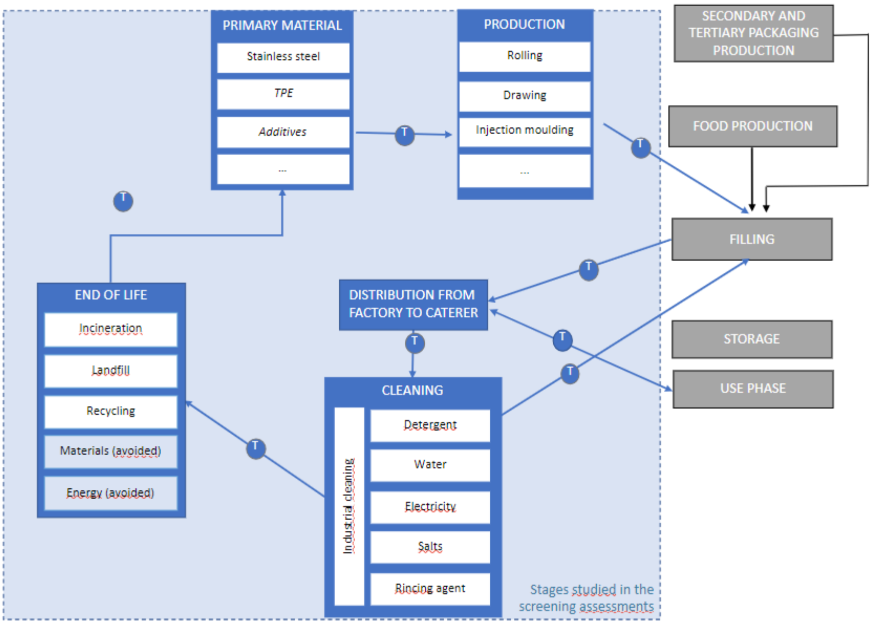


Figure 18: System boundaries for the Ausolan UC stainless steel packaging life cycle

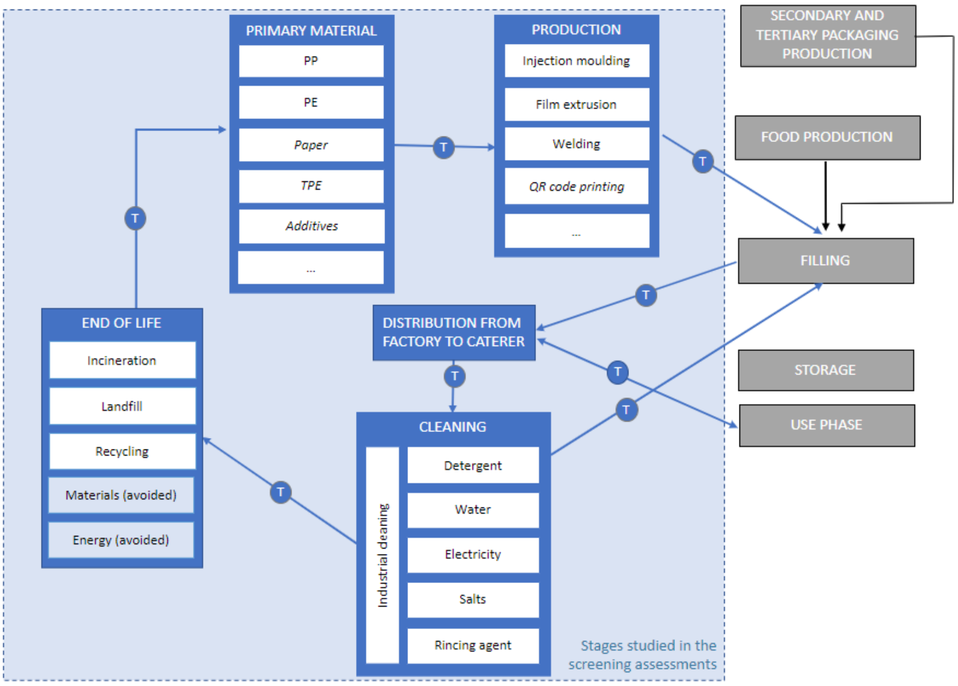


Figure 19: System boundaries for the Ausolan UC reusable packaging life cycle

The following steps, associated with the packaged product, can be impacted by the packaging choice. However, they will be excluded from the screening study perimeter, as recommended by the ADEME methodology.

- Food production;
- Tray filling;
- Use phase (food heating or refrigerating).

Moreover, the storage steps are also excluded from the perimeter because they are considered equivalent in both systems, and will not change the conclusion.
The secondary and tertiary packaging production will be excluded in the first screening study to focus on the primary packaging eco-design.

As explained in the LCA methodology part, the reuse infrastructures are not included in the perimeter, as no data is considered relevant enough.

4.5. Dawn Meats use-case

This use-case is a meat secondary food packaging for delivery to restauration premises. This B2B solution will be tested in the United Kingdom.

4.5.1. Sources to initiate the description of the screening study

The information for the following scope was mostly based on the work performed in WP1, with T1.4 specifications sheets and T1.2 Value chain. One WP7 specific meeting was planned with the use-case leaders and end-users to present them the work done on the scope, during which it was modified to its final form presented in this report. Only the functional unit was uncertain and we decided to try an individual piece of meat of standard size, but it may change rapidly.

4.5.2. Scope of the screening studies

Functional unit & reference flow

A first description of the functional unit for this system is: **"Contain 250g of meat, preserve it for 21 days and deliver it from the producer's factory to the restauration businesses"**.

To perform this functional unit, the two systems studied are:

- Baseline: One single-use meat packaging:
  - Disposable tray
  - Disposable film
- Case study: One use of a reusable meat packaging:
  - Reusable tray (20 times)
  - Disposable film

System boundaries

The steps included in the screening studies' perimeter are the:

- Raw material extraction and production:
  - PET for the single-use and reusable trays
  - PE and EVOH for the disposable film
  - Tritan, PP, cPET for the reuse iterations
  - Additives for both iterations
- Production:
  - Injection moulding for the reusable packaging
  - Extrusion and thermoforming for the single-use packaging
  - Extrusion and welding for the film
  - QR code printing for the reuse iterations
- Cleaning of reusable packaging
- End of life:
  - Treatment of waste generated during the life cycle (recycling, energy recovery, landfill)
- Transport: distribution of raw materials and components to the manufacturing plant, empty packaging from the plant to the filler, full packaging from the filler to the restaurant, return scheme of the reusable packaging, collection and transport of production and post-consumer waste to waste treatment facilities.

These steps are presented in the perimeters described in Figure 20 for the single-use packaging and Figure 21 for the reusable packaging.

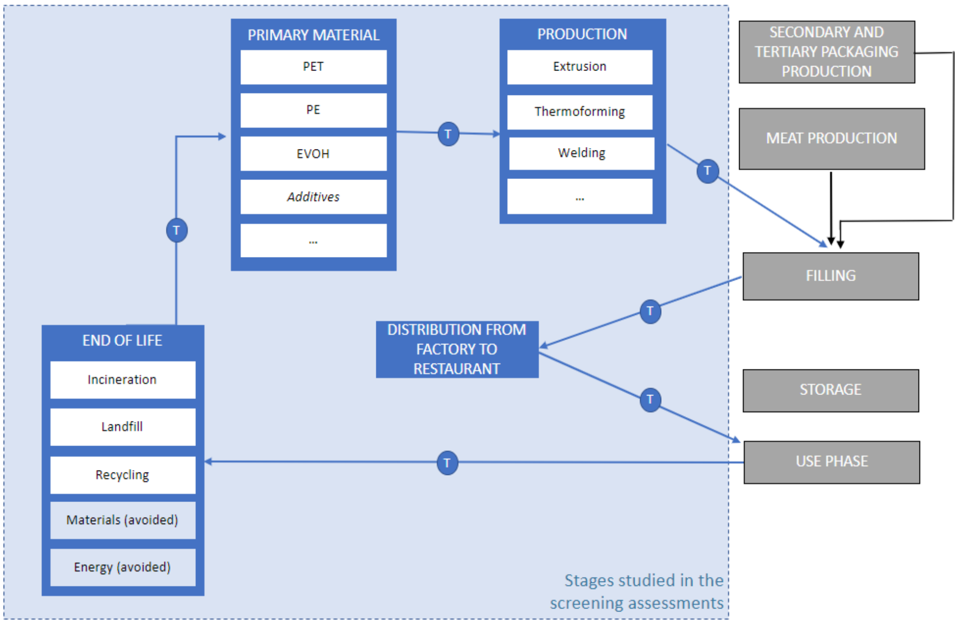


Figure 20: System boundaries for the Dawn Meats UC single-use packaging life cycle

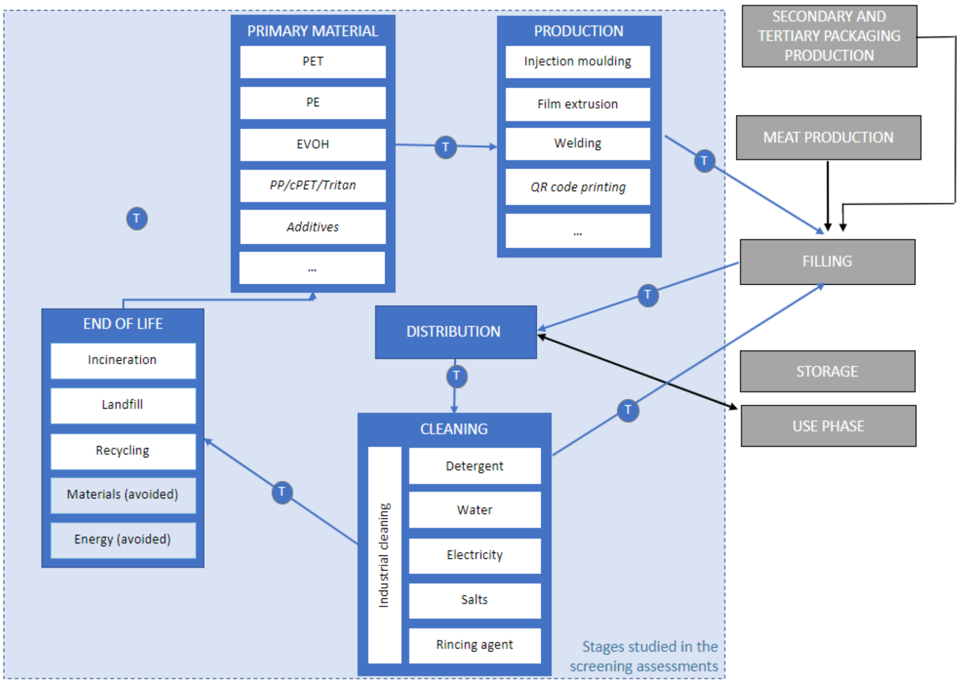


Figure 21: System boundaries for the Dawn-Meats UC reusable packaging life cycle

The following steps, associated with the packaged product, can be impacted by the packaging choice. However, they will be excluded from the screening study perimeter, as recommended by the ADEME methodology.

- Meat production and processing;
- Package filling;
- Use phase (refrigeration or heating).

Moreover, the storage steps are also excluded from the perimeter because they are considered equivalent in both systems, and will not change the conclusion.

The secondary and tertiary packaging production will be excluded in the first screening study to focus on the primary packaging eco-design.

As explained in the LCA methodology part, the reuse infrastructures are not included in the perimeter, as no data is considered relevant enough.

4.6. Uzaje use-case

This use-case is a rigid catering tray for on-the-spot food consumption in supermarkets lunch corners. This B2C solution will be tested in France.

4.6.1. Sources to initiate the description of the screening study

For this use-case, the first draft of the scope and perimeter was inspired by the work made in IPC's project "ACV REEMPLOI", which involved the same partners as this use-case. The work performed was presented on a specific WP7 meeting during which some questions were raised on whether the business model was chosen or not. After the Use-Case meeting on 01/02/2023, it was decided that the model described in the following scope was the most likely to happen, even if some changes may happen during the screening phase. Moreover, the functional unit may change considering the container capacity hasn't been decided yet.

4.6.2. Scope of the screening studies

Functional unit & reference flow

A first description of the functional unit for this system is: **"Contain, allow refrigerated storage for 2 days, allow distribution to a supermarket food corner in France, so that 1000mL of prepared dish can be consumed on site"**.

To perform this functional unit, the two systems studied are:

- Baseline: One single use PP container with a single-use PP lid;
- Case study: One use of a reusable container with a reusable lid (both reused 20 times).

System boundaries

The steps included in the screening studies' perimeter are the:

- Raw material extraction and production:
  - PP for both types of primary packaging
  - Paper for the tamper-evident system
  - Tritan, PBT, cPET, PLA for the reuse iterations
  - Additives for both iterations
- Production:
  - Injection moulding for the reusable packaging
  - Extrusion and thermoforming for the single-use packaging
  - Printing of the paper
  - Coating for the reuse iterations
  - QR code printing for the reuse iterations
- Cleaning of reusable packaging
- End of life:
  - Treatment of waste generated during the life cycle (recycling, energy recovery, landfill)
- Transport: distribution of raw materials and components to the manufacturing plant, empty packaging from the plant to the filler, full packaging from the filler to the supermarket, return scheme of the reusable packaging, collection and transport of production and post-consumer waste to waste treatment facilities.

These steps are presented in the perimeters described in Figure 22 for the single-use packaging and Figure 23 for the reusable packaging.

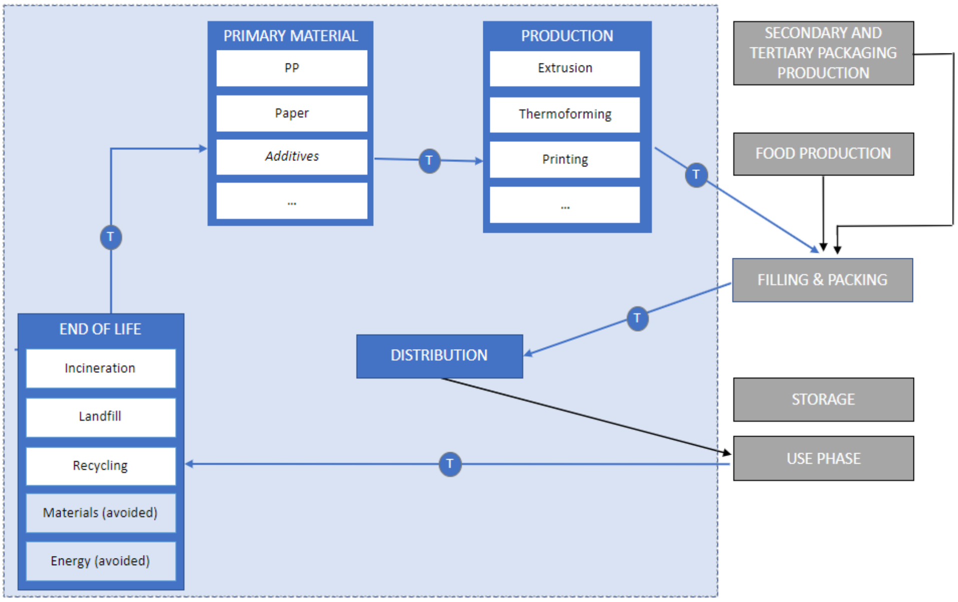


Figure 22: System boundaries for the Uzaje UC single-use packaging life cycle

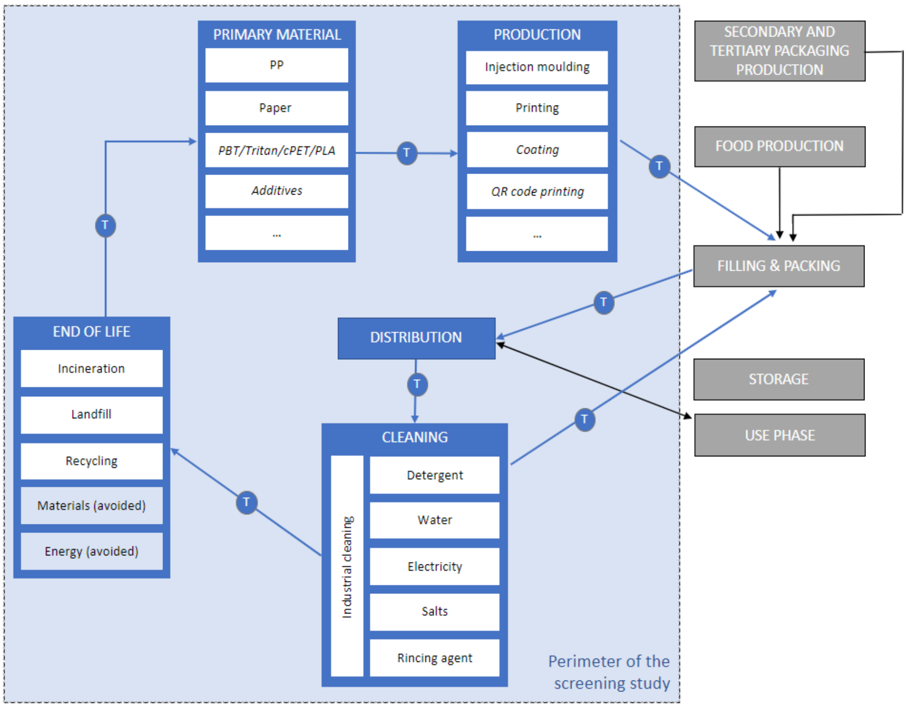


Figure 23: System boundaries for the Uzaje UC reusable packaging life cycle

The following steps will be excluded from the study perimeter because they are considered equivalent in both systems, and will not change the conclusion:

- Food production and processing;
- Package filling;
- Use phase (refrigeration or heating).

Moreover, the storage steps are also excluded from the perimeter because they are considered equivalent in both systems, and will not change the conclusion.
The secondary and tertiary packaging production will be excluded in the first screening study to focus on the primary packaging eco-design.

As explained in the LCA methodology part, the reuse infrastructures are not included in the perimeter, as no data is considered relevant enough.

4.7. Data collection strategy

4.7.1. Life Cycle Assessment

For the screening studies, since the goal is to identify the environmental hotspots of reusable business models, secondary data will be used for most of the assessment. We will use public databases (such as EcoInvent 3.9.1) to model the following life cycle stages: Primary Material, Production, End-of-life and for all Transport. Based on the partners experience, there is no available data on industrial cleaning for packaging. We will use primary data (factory specific) to model the cleaning stage of the life cycle.
A document will inform the data used for each elementary flow in all use-cases associated with a data quality rating. It will enable to identify easily the need of developing specific data, if the corresponding elementary flow is a major contributor and the data quality is equivalent or less than fair.

4.7.2. Life Cycle Costing

Usually, the LLC takes the elementary flows collected by the LCA to convert them into financial impacts. During the screening studies, the data for LCC will be mainly from databases as for the LCA, but some steps not taken into account in the LCA screenings are essential to have a good overview of the use-cases economic impact (labour and maintenance costs, machine purchasing, infrastructures…).
In parallel to the LCC screening studies begins WP4, which will assess the use-case business models. The two tasks are looking for similar inputs from use-case leaders. Therefore, they will work together to get as much primary data as possible.

4.7.3. Social Impact Assessment

During the screening studies, the goal is to identify the social hotspots of the different use cases and select the relevant social topics/impact subcategories for packaging-specific assessment. To do so, we will use public data sources such as the International Labour Organisation (ILO), the World Bank, the United Nations International Children's Emergency Fund (UNICEF) or the Social Hotspots Databases (SHDB). The result of this work will be a shortlist of social topics with a high risk of social impact.
For the full assessment, this shortlist of social topics will be assessed by higher quality data and mainly by using company-specific data, obtained through questionnaire, interview and audits. For company's own operations (consortium partner's operations) we will use company-specific data as much as possible. For the upstream and downstream processes, we might still use country or sector-specific data.

4.8. Evolutions for the full assessment

4.8.1. Scope of the full assessment

In the full assessment, the steps that are out of the screening perimeter in every use-case will be integrated in the perimeter, as the aim of the full assessment is not only to compare the solutions, but to give the most comprehensive information on the real impact of a reusable solution.

Some life cycle steps may be excluded, if the screening studies revealed that their contribution to the whole life cycle impact for all the indicators is negligible.

As recommended by the ADEME methodology, LCA study must be done without the packaged product life cycle but it can be optionally integrated in a second LCA to see the impact of the packaging in the whole use-case system.

Likewise, the LCC screening focuses on direct costs incurred by the product within the chosen perimeters. Collection of externalities, to complete this first screening, will be realized outside the LCA perimeter. This external cost assessment will fully identify all costs that will ultimately influence the product business model.

4.8.2. Data collection and data quality

From the beginning of the screening studies to task 7.5, more and more data will be provided from WP2 to WP5 so that the studies will use more primary data and be more true to the real use-cases tested in WP6. There will be an iterative process that may change the perimeter of the study, the functional unit or the reference flows as the screenings will also give inputs to the above-mentioned WPs.

However, the Technological Readiness Level will still differ between the solution developed in the project and the already commercialised single-use and reusable solutions compared. This may cause discrepancy in the data quality ratio of the compared scenarios and give studies in disfavour of the reusable plastic packaging. To mitigate this risk, the sensitivity analyses will enable to present prospective results when the packaging reuse value chain will be more commercially mature. Moreover, companies already selling reusable solutions will be contacted to collaborate on the full assessments. This will help integrating more robust and representative data (washing, reverse vending machine…) and parameters (return rate, decommissioning rate, transport distances…) in the reusable plastic packaging model, thus correcting the potential discrepancies.

5. Conclusions

In conclusion, this deliverable shows not only what will be done during the next tasks of Work Package 7, but also how the choices made on the LCA, LCC and SLCA methodologies and the studies goal and scope will evolve.

As it can be seen in the literature review, LCA are where methodology is the most mature and where the most studies on reusable packaging has been done. Moreover, LCA is where both partner, IPC and USFD, have the most experience. The work on methodology during the screening phase will then be less time consuming than for the other two assessments and will be dedicated to work on a product category rule, based on the ADEME methodology and suitable to the PEF methodology.
For the LCC analysis, the benchmark of the main methodologies as well as the partners' favoured method together with their experience in that domain showed that there is a need of creating a composite methodology, coupling a screening of the cost along the value chain together with a TCO analysis that will additionally project capital costs over a longer period. The screening studies will be the occasion to test this method and make it as robust as possible for the full assessment.
Since SLCA is the least developed technique, the screening phase will be challenging for both partners, who have no or few experience in SLCA practice. The work on this deliverable shows that there are guidance documents, approved by the community. Our objective will be to follow these documents and develop an expertise. We will also take an interest in Corporate Social Responsibilities (CSR) as a continuation of our methodological work. It would be interesting to identify the used social criteria for the CSR reports of the partners of the project.

Like the methodology, the work on the scopes is based on many assumptions considering the work packages giving the inputs have not begun or delivered results. The scopes written for the screening studies take into account this constraint and justifies the simplifications made accordingly. As the screening step will progress, and the other work packages provide inputs, the scopes will integrate more life cycle steps and more flows to perform studies that are closest to the real use-case developed.

As a reminder, this deliverable has been written in the early stage of Buddie-Pack, before key choices from the other work packages: business model definition, material selection, value chain… Moreover, the screening phase is an iterative process destined to challenge the methodological choices made in this deliverable.
In conclusion, even if the work performed on the methodology before the screening studies is necessary, the choices made in this deliverable are expected to evolve throughout the project.

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8. Annexes

8.1. LCA existing methodologies

ISO 14040-14044

The ISO 14040/14044 are standards for "Environmental management - Life cycle assessment”. ISO 14040 has been first published in 1997, followed by ISO 14041 in 1998 and ISO 14042 and 14043 in 2000. They have been cancelled in 2006 to be replaced by a new ISO 14040[12] and ISO 14044[13] combining the three other. ISO 14040 is intended for non-expert readers and presents good practices in general for conducting an LCA. ISO 14044 is written for LCA practitioners and specifies the requirements for each phase of the LCA.

According to ISO 14040/14044, an LCA should be divided into four phases, as presented below in Figure 24. The analysis of other methods will follow this formalism.

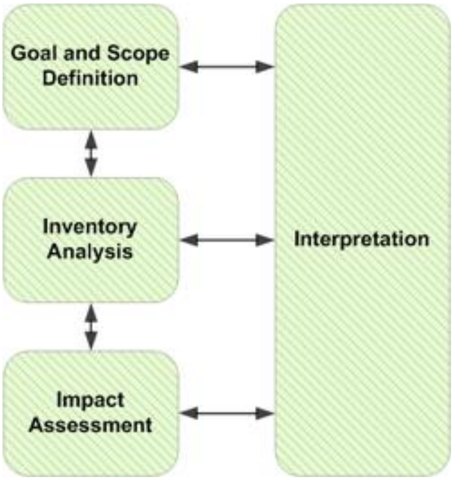


Figure 24: Diagram of the stages of a life cycle assessment

The methodology presented by these standards is general and does not propose sector-specific documents. There are therefore no recommendations relating to the modelling of packaging or transport, or to reuse.

FD CEN/TR 13910

This technical report defines and describes how to apply life cycle assessment to packaging and distribution systems. It takes each part described in ISO 14040 and 14044 and specifies it for the packaging sector. Therefore, it can be seen as a category rule of the ISO 14044 standard. However, it does not provide an operational methodology, i.e. calculation methods and reference values to be used for each stage of the life cycle of a packaging.

PEF

The Product Environmental Footprint (PEF) is the European system for Life Cycle Assessment, aiming to increase comparability between products of the same product category. It was created by the European Platform for Life Cycle Assessment (EPLCA). The European Commission has created a general framework but there are also sectoral documents: the PEF-Category Rules (PEFCR) which are a set of rules aiming to harmonise the eco-labelling for the same category of products, to facilitate their comparison. As explained by article by Bach et al. [45], ISO 14040/44 is the basis for ISO 14025 [41] as well as for the PEF guide [44]. However, it should be noted that the PEF guide is not conform with ISO 14040/44, and even partly contradicting, e.g., PEF allows for comparisons and comparative assertions based on normalized and weighted results, which is explicitly excluded in ISO 14040/44. The links between PEF, PEFCR, ISO 14040/44 and ISO 14025 are explained in Figure 25.

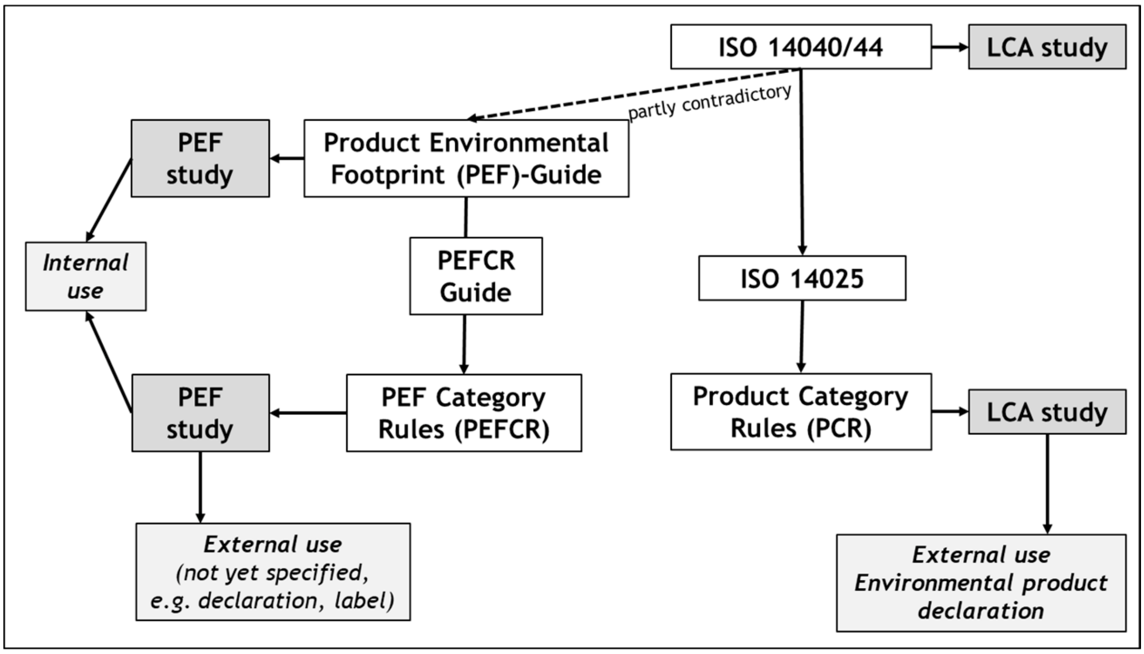


Figure 25: Comparison of PEF method and the PCR concept based on ISO 14040/44 (Source: Bach et. al., 2018[45])

The Table 6 shows the product categories for which there is a category rule, that is to say for which comparative studies are allowed by the PEF.

Table 6: Available PEFCRs

Beer	Dairy	Decorative paint
Feed for food producing animals	Hot and cold water supply pipe systems	Household liquid laundry
Intermediate paper product	IT equipment	Leather
Metal sheets	Packed water	Pasta
Pet food	Photovoltaic electricity production	Rechargeable batteries
T-shirt	Thermal insulation	Uninterrupted Power Supply
Wine		

There is no PEFCR for packaging yet. However, the PEFCR Guidance [47], i.e. the guide for PEFCRs creation, can be used for a PEF study for product groups not covered by an approved PEFCR.
The methodology provides detailed guidance and requirements on how to model specific life cycle stages, processes and other aspects of the product life cycle:

- Functional unit and reference flow definition
- List of impact categories
- Cut-off criteria
- Extended product lifetime (reuse rate)
- Agricultural modelling
- Biodiversity
- Electricity modelling
- Transport and logistics modelling

- Infrastructure and equipment modelling
- Packaging modelling
- Storage modelling
- Use stage modelling
- End of life modelling
- GHG emissions and removals
- Data collection requirements and quality requirements.

The methodology uses the re-use rate, i.e., the number of rotations or uses the product undergoes.
Reuse affects the calculation of several stages of the product life cycle:

- Raw materials: the amount of material involved in the packaging should be divided by the number of uses;
- Transport from the packaging manufacturer to the factory of the packaged product: the impact of the journey should be divided by the number of uses;
- Transport from factory to consumer: the impact of the round trip should be divided by the number of uses;
- Processing at the factory: once the packaging is returned, the consumption related to cleaning, repairing or refilling the packaging should be taken into account;
- End of life: the amount of material treated at the end of life should be divided by the number of uses.

Two calculation methods are available to calculate the reuse rate of reusable packaging managed by the manufacturer of the packaged product:

- Option A: Using specific data from the packaging value chain

$$Reuse\ rate\ of\ the\ pool = \frac{\#F_i}{\#B}$$

$$Net\ material\ use(kg/FU) = \frac{\#B}{\#F_i} \times m_{mat/packaging}$$

  With:
  #Fi: Number of bottles filled during the lifetime of the bottle pool
  #B: Number of bottles at initial stock plus purchased over the lifetime of the bottle pool

- Option B: If no specific data is available

$$Reuse\ rate\ of\ the\ pool = \frac{LT}{(LT \times \%Los) + \frac{1}{\#Rot}}$$

  With:
  #Rot: Average number of rotations of a single packaging, during one calendar year (if not broken). One loop consists of filling, delivery, use, back for washing
  LT: Estimated lifetime of the bottle pool (in years)
  %Los: Average percentage of loss per rotation. This refers to the sum of losses at consumer and at filling sites.

There is also a calculation method for the allocation of impacts and benefits associated with the end of life scenario, called the Circular Footprint Formula (CFF). This formula is divided in three parts: material recovery, energy recovery and disposal.

Material

$$(1-R_1)E_V + R_1 \times \left(A \times E_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

$$(1-R_2-R_3)E_D$$

With:

A: allocation factor of burdens and credits between supplier and user of recycled materials.
B: allocation factor of energy recovery processes.
Q_{Sin}: quality of the ingoing secondary material.
Q_{Sout}: quality of the outgoing secondary material.
Q_p: quality of the virgin material.
R_1: proportion of material in the input to the production that has been recycled from a previous system.
R_2: proportion of the material in the product that will be recycled (or reused) in a subsequent system.
R_3: the proportion of the material in the product that is used for energy recovery at EoL.
$E_{recycled}$: specific emissions and resources consumed arising from the recycling process of the recycled (or reused) material.
$E_{recyclingEoL}$: specific emissions and resources consumed arising from the recycling process at EoL.
E_v: specific emissions and resources consumed arising from the acquisition and preprocessing of virgin material.
E^*_v: specific emissions and resources consumed arising from the acquisition and preprocessing of virgin material assumed to be substituted by recyclable materials.
E_{ER}: specific emissions and resources consumed arising from the energy recovery process
$E_{SE,heat}$ *and* $E_{SE,elec}$: specific emissions and resources consumed that would have arisen from the specific substituted energy source, heat and electricity respectively.
E_D: specific emissions and resources consumed arising from the disposal of waste material at the analysed product's EoL, without energy recovery.
$X_{ER,heat}$ *and* $X_{ER,elec}$: the efficiency of the energy recovery process for both heat and electricity.
LHV: lower heating value of the material in the product used for energy recovery.

Default values for some parameters (A, R_1, R_2, R_3 and Q_s/Q_p for packaging) are available in the Annex of the PEF referential.

The 16 environmental impact indicators recommended by the PEF method follow the International Reference Life Cycle Data System (ILCD) recommendations for the impact characterisation methods showed in Table 7. The recommended characterisation models and associated characterisation factors in ILCD are classified according to their quality into three levels: "Level I" (recommended and satisfactory), "Level II" (recommended but in need of some improvements) or "Level III" (recommended, but to be applied with caution).

Table 7: Recommended impact categories and characterisation methods by the ILCD

Impact category	Recommended default LCIA method	Robustness
Climate change	IPCC 2013 100y	I
Particulate matter	RiskPoll model & Greco et al 2007	I
Ozone depletion	WMO 1999	I

Ionizing radiations	Human health effect model (CML, ReCiPe, Ecoindicator99 & Impact 2002+)	II
Acidification	Accumulated exceedance	II
Eutrophication, terrestrial	Accumulated exceedance	II
Eutrophication, freshwater	EUTREND (ReCiPe)	II
Eutrophication, marine	EUTREND (ReCiPe)	II
Photochemical ozone formation	LOTOS-EUROS (ReCiPe)	II
Resource use, fossils	CML 2002	II
Resource use, minerals & metals	CML 2002	II
Human toxicity, cancer	USEtox	II/III
Human toxicity, non-cancer	USEtox	II/III
Ecotoxicity, freshwater	USEtox	II/III
Water use	Swiss Ecoscarcity	III
Land use	SOM model	III
Ecotoxicity (marine & terrestrial)	No method recommended	

The methodology also recommends performing a normalisation and a weighting of the impacts, as a way to choose the most relevant impact categories. The current PEF method includes no impact category named "biodiversity". However, the current PEF method includes at least 6 impact categories that have an effect on biodiversity (i.e., climate change, eutrophication aquatic freshwater, eutrophication aquatic marine, acidification, water use, land use). As biodiversity is an important topic on the political agenda, when developing a PEFCR, biodiversity shall be addressed separately.

In conclusion, the PEF method is one of the most advanced methodologies as it gives many operational guidelines on how to model each life cycle step. As there is no category rule for plastic packaging, comparative assertions between two packages are not allowed by the PEF.

ADEME methodology

ADEME is the French Agency for Ecological Transition, created in 1991. They work with all stakeholders (state, businesses, local authorities, citizens) and are involved in the innovation & research sector to tackle climate change and the degradation of resources. In 2022, a reference framework for the comparative LCA of packaging solutions was published by the ADEME. This methodology is destined to help anyone involved in the commissioning, piloting and implementation of comparative LCA studies of different packaging solutions. It can also be used as a reference to critically analyse an existing LCA study, to better understand the assumptions made and its field of application. Alternatives to single-use plastic packaging, such as reusable packaging or bio-based materials, are explored.

The main document includes several technical sheets, described in Figure 26, sorted according to different themes in order to guide stakeholders, both experts and non-experts, through each step of the LCA.

Comission an LCA study
- Role of the commissioner
- Critical review
- Capitalisation

Define the scope of the study and perimeter
- Functional unit
- Packaging description
- Steps & activities to be included in the perimeter
- Integration of the packaged product life cycle
- Integration of reuse infrastructures

Model
- Energy mix
- Recycled material rate
- Number of packaging uses
- Transport (empty & full package, empty return)
- Assess recyclability

Use reference values
- Road transport
- Rate of recycled packaging waste
- Rate of non-recycled packaging waste
- Energy recovery from incinerated waste
- Waste colection and transport

Quantify the impacts
- Impact indicators to be assessed
- Climate change assessment
- Risks of packaging waste in the environment

Figure 26: Summary of the methodological sheets of the ADEME Reference Framework

Two calculation methods are available to calculate the reuse rate of reusable packaging managed by the manufacturer of the packaged product:

- Option A: Using specific data from the packaging value chain

$$Reuse\ rate\ of\ the\ pool = \frac{\sum_{i=1}^{A} \#Filled\ packages\ on\ year\ i}{\#Packages_{launch} + \sum_{i=1}^{A} \#Renewed\ packages\ on\ year\ i}$$

- Option B: If no specific data is available

$$Nombre\ d'utilisations = \frac{1}{\left(\frac{1}{Rotan \times DVM} + Renewal\ rate\right)}$$

With :

- DVM: lifespan of the reusable/recyclable packaging model
- Rot_{an} : annual number of rotations
- Renewal rate calculation :

$$Renewal\ rate = 1 - Return\ rate + Return\ rate \times Decommissioning\ rate$$

For the end of life, the ADEME methodology follows the CFF created in the PEF with adjustments. For the material recovery part, the formula is the same but a default value is only given for the A factor and specific values are encouraged for the other factor. For the energy recovery part, the principle is the same but the methodology presents the formula differently and suggests reference values. The electricity and heat produced from waste incineration are given with the following formulas.

$$Q_{Elec} = M_{Waste} \times LHV_{Waste} \times X_{ER,\ Elec}$$
$$Q_{Heat} = M_{Waste} \times LHV_{Waste} \times X_{ER,\ Heat}$$

With:

M_{Waste}: incinerated waste mass.

$X_{ER,heat}$ and $X_{ER,elec}$: efficiency of the energy recovery process for both heat and electricity. Reference values are given in the annex.

LHV_{Waste}: lower heating value of the material in the product used for energy recovery. A formula is given to calculate it with reference values if it is not known.

It can be noted that there is no B factor like in the CFF. 100% of the impacts and benefits of incineration are then allocated to the studied packaging.

The ADEME methodology chose to be aligned with the PEF recommendations for the impacts assessments categories, available in Table 7. However, if a restricted panel of indicators were to be chosen, the methodology suggests analysing at least the climate change, acidification, particulate matter, photochemical ozone formation, fossil and mineral resource use. If a reusable solution is studied, water consumption should be added. Unlike the PEF method, no normalisation or weighting are recommended.

As it can be seen, the ADEME methodology follows many of the guidelines proposed by the PEF, adding reference values for packaging in a French geographic scope. Thus, it can be seen as a packaging product category but too much country focused to be applied to the European use-cases of Buddie-Pack.

EPD "Packaging" Category Rule

The international EPD system (Environmental Product Declarations) is a programme for the production of type III environmental declarations in accordance with ISO 14025. Environmental declarations are derived from an LCA report that complies with ISO 14040/14044. By their nature, environmental declarations allow for the voluntary communication of the environmental impacts of a product by its manufacturer, but do not allow for an assessment of the environmental superiority of one product over another.

The implementation of EPDs is subject to a general methodological document, but there are also sectoral documents governing the modelling of a product category according to specific rules, the PCR (Product Category Rules). The EPD System is also responsible of producing those PCRs. There are several PCRs that may be relevant to plastic packaging, listed in the Table 8 below.

Table 8: PCRs identified for packaging EPD

PCR name	Programme	Registration number
Closable flexible plastic packaging	International EPD® System	2017:05
Crates for food	International EPD® System	2018:02
Packaging	International EPD® System	2019:13

The "Packaging" PCR is the most comprehensive as it covers household, industrial and commercial packaging and addresses the concept of reuse. It will therefore be described in this section.

The functional unit is one package. Technical information of the packaging such as material, dimensions, weight, maximum load etc. must be added. For a reusable packaging, the number of uses and the maximum load during the life of the product should be entered. The total volume transported during the life of the packaging can be added as a second functional unit.

In the case of a household or reusable packaging, a cradle-to-grave scope is mandatory. The life cycle must include the stages of:

- Production and supply of materials;

- Production of the packaging;
- Transport to filling;
- Filling;
- Distribution;
- Transport to repackaging
- Repackaging;
- Transport to filling;
- Disassembly;
- Transport to the treatment facility;
- Treatment for end of life.

There are no given guidelines to calculate the real uses number of the reusable packaging.

The EPD program provides a list of impact indicators to be used by default based on the EN 15804 standard [43], for construction products environmental declarations, shown in Table 9.

Table 9: Impact categories and characterisation methods required by the EPD system

Impact category		Method	Unit
Climate change	**Fossil**	GWP100	kg CO_2 eq.
	Biogenic	GWP100	kg CO_2 eq.
	Land use	GWP100	kg CO_2 eq.
	Total	GWP100	kg CO_2 eq.
Acidification		Accumulated exceedance	kg H^+ eq.
Ozone depletion		ODP	kg CFC_{11} eq.
Eutrophication	**Freshwater**	EUTREND	kg P eq.
	Marine	EUTREND	kg N eq.
	Terrestrial	Accumulated exceedance	kg PO_{43}^- eq.
Photochemical ozone formation		LOTOS-EUROS	kg NMVOC eq.
Resource use – minerals & metals		ADP minerals & metals	kg Sb eq.
Resource use - fossils		ADP fossil resources	MJ
Water use		AWARE	m^3 eq.

The integration of inventory indicators is also recommended or mandatory:

- Primary energy consumption mandatory
- Energy consumption and secondary materials optional
- Waste and outflows optional

KIDV simplified tool

The Dutch Institute for Sustainable Packaging (KIDV) is a governmental organisation, financed by the household waste tax, which aims to provide practical information to businesses on how to make and use more circular packaging. Together with the University of Utrecht and Partners for Innovation, a simplified tool for comparing the impact of reusable and single-use packaging has been developed. This calculation tool gives an overview of all steps in the reusable packaging chain and provides an indication of CO2 emissions and full costs, compared to single-use packaging.

The functional unit is related to the volume of the packaged product. A precise description of the reference flow is not required. The integration of secondary and tertiary packaging is possible but optional.
The life cycle stages studied are:

- Production of materials and packaging;
- Transport from producer to packer;
- Transport to distribution centre;
- Transport to the consumer;
- For reuse, return transport and washing;
- Transport to end of life;
- End-of-life treatments.

The following stages are excluded from the scope, as they are not significant in terms of impact on CO2 emissions:

- Filling of the packaging;
- Storage;
- Packaged product consumption.

To model the reusable packaging, the number of uses and the return rate must be entered.
For the manufacture of packaging, the type of material, the mass, the proportion of recycled material, and the shaping process are requested. For transport, the type of transport, the distance and the mass of transported packaging are requested. For washing, the type of treatment and the washing rate are requested. For end-of-life, each material is asked to be assigned a scenario of choice between 100% recycling, 100% incineration or the Dutch household scenario.
The data used is taken or extrapolated from Ecoinvent and the literature.
The impact of incorporating recycled material and end-of-life recycling is obtained from the use of the CFF.

At the end of the modelling, a comparative analysis between the reusable packaging for one use and the single-use packaging is provided on the CO_2 impact and the total cost. For each of the two indicators, an analysis of the number of reuses to reach the break-even point is proposed in the tool.

This tool doesn't follow the steps of a LCA according to ISO 14040/14044 standards, but enables to quickly identify the main contributors and the break-even point for a reusable packaging, by knowing the minimum information on its life cycle (mass and type of material, type of washing, transport types and distances, end-of-life scenario). Therefore, it is a good starting point for the screening studies as it gives a first data collection plan and an idea of the secondary data that could be found in ecoinvent and the literature.

8.2. LCA literature review

The studies selected with the criteria given part 2.1.2 and for their similarity with the Buddie-Pack use-cases are the following ones:

- UC 1: Rigid Take-away food trays
    - Gallego-Schmid, A., Mendoza, J.M.F., Azapagic, A., 2019. Environmental impacts of takeaway food containers. Journal of Cleaner Production 211, 417–427. https://doi.org/10.1016/j.jclepro.2018.11.220

- UC 3: Semi-rigid catering trays
    - Antony, F., Gensch, C.-O., 2017. Life cycle comparison of reusable and non-reusable crockery for mass catering in the USA.

- UC 5: On the spot food consumption in supermarkets lunch corners

  - RDC Environnement, 2014. Étude visant à déterminer les conditions à réunir pour s’assurer que l’option « emballage réutilisable » pour la restauration à emporter et pour les commerces alimentaires est plus intéressante d’un point de vue environnemental

- UC 2: Refill & Reusable packaging for detergents (refillable bottle)
  - Nessi, S., Rigamonti, L., Grosso, M., 2014. Waste prevention in liquid detergent distribution: A comparison based on life cycle assessment. Science of The Total Environment 499, 373–383. https://doi.org/10.1016/j.scitotenv.2014.08.024

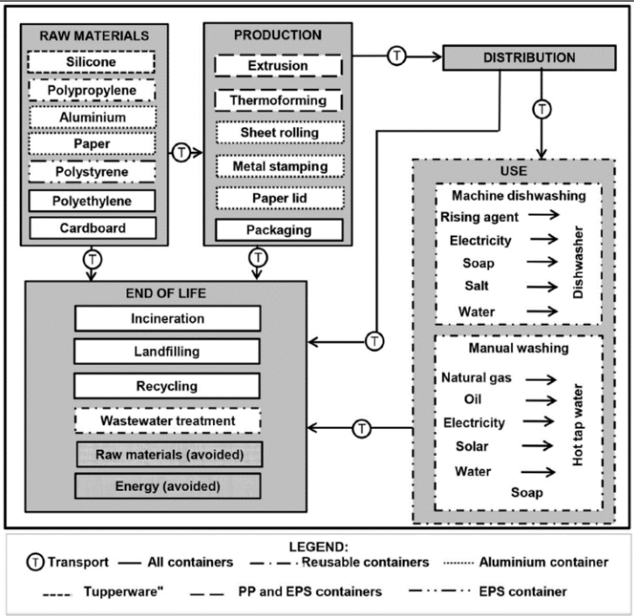
- UC 6: Refill & Reusable packaging for detergents (Bag-in Box)
  - Biganzoli, L., Rigamonti, L., Grosso, M., 2018. Intermediate Bulk Containers Re-use in the Circular Economy: An LCA Evaluation. Procedia CIRP 69, 827–832. https://doi.org/10.1016/j.procir.2017.11.010

The following studies do not specifically correspond to use-cases, but were selected anyway because of their methodological consistency:

- Accorsi, R., Cascini, A., Cholette, S., Manzini, R., Mora, C., 2014. Economic and environmental assessment of reusable plastic containers: A food catering supply chain case study. International Journal of Production Economics 152, 88–101. https://doi.org/10.1016/j.ijpe.2013.12.014
- Saunier, F., 2017. Analyse du cycle de vie de différents types de vaisselle et de scénarios d’opération des aires de service alimentaire de polytechnique Montréal.

1. *Environmental impact of takeaway containers [9]*

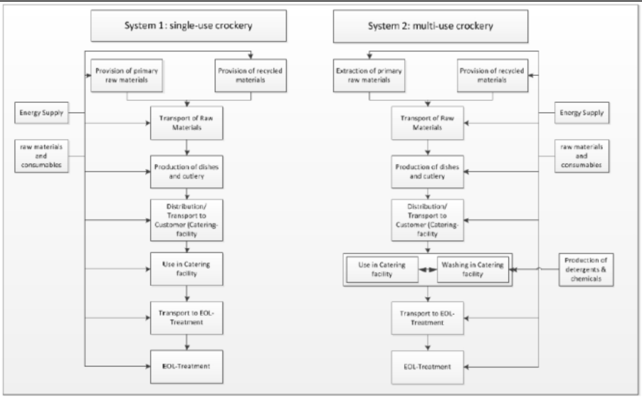
Authors	Gallego-Schmid, A. (University of Manchester) ; Mendoza, J. ; Azapagic, A.			
Year	2018			
Geographic scope	EU			
Goal of the study	1) Estimate and compare the environmental impacts of three commonly-used takeaway food containers: aluminium, EPS and PP; 2) Assess the environmental implications of reusing PP takeaway containers and using reusable PP food savers (Tupperware) instead of single-use containers; 3) Evaluate the environmental effects of different end-of-life management options for the takeaway containers at the EU level.			
Type of packaging studied	Type I			
	Packaging 1	Packaging 2	Packaging 3	Packaging 4
Material	Aluminium body, Paper/PE lid	PP	EPS	PP body, PP/silicone lid
Weight per product (g)	14,5	31,5	7,8	141.3
Number of uses	1	1	1	
EoL scenario	Actual scenario, UE recycling rate for 2025, worst scenario in UE, best scenario in UE			
Functional unit	Goal 1&2: production, use and disposal of a container storing a meal for one person.			

	Goal 3: total number of takeaway containers used annually in the EU.
System boundaries	

Methodological choices	Attributional approach. Modelling the impacts of recycling: avoided impact method (100:0 allocation).
Data sources	Primary data: technical data on the containers and production data Secondary data: the rest (ecoinvent, GaBi, literature)
Impact categories	Climate change; Ozone depletion; Photochemical ozone formation; Acidification; Eutrophication; Ecotoxicity (terrestrial, freshwater, marine); Human toxicity; Depletion of abiotic resources- fossils; Depletion of abiotic resources- minerals; Non-renewable primary energy consumption.
Method	CML 2001
Sensitivity analysis	No sensitivity analysis
Uncertainty analysis	No uncertainty analysis

2. *Life cycle comparison of reusable and non-reusable crockery for mass catering in the USA [4]*

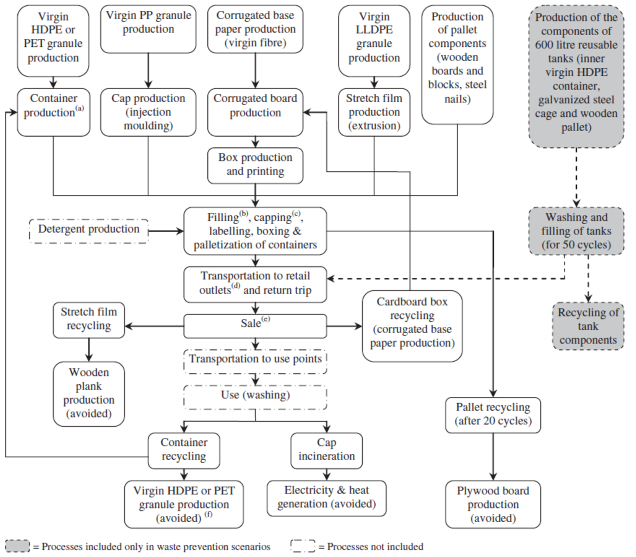
Authors	MEIKO / Öko-Institut e.V.		
Year	2017		
Geographic scope	USA		
Goal of the study	Evaluate and compare the environmental impacts of two types of tableware (disposable and reusable), used in fixed (not mobile) catering facilities.		
Type of packaging studied	Type I		
	Scenario 1	Scenario 2	Scenario 3
Description	Non-patient meals in a hospital cafeteria	School cafeteria	Hotels offering breakfast

Number of uses of reusable items	1000
EoL scenario	20% incineration, 80% landfill for single-use; 100% landfill for reusable
Functional unit	Provision of dishes for the hygienic delivery of X portions of food a day within a year in a stationary out-of-home cafeteria in the USA.
System boundaries	 Included: manufacture of tableware, supply to the catering service, distribution to the consumer, use, washing (for reusable tableware), end-of-life management, transport. Excluded: Storage of food excess, management of waste from meal preparation, activities associated with the kitchen (storage, manufacture of dishwashers, accessories).
Methodological choices	Attributional approach. Modelling the impacts of recycling: avoided impact method (50:50 allocation).
Data sources	Primary data: Data from three hospitals in the US, Data from five schools (elementary, middle, and high school) in the US, Data from three hotels in the US. Secondary data: the rest (ecoinvent)

<table>
<tr><td>Impact categories</td><td>
<table>
<tr><th>Method</th><th>Impact category [unit]</th></tr>
<tr><td>Cumulative Energy Demand</td><td>CED_{total} [MJ]</td></tr>
<tr><td rowspan="9">TRACI[11]</td><td>Ozone depletion [kg CFC-11-eq.]</td></tr>
<tr><td>Global Warming (100a) [kg CO_2-eq.]</td></tr>
<tr><td>Acidification [moles H^+-eq.]</td></tr>
<tr><td>Eutrophication [kg N]</td></tr>
<tr><td>Photochemical oxidation [kg NOx-eq.]</td></tr>
<tr><td>Ecotoxicity [kg 2,4-D-eq.]</td></tr>
<tr><td>Human health (air pollutants) carcinogens [kg benzene-eq.]</td></tr>
<tr><td>Human health (air pollutants) non-carcinogens [kg toluene-eq.]</td></tr>
<tr><td>Human health (air pollutants) respiratory effects average [kg PM2.5-eq.]</td></tr>
<tr><td rowspan="5">ReCiPe Midpoint (H) w/0 LT</td><td>Terrestrial acidification w/o LT, TAP 100 w/o LT [kg SO_2-eq.]</td></tr>
<tr><td>Agricultural land occupation w/o LT, [m^2*a]</td></tr>
<tr><td>Natural land transformation w/o LT [m^2]</td></tr>
<tr><td>Fossil Depletion w/o LT, FDP w/o LT [kg Oil-eq.]</td></tr>
<tr><td>Water depletion w/o LT, WDP w/o LT [m^3]</td></tr>
<tr><td rowspan="2">USE_{TOX}</td><td>USE_{tox} human toxicity, total [CTU_h]</td></tr>
<tr><td>USE_{tox} ecotoxicity, total [CTU-eq.]</td></tr>
</table>
</td></tr>
<tr><td>Sensitivity analysis</td><td>- Distances for the distribution of single-use tableware
- Use of a cooling system for single-use tableware waste
- Difference in electrical mix
- Lifetime of reusable tableware
- Modelling of recycling impacts for single-use tableware (100:0)
- Higher weight of single use ware
- Use of standard dishwashers instead of BAT (best available technology)
- Use of a reusable tray instead of a single-use tray in the hospital scenario</td></tr>
<tr><td>Uncertainty analysis</td><td>No uncertainty analysis</td></tr>
</table>

3. *Waste prevention in liquid detergent distribution: A comparison based on life cycle assessment [15]*

Authors	Simone Nessi, Lucia Rigamonti, Mario Grosso
Year	2014
Geographic scope	Italy
Goal of the study	Evaluate whether, and under which conditions, distribution through self-dispensing systems allows to reduce impacts, compared to distribution with single-use containers.

<table>
<tr><td colspan="2"></td><td colspan="2">Quantify achievable waste prevention and impact reduction potentials.</td></tr>
<tr><td colspan="2">Type of packaging studied</td><td colspan="2">Type I</td></tr>
<tr><td></td><td>Scenario 1</td><td>Scenario 2</td><td>Scenario 3</td></tr>
<tr><td>Material</td><td>Distribution with single-use HDPE containers</td><td>Distribution with single-use PET containers</td><td>Distribution through self-dispensing systems with the provision to the consumer of a refillable virgin HDPE container</td></tr>
<tr><td>Number of uses</td><td colspan="3">1 to 50</td></tr>
<tr><td>EoL scenario</td><td colspan="3">All packages are recycled except the caps(incineration)</td></tr>
<tr><td colspan="2">Functional unit</td><td colspan="2">The distribution of 1000 litres of detergent nearby a retail outlet of the large-scale retail trade in Italy</td></tr>
<tr><td colspan="2">System boundaries</td><td colspan="2">
</td></tr>
<tr><td colspan="2">Methodological choices</td><td colspan="2">Attributional approach.
Modelling the impacts of recycling: CFF</td></tr>
<tr><td colspan="2">Data sources</td><td colspan="2">Primary data: technical data on the containers and production data
Secondary data: the rest (ecoinvent, GaBi, literature)</td></tr>
<tr><td colspan="2">Impact categories</td><td colspan="2">climate change, ozone depletion, photochemical ozone formation, acidification, eutrophication (terrestrial, freshwater and marine), freshwater ecotoxicity, human toxicity, (cancer effects and non-cancer effects), particulate matter, water resource depletion and mineral and fossil resource depletion
Inventory indicator: Cumulative Energy Demand</td></tr>
<tr><td colspan="2">Method</td><td colspan="2">ILCD recommended impact assessment models</td></tr>
<tr><td colspan="2">Sensitivity analysis</td><td colspan="2">- Single-use containers entirely made from recycled HDPE or PET granules
- Number of uses</td></tr>
<tr><td colspan="2">Uncertainty analysis</td><td colspan="2">No uncertainty analysis</td></tr>
</table>

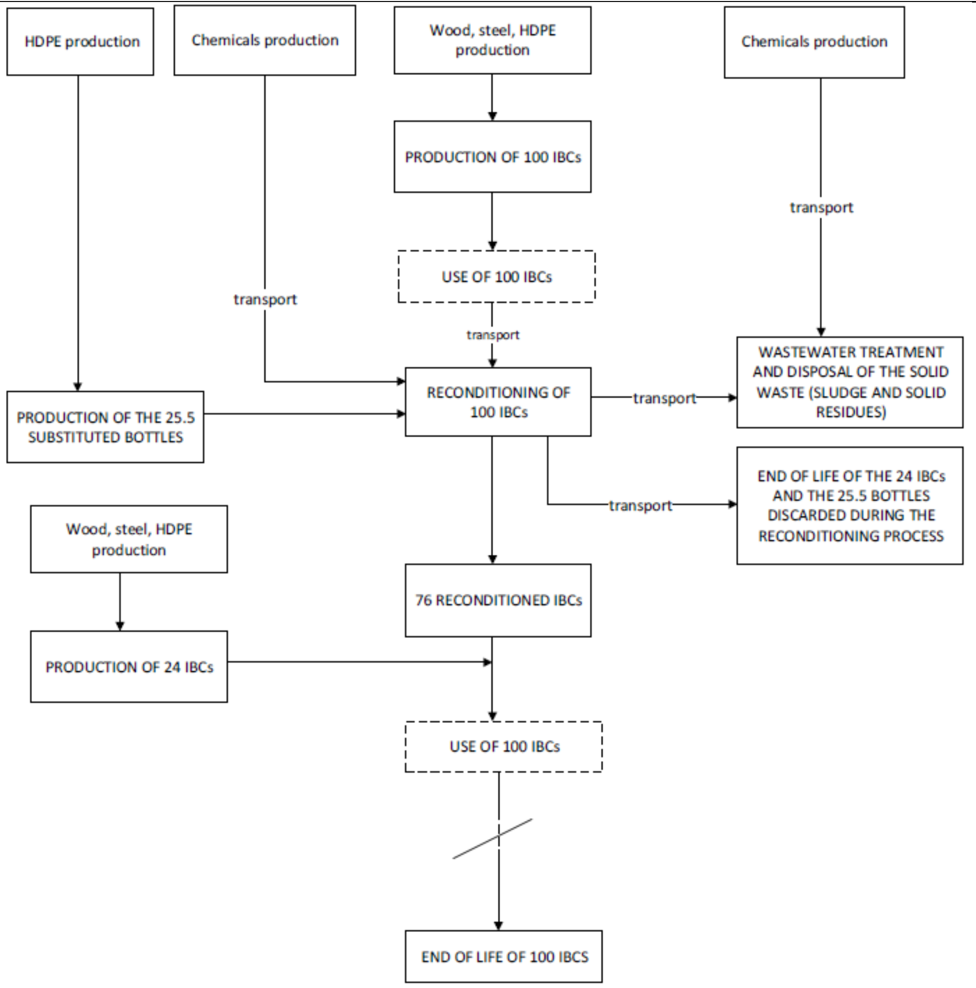
4. *Étude visant à déterminer les conditions à réunir pour s'assurer que l'option « emballage réutilisable » pour la restauration à emporter et pour les commerces alimentaires est plus intéressante d'un point de vue environnemental*

Authors		Bruxelles Environnement / RDC Environment
Year		2017
Geographic scope		Belgium
Goal of the study		1) Define the management systems for refillable containers; 2) Determine the thresholds at which refillable containers are more attractive than single-use containers; 3) Determine the parameters that may reduce the potential environmental benefits associated with reusable packaging.
Type of packaging studied		Type I
	Single-use packaging	Reusable packaging
Materials	PP, PET, PLA, EPS/PS, cardboard, aluminium/carboard	PP, PET, glass/PP, stainless steel/PP
Functional unit		Carry takeaway food in a container suitable for one serving (reference volume of 750 mL)
System boundaries		Inclusion: production of raw materials and transport to the manufacturing plant; manufacturing/shaping of the container and transport to the restaurant/food trade; logistics of collection and redistribution of containers; washing of the container; production and end-of-life of transport packaging; transport to an end-of-life treatment unit; end-of-life of systems Exclusion: washing site infrastructure in the case of centralised management of reusable containers; product storage; possible printing of reusable containers; possible deposit system for containers; transport from the consumer to the restaurant or shop (identical for all systems).
Methodological choices		Attributional approach. Modelling the impacts of recycling: avoided impact method (100:0 allocation).
Data sources		Primary data: Mass of reusable and single-use containers: data measured by the provider Secondary data: Washing: modelling based on data available in the literature Other data: ecoinvent
Impact categories		Climate change; Acidification; Marine eutrophication; Fossil resource depletion Inventory indicator: Raw water consumption

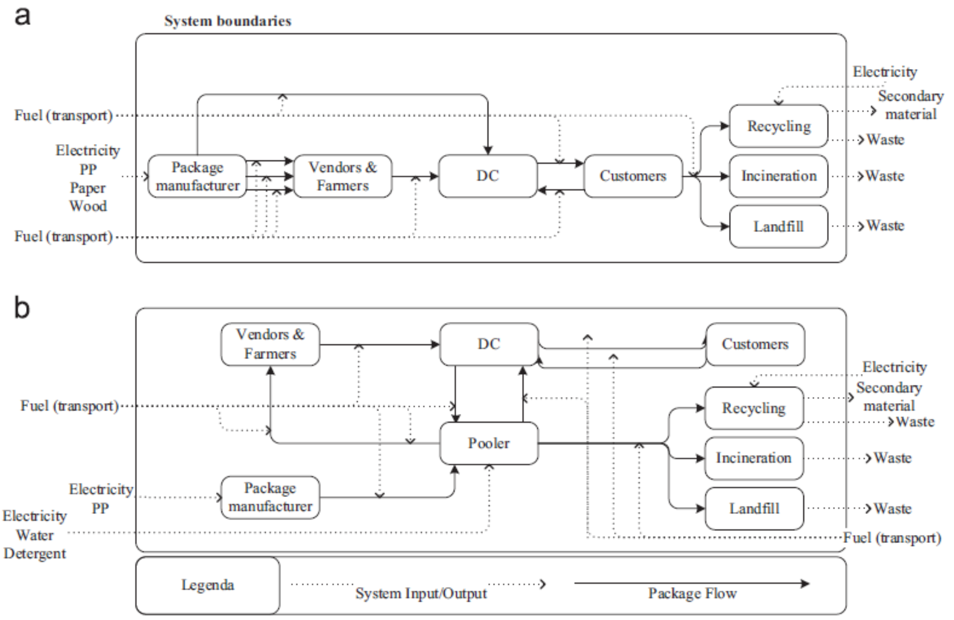
Method	IPCC (2013) ; Seppälä et al., 2006 et Posch et al., 2008 ; Struijs et al, 2008 ; Guinée et al., 2002 and Van Oers et al., 2008
Sensitivity analysis	Washing by the consumer by hand Number of uses
Uncertainty analysis	Aluminium tray recycling rate

5. Intermediate Bulk Containers Re-use in the Circular Economy: An LCA Evaluation [5]

Authors	Laura Biganzoli, Lucia Rigamonti, Mario Grosso		
Year	2018		
Geographic scope	Italy		
Goal of the study	- Evaluate the environmental performance of the life cycle of reusable IBCs; - Identify the contribution of the reconditioning process to the total impacts of the life cycle; - Understand if a system based on reusable IBCs performs better than a system based on single-use IBCs.		
Type of packaging studied	Type I & II		
	Component 1	Component 2	Component 3
Description	Bottle	Cage	Pallet
Material	HDPE	Steel	Wood, HDPE & Steel
Weight per product (kg)	16	22	23, 19 & 20
Number of uses	1 to 5		
EoL scenario	100% recycling if the IBCs do not contain chemical residues at the solid phase, 25,3%incineration/74,7% recycling if the IBCs contain chemical residues at the solid state		
Functional unit	100 1m3 ready-to-use Intermediate Bulk Containers		

System boundaries	 Included: the IBCs production and production of the substituted bottles, the reconditioning process, the end of life of the IBCs (after n uses and after being discarded in the reconditioning process) and of the discarded bottles, the end of life of all the residues generated during the reconditioning process, transport type. Excluded: the use phase of IBCs
Data sources	Primary data: components mass, reconditioning process, transport types Secondary data: materials and chemicals production (ecoinvent), end-of-life (literature), transport distances (asumptions)
Impact categories	climate change, ozone depletion, human toxicity non cancer effect, human toxicity cancer effect, particulate matter, photochemical ozone formation, acidification, terrestrial eutrophication, freshwater eutrophication, marine eutrophication, freshwater ecotoxicity, and mineral and fossil resources depletion. Inventory categories: net water consumption, Cumulative Energy Demand
Method	EF for the impact categories
Sensitivity analysis	- two different combination of chemicals used to wash the bottles - washing water heated by using oil or natural gas - Steel recovery quality ration from 1:1 to 1:0,7
Uncertainty analysis	No uncertainty analysis

6. Economic and environmental assessment of reusable plastic containers: A food catering supply chain case study [1]

Authors	Riccardo Accorsi, Alessandro Cascini, Susan Cholette, Riccardo Manzini, Cristina Mora			
Year	2013			
Geographic scope	Italy			
Goal of the study	a. identification of the environmental impacts generated by single-use packages flowing throughout the FCC and its processes (i.e. manufacturing, transport, end-of-life treatments); b. evaluation of the environmental impacts due to the use of RPCs and the dedicated supply and distribution network; c. identification of the critical parameters (e.g. washing frequency and lifespan) that mostly affect the environmental impact of the RPC packaging system, through the application of sensitivity analysis; d. what-if multiscenario analysis of the packaging system from the sustainability perspective, by varying package end-of-life scenarios and RPC lifespan.			
Type of packaging studied	Type II			
	Packaging 1	Packaging 2	Packaging 3	Packaging 4
Material	Cardboard	PP	Wood	PP
Weight per product (g)	785	900	900	2000
Number of uses	1	1	1	50
EoL scenario	100% incineration, 100% landfill, 25%incineration/25%landfill/50%recycling			
Functional unit	Transportation of 1200t of fruits and vegetables throughout the food catering chain			
System boundaries				
Methodological choices	Cut-off method for end-of-life			
Data sources	Primary data: packing materials and vehicle types Secondary data: the rest (literature, ecoinvent)			

Impact categories	Carbon footprint (IPCC 2007 GWP 100) , Differential cost between single-use & reusable
Sensitivity analysis	Reusable packaging: - Lifespan of 30, 50 and 70 use cycles; - Washing rate of 100% and 50%; - reuse transport network multiplied by 1,2,3,4 and 5.
Uncertainty analysis	No uncertainty analysis

7. *Analyse du cycle de vie de différents types de vaisselle et de scénarios d'opération des aires de service alimentaire de polytechnique Montréal*

Authors	CIRAIG		
Year	2017		
Geographic scope	Canada		
Goal of the study	1) compare reusable and single-use tableware available in the Aramark Quebec catalogue; 2) compare different annual scenarios for the supply of tableware and the management of residual materials generated in food service areas.		
Type of packaging studied	Type I		
	System 1	System 2	System 3
Description	Single-use crockery	Biodegradable crockery	Reusable crockery
Materials	XPS plate, EPS & PS bowls, XPS shell, PE/cardboard & PS cups, EPS drinking glass, PP cuttlery	Bagasse & cardboard plate, cardboard/PLA bowls, bagasse & cardboard shell, cardboard/PLA cups, PLA drinking glass, cornstarch cuttlery	ceramic plate, ceramic bowls, PP shells, ceramic cups, glass drinking glass, steel cuttlery
Number of uses	1	1	500 (800 for the steel cutlery)
EoL scenario	a: landfill, b: landfill/composting, c: catalytic decomposition, d: catalytic decomposition/composting		
Functional unit	Section A: one piece of tableware used at Polytechnique Section C: supply dishes and manage residual materials generated in Polytechnique's food service areas during the 2013-2014 school year		

System boundaries

Scénario	Option de vaisselle	Fin de vie				Commentaires
		Vaisselle	Matières organiques	Matières recyclables	Autres résidus**	
1.a	Jetable – non biodégradable	Enfouissement	Enfouissement (100 %)	Recyclage (80 %)	Enfouissement	Scénario de référence actuel
1.b		Enfouissement	Compostage (40 %)	Recyclage (80 %)	Enfouissement	Scénario en cours d'implémentation à Polytechnique
1.c		Décomposition catalytique	Décomposition catalytique * (100 %)	Recyclage (80 %)	Décomposition catalytique /Enfouissement / Recyclage	
1.d		Décomposition catalytique	Compostage (40 %)	Recyclage (80 %)	Décomposition catalytique /Enfouissement / Recyclage	
2.a	Jetable - biodégradable	Enfouissement	Enfouissement (100 %)	Recyclage (80 %)	Enfouissement	
2.b		Compostage	Compostage (80 %)	Recyclage (80 %)	Enfouissement	
2.c		Décomposition catalytique *	Décomposition catalytique * (100 %)	Recyclage (80 %)	Décomposition catalytique /Enfouissement / Recyclage	
3	Réutilisable	Recyclage ou enfouissement	Décomposition catalytique * (100 %)	Recyclage (80 %)	Décomposition catalytique /Enfouissement / Recyclage	Scénario de référence à long terme

System boundaries	Included: production and transport of materials, production of II/III packaging, production, distribution, washing for reusable tableware, end-of-life treatment (transport, management, avoided production), infrastructure at all stages, procurement and waste management. Excluded: handling and storage in the use phase (identical for all scenarios), use of tableware (identical for all scenarios) and cafeteria operations (excluded from the scenario boundaries. For section C, the upstream phases (production, etc.) of the waste materials are neglected, as the focus is only on the end-of-life phase.
Methodological choices	Attributional approach. Modelling the impacts of recycling: avoided impact method (100:0 allocation). Modelling of impacts for other life cycle stages: allocation of impacts per tonne*km for transport and not by volume; allocation of impacts per piece of dish for washing and not by volume.
Data sources	Primary data: Tableware parts: data provided by Aramark Quebec, by suppliers or generic. Secondary data: Dishwasher (EU/ Öko-Institut e.V., 2011), Catalytic decomposition & Composting (literature), the rest (ecoinvent)
Impact categories	Impact & damage categories Human health (Human toxicity (carcinogenic and non-carcinogenic); Particulate matter emissions; Ionising radiation; Ozone depletion; Photochemical ozone formation) Ecosystem quality (Ecotoxicity (aquatic, terrestrial); Acidification (aquatic, terrestrial); Aquatic eutrophication; Land use) Resources (Non-renewable energy; Depletion of mineral resources) Global warming (Climate change)
Method	Impact 2002+ v2.10
Sensitivity analysis	Section A : Location of production of single-use tableware (100% in Quebec, except for the raw material), Energy for the production of bagasse (-50% of energy needed to shape the plates), Transport distance for the supply of materials (2000 km instead of 100 km) Section C : Impact assessment with ReCiPe instead of Impact 2002+, Modelling of the biodegradable scenario with bagasse tableware instead of cardboard when both are possible

	Others: End-of-Life method from avoided impact method to stocks method, Reuse rate
Uncertainty analysis	Measurement of uncertainty based on Impact 2002+ methodology: - 10% on Climate Change and on Resources - 1-2 ODG on Human health and on Ecosystem quality

8.3. LCC literature review

Names of the studies:

Monireh Mahmoudi, Irandokht Parviziomran, March 2020, Reusable packaging in supply chains: A review of environmental and economic impacts, logistics system designs, and operations management. International Journal of Production Economics 228:107730.
https://doi.org/10.1016/j.ijpe.2020.107730

Thiago L.M. Albuquerque, Claudia A. Mattos, Gabriela Scur, Kumiko Kissimoto, 2019. Life cycle costing and externalities to analyze circular economy strategy: Comparison between aluminum packaging and tinplate.
Journal of Cleaner Production 234 (2019) 477e486
https://doi.org/10.1016/j.jclepro.2019.06.091

Dobon, A., Cordero, P., Kreft, F. et al. The sustainability of communicative packaging concepts in the food supply chain. A case study: part 2. Life cycle costing and sustainability assessment. Int J Life Cycle Assess 16, 537–547 (2011).
https://doi.org/10.1007/s11367-011-0291-9

Marianna Lena Kambanou, Tomohiko Sakao, January 2020, Using life cycle costing (LCC) to select circular measures: A discussion and practical approach.
Resources, Conservation & Recycling 155 (2020)
https://doi.org/10.1016/j.resconrec.2019.104650

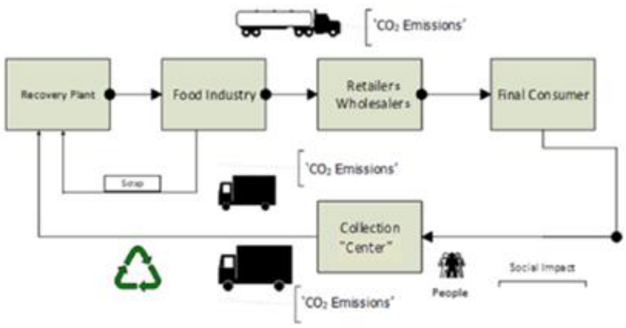
CerCeDD, CTTÉI,Julien Beaulieu, Marc Journeault, 2022, Réaliser une analyse des coûts des flux de matières (ACFM).
Bibliothèque et Archives nationales du Québec.

Caldeira C., Farcal R., Moretti C., Mancini L., Rasmussen K., Rauscher H., Riego Sintes J., Sala S. Safe and Sustainable by Design chemicals and materials - Review of safety and sustainability dimensions, aspects, methods, indicators, and tools. EUR 30991 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-47560-6, doi:10.2760/879069, JRC127109

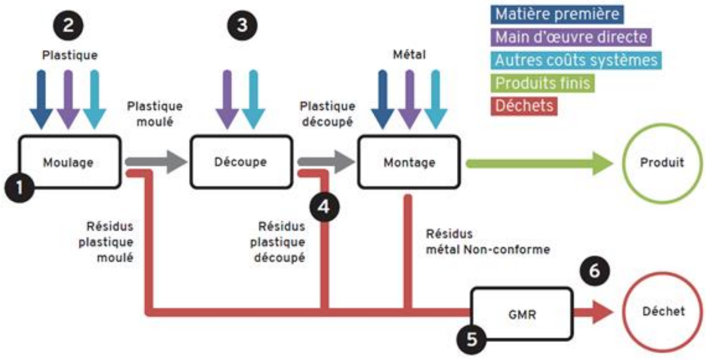
Title	Reusable packaging in supply chains: A review of environmental and economic impacts, logistics system designs, and operations management.
Authors	Monireh Mahmoudi, Irandokht Parviziomran,
Year	2020
Geographic scope	USA

Goal of the study	To review: the extant literature in light of (1) the environmental and economic costs of reusable packaging, (2) the design of reusable packaging logistics systems, (3) the implications of operations management for reusable packaging. Based on analysis of existing studies, deliver insights and potential opportunities for future research on reusable packaging
Functional unit	
System boundaries	
Economic impact assessment method	
Data collection	

Title	Life cycle costing and externalities to analyse circular economy strategy: Comparison between aluminium packaging and tinplate
Authors	Thiago L.M. Albuquerque, Claudia A. Mattos*, Gabriela Scur, Kumiko Kissimoto
Year	2019
Geographic scope	Brazil
Goal of the study	This paper aims to analyse the benefits of using aluminium packaging in the food sector by combining the life cycle costing (LCC) model and externalities in the CE. The results obtained through the LCC concept and externalities indicate an economic benefit and CO2 reduction. This paper seeks to fill the research gap regarding expenditures and benefits for the analysis of production costs, environmental impacts, and externalities in an integrated manner.
Functional unit	
System boundaries	The study was segmented into four stages: (1) cost of production of cans (comparison between aluminium and tinplate); (2) identification of the economic benefit in its logistic operation; (3) externalities; and (4) comparison of the life cycle cost of aluminium and tinplate.

	 **Fig. 1.** Closed-loop production system (aluminum and tinplate). **Source:** Authors
Economic impact assessment method	The PSILA is a theoretical model created by Low et al. (2014) that was described as a modelling and cost analysis technique in closed cycle productive systems. This technique was developed to address the shortcomings that the LCC methods had in integrating the product life cycle into closed-loop systems, but its application is useful in two other factors for the design of this system: (1) in products with high complexity that allow this technique to perform the distribution of the closed-cycle production system in smaller subsystem models; and (2) in the union of the phases of the main production system (MPS) with the end-of-life (EOL) system of the product, allowing for the capture of closed-cycle costs in both phases.
Data collection	The professionals interviewed to gather information about the plant were business managers, and in the food company, they were the general operations director and the commercial manager; both contacts are decision makers and are responsible for the strategic decisions implemented in their businesses.

Title	Guide : réaliser une analyse des coûts des flux de matières (ACFM)
Authors	Julien Beaulieu, ing., M. ing., PMP (CTTÉI)Marc Journeault, Ph. D., CPA, MBA (CerCeDD, Université Laval)
Year	2022
Geographic scope	Canada
Goal of the study	Collaboration between the CTTÉI and CerCeDD has led to a simplification of the MFCA so that it is more accessible to companies to make it more accessible to businesses. This guide is intended to provide companies and the consultants This guide is intended to

	provide companies and the consultants who support them with the tools they need to carry out such an approach.
Functional unit	
System boundaries	
Economic impact assessment method	Material flow cost accounting (MFCA) aims to calculate the "cost" of waste. It takes into consideration the obvious costs related to waste management (e.g., waste container rental, disposal fees, gasoline surcharge, etc.) as well as hidden costs (e.g., purchase of materials, energy expenses, labor costs, capital costs, depreciation of certain equipment, etc.).

Title	The sustainability of communicative packaging concepts in the food supply chain. A case study: part 2. Life cycle costing and sustainability assessment
Authors	Antonio Dobon & Pilar Cordero & Fatima Kreft & Søren R. Østergaard & Helle Antvorskov & Mats Robertsson & Maria Smolander & Mercedes Hortal
Year	2011
Geographic scope	Europe, Netherland
Goal of the study	This paper is the second part of a two-paper series dealing with the sustainability evaluation of a new communicative packaging concept. The communicative packaging concept includes a device that allows changing the expiry date of the product as function of temperature during transport and storage: a flexible best-before-date (FBBD). Such device was analysed in a consumer unit consisting of a nanoclay-based polylactic acid tray filled with pork chops.
Functional unit	The production, packaging and delivery to the point of sale of 1,000 kg of pork chops in The Netherlands using nanoclay based PLA packaging having affixed or not an FBBD communicative device.

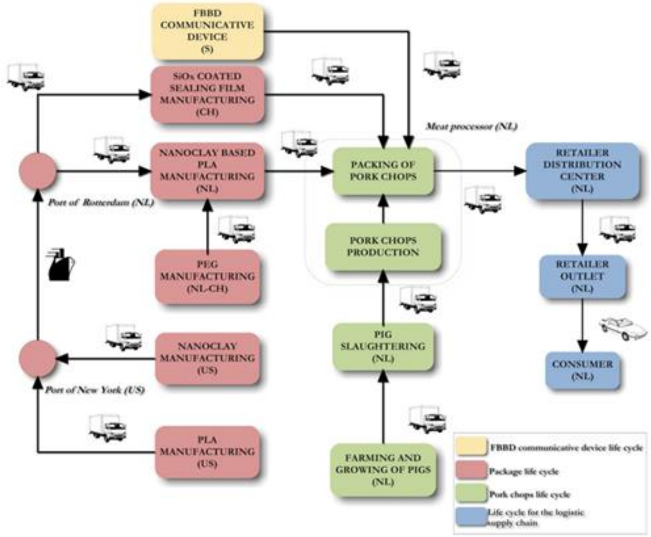
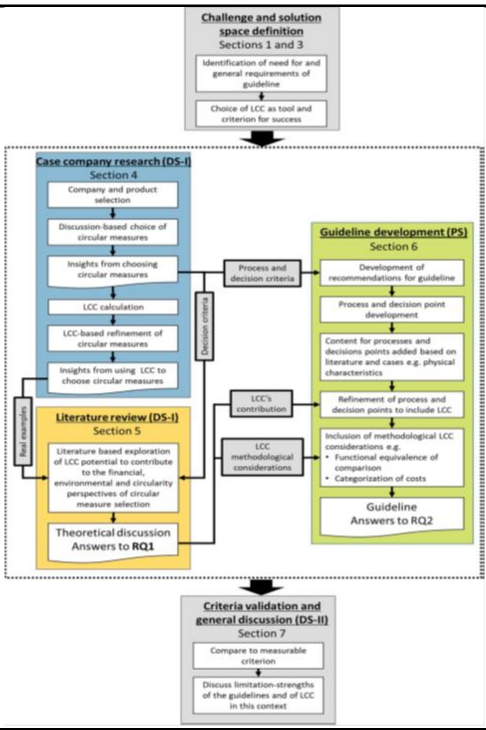
<table>
<tr><td>System boundaries</td><td>

Fig. 3 Life cycle considered within this study (Dobon et al. 2011)
The system boundaries included the raw material extraction, the packaging production and the meat processing, as well as the delivery to the retail outlet. As explained in the LCA (Dobon et al. 2011), use and end-of life phases were excluded from the system boundaries.</td></tr>
<tr><td>Economic impact assessment method</td><td>LCC</td></tr>
<tr><td>Data collection</td><td></td></tr>
</table>

Title	Using life cycle costing (LCC) to select circular measures: A discussion and practical approach
Authors	Marianna Lena Kambanou*, Tomohiko Sakao
Year	2020
Geographic scope	Sweden
Goal of the study	A guideline based on Life Cycle Costing (LCC), which fulfils the aforementioned criteria, has been created. The guideline directs the companies towards measures at the top of the CE hierarchy and LCC is used to assess profitability and provide information on material circularity. Its development follows the Design Research Methodology (DRM) and is based on using LCC at three case companies when selecting circular measures and on literature. Insights on the companies' processes and decision criteria as well as the LCC results are presented.
Functional unit	

System boundaries	
Economic impact assessment method	For cost calculations, the LCC methodology proposed by Bovea and Vidal (2004) was taken into account. According to Bovea and Vidal's LCC methodology, not only costs related to material and energy flows (IC) are considered but also costs due to impacts over the whole society that the system product under study may cause (EC). Therefore, in order to assess the IC, the most important economic inputs were analysed: raw material cost, energy cost, labour cost and profit; taking into account energy and material flows considered in the LCA (Dobon et al. 2011).
Data collection	

8.4. SLCA existing methodologies

UNEP/SETAC Guidelines

A detailed description of the reference scale approach and the impact pathway approach:

On one hand, reference scale approaches are more developed and are operational at present, with many existing case studies. It assesses the social performance of the product system based on specific benchmarks of the expected activity. Reference scales, established during the Inventory phase, usually are ordinal 5-point scales, with each level corresponding to a Performance Reference Point (PRP). The PRPs are thresholds/targets/objectives/ setting several levels of social risk/performance. They can be quantitative or qualitative, based on local legislation, industry best practices or international standards. To improve the precision of the reference scale and to provide clarity on what type of data is needed for the inventory, it can be useful to establish Performance Indicators (PIs) for each of the scale levels. The figures below are showing the example of a reference scale for the subcategory "freedom of association and collective bargaining" with the associated PIs.

Reference scales		Relevant PIs
+2	The company or facility engages in a dialogue with the collective representation of workers and incorporates their views into management decisions.	2-3 and 5-6
+1	The company or facility recognises the collective representation of organized workers in negotiations.	2-3 and 5
0	The company or facility has a system in place to enforce the policy that allows freedom of association and collective bargaining AND no incidents have been discovered that the company or facility prevents workers' freedom of association and collective bargaining.	2-3
-1	Incidents have been discovered that show that the company or facility prevents workers' rights to freedom of association and collective bargaining, but a corrective action plan with a clear timeline for completion has been developped OR the company or facility has a policy that allows freedom of association and collective bargaining but does not have a system in place to enforce the policy.	4 or 1
-2	Incidents have been discovered that show that the company or facility prevents workers' rights to freedom of association and collective bargaining but a corrective action plan with a clear timeline for completion has not been developed.	-

Figure 27: Example of Reference scale with aggregated reference value (Source: UNEP/SETAC Guidelines 2020)

Performance indicators	
1	The company or facility has a policy that allows freedom of association and collective bargaining.
2	The company or facility has a system in place to enforce the policy that allows freedom of association and collective bargaining.
3	No evidence indicates that he company or facility/management has taken disciplinary actions against workers organising themselves collectively.
4	Incidents have been discovered that show that the company or facility prevents workers' rights to freedom of association and collective bargaining, and a corrective action plan with a clear timeline for completion has been developped.
5	The company or facility recognises the collective representation of organized workers in negotiations.
6	The company or facility engages in a dialogue with the collective representation of workers and incorporates their views into management decisions.

Type of data sources	Example
News	The management of the facility has taken disciplinary actions against workers organising themselves collectively.
NGO reports	
Social media	

Figure 28: Performance indicators associated with the reference scale in the Figure 7 (Source: UNEP/SETAC Guidelines 2020)

On the other hand, the impact pathway approach is more suited to the field of research. Instead of stakeholder groups, the impact pathway approach focuses on Impact Categories such as Human Rights or Working Conditions. To determine the social consequences of a product system, it is required to identify the social mechanism describing the cause-effect chain. The social mechanisms are represented by social impact categories, indicators and characterization models. The Figure 29 below illustrates a full Life Cycle Sustainability Assessment (LCA, SIA & LCC), using an Impact Pathway approach.

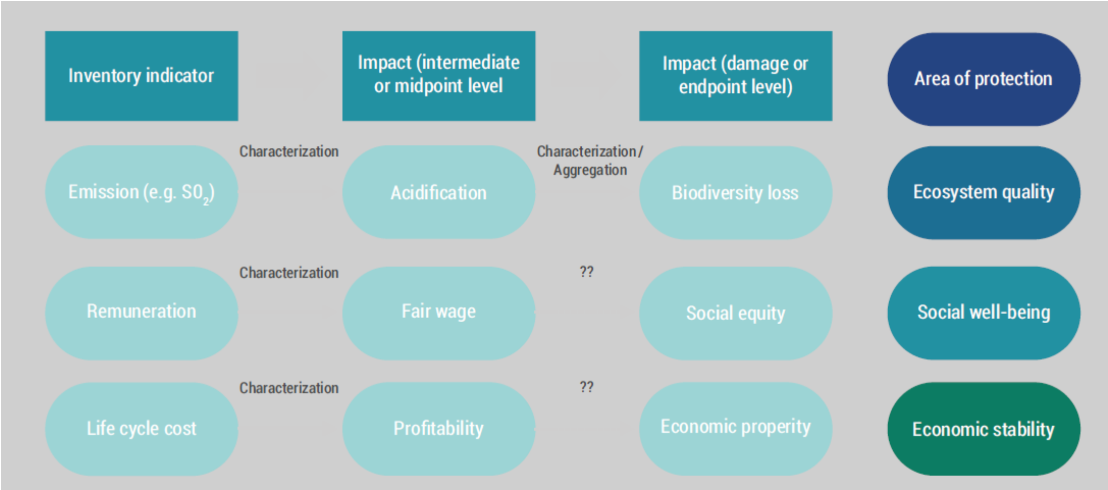


Figure 29 : Example of an impact pathway scheme (Source: UNEP/SETAC Guidelines 2020)

WBCSD

PVC CASE STUDY EXAMPLE

Using the same hypotheses and information described in section 5.6 for the PVC (pipes for water delivery in Europe) case study, the following assessment was made on the level of data used for the PVC product application assessment:

		UPSTREAM		COMPANY'S OWN OPERATIONS	DOWNSTREAM		END OF LIFE
Key life cycle stages (resulting from the hotspot analysis)		Oil extraction	Refining of naphta	Chlorine, ethylene, VC and PVC manufacturing	Pipe manufacturing	Pipe installation	PVC pipe waste management
Source of information		Tier 2	Tier 1	Company's own sites	Customers	Installation	End of life
Operating country		North Sea (40%) and Venezuela (60%)	Europe	Europe	Spain	France	France
Assumption of source of infor-mation	Ex: for the key actor, identify public complaints (in media), search for information from the main plant…	Key actors (Norway); country specific information (Venezuela)	Key actors	Key actors	Key actors	Key actors To complete	Key actors To complete
Data gathering level	Ex: main suppliers (Gazprom, Total, Shell, etc.): database, surveys, audits	Country-specific data	Company specific data	Company specific data	Sector specific data	Company specific data	Company specific data
	Ex: company-specific						
	Ex: generic data (industry, sector, etc.)						
	Databases: LtO questions (TFS), IPIECA & OGP (oil industry)						
Estimated time (hrs) and resources (people) needed	Give: deadlines and real time estimation Expertise needed (ex LCA practitioner, etc.)	2.5 h, 1 person (for the 3 indicators below in grey)	2.5 h, 1 person (for the 3 indicators below in grey)	2.5 h, 1 person (for the 3 indicators below in grey)	1.5 h, 1 person (for the 3 indicators below in grey)	0.5 h, 1 person (for the 3 indicators below in grey)	0.5 h, 1 person (for the 3 indicators below in grey)
Fair wages indicator	Indicators result	-1	1	2		1	1
	Data quality	3	2	1	2	2	2

Figure 30: Justification of the key life cycle stages selection (Source: The Social Life Cycle Metrics for Chemical Products)

The selection of key life cycle stages is based on the following justifications:

	UPSTREAM				CHEMICAL COMPANY'S OWN OPERATIONS
Life cycle stages	Oil extraction	Refining of naphtha	NaCl manufacturing	Additives (colorants, pigments, anti-oxidants) manufacturing	Ethylene, chlorine, VC, PVC production
Details on the life cycle stage location	North Sea (40%) and Venezuela (60%)	Europe	Europe	Europe	
Key questions					
Is there evidence of social violations and situations of risk at this stage in the value chain?	No	No	No	No	Automatically included in the assessment as it concerns the company's own operations
Are there specific benefits during this life cycle stage?	No	No	No	No	
Is this life cycle stage relevant to the functional unit and to the goal of the study (in term of mass, business importance, etc.)	Yes	Yes	No (not significant in term of mass)	No (up to 5% in mass maximum)	
Does this life cycle stage occur in a country with known international human rights violations or social risks?	Yes, Venezuela	No	No	Europe, highly regulated	
Are there specific risks resulting from the company's structure & organization?	Multinational companies	Multinational companies	Multinational companies	No	
Are there specific hazards due to the activity considering the impact categories?	Yes, subcontractors in the oil sector, with higher exposure to labor issues	No	No	No	
Conclusion	Key life cycle stage	Key life cycle stage	Not included in the assessment	Not included in the assessment	Key life cycle stage

Figure 31: Example of analysis of data gathering levels for the "Fair wages" social topic (Source: The Social Life Cycle Metrics for Chemical Products)

CRITERIA	SCORE	1	2	3	4	5
Accuracy, integrity, and validity	Own operations and direct suppliers	Independent 3rd party verified data provided with documentation	Non-verified internal data with documentation, or verified data partly based on assumptions	Non-verified data partly based on assumptions, or data based on grey scientific report	Qualified estimate (e.g. by an internal or external expert), or data based on non-scientific report	Non-qualified estimate, or unknown source
	Other value-chain actors	Data obtained from value-chain actor directly and provided with 3rd party documentation	Data obtained from value-chain actor directly with documentation	Data obtained from other value-chain actors with poor or incomplete documentation	Data obtained from literature	Unknown source
Timelines		Data from current reporting period	Data from previous reporting period	Data from 2 years before reporting period	Data from 3 years before reporting period	Data from more than 3 years before reporting period, or unknown age of data
Correlation		Data from specific site under study	Data from other sites of the company in the same region	Data from relevant sites of the company in other regions	Data from other companies in same region with similar production conditions	Average sector or country data from public or 3rd party database provider

Figure 32: Data quality matrix (Source: The Social Life Cycle Metrics for Chemical Products)

8.5. SLCA literature review

Name of the studies:

Yıldız-Geyhan, E., Altun-Çiftçioğlu, G.A., Kadırgan, M.A.N., 2017. Social life cycle assessment of different packaging waste collection system. Resources, Conservation and Recycling 124, 1–12. https://doi.org/10.1016/j.resconrec.2017.04.003

Ekener-Petersen, E., Finnveden, G., 2013. Potential hotspots identified by social LCA—part 1: a case study of a laptop computer. Int J Life Cycle Assess 18, 127–143. https://doi.org/10.1007/s11367-012-0442-7

Foolmaun, R.K., Ramjeeawon, T., 2013. Comparative life cycle assessment and social life cycle assessment of used polyethylene terephthalate (PET) bottles in Mauritius. Int J Life Cycle Assess 18, 155–171. https://doi.org/10.1007/s11367-012-0447-2

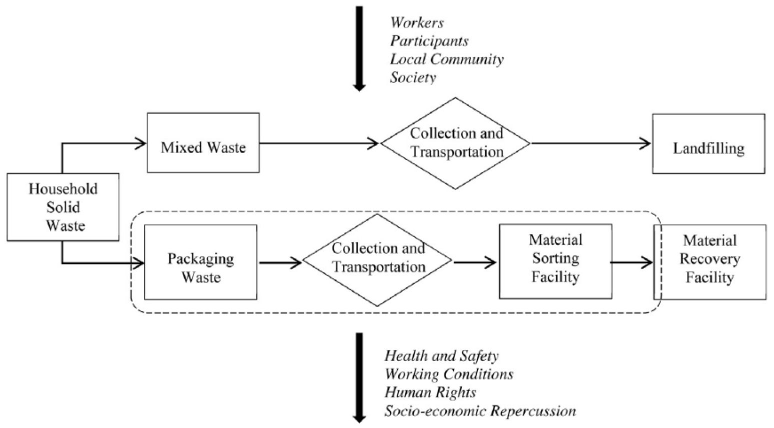
Prasara-A, J., Gheewala, S.H., 2018. Applying Social Life Cycle Assessment in the Thai Sugar Industry: Challenges from the field. Journal of Cleaner Production 172, 335–346. https://doi.org/10.1016/j.jclepro.2017.10.120

Reinales, D., Zambrana-Vasquez, D., Saez-De-Guinoa, A., 2020. Social Life Cycle Assessment of Product Value Chains Under a Circular Economy Approach: A Case Study in the Plastic Packaging Sector. Sustainability 12, 6671. https://doi.org/10.3390/su12166671

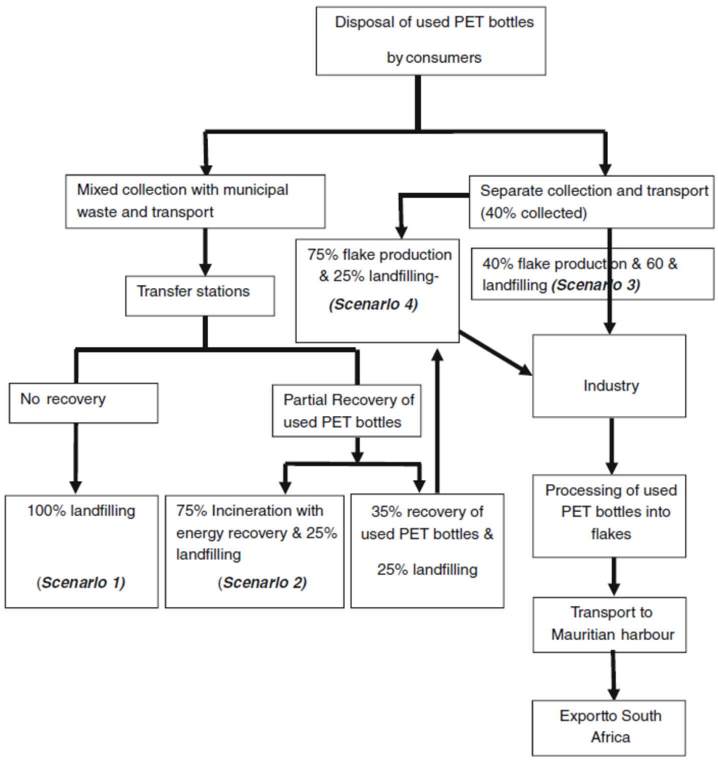
McCord, S., Armstrong, K., Styring, P., 2021. Developing a triple helix approach for CO_2 utilisation assessment. Faraday Discuss. 230, 247–270. https://doi.org/10.1039/D1FD00002K

Siebert, A., Bezama, A., O'Keeffe, S., Thrän, D., 2018. Social life cycle assessment indices and indicators to monitor the social implications of wood-based products. Journal of Cleaner Production 172, 4074–4084. https://doi.org/10.1016/j.jclepro.2017.02.146

Title	Social life cycle assessment of different packaging waste collection system
Authors	Eren Yıldız-Geyhana, Gökçen Alev Altun-Çiftçioğlua and Mehmet Arif Neşet Kadırgana
Year	2017
Geographic scope	Turkey, Istanbul
Goal of the study	Analyse the existing formal and informal collecting system and compare them with the alternative scenarios. Find the social weaknesses and strengths of the currently applied collection systems.
Functional unit	Collection of 1 ton packaging waste
System boundaries	Collection, transportation and separation processes.

	
Methodology	UNEP/SETAC guide (2009) and literature review
Social impact assessment method & Scoring system	All indicators were measured in either quantitatively or semi-quantitatively. Later on, these indicators were converted into comparable scores low (0), medium (0.5) and high (1). The lowest score indicates (or represents) the "most positive" social impacts, the highest score indicates the "most negative" social impact. These scores assigned to each indicator by classifying the percentages as 0–33%, 33–66% and 66–100% and marked as (1), (0.5) and (0), respectively
Data collection	Generic data: Technical reports, publications and statistical sources Specific data: Company records, interviews with stakeholders and observation during field visits
Stakeholder categories	Workers, Consumers, Local Community & Society
Subcategories	Healthy and safe working conditions, Job satisfaction and engagement, Working Hours, Wage, Forced labour, Child labour, Freedom of association and collective bargaining, Discrimination Service satisfaction Healthy and safe living conditions, Secure living conditions, Employment, Social acceptability Contribution to economic development

Title	Comparative life cycle assessment and social life cycle assessment of used polyethylene terephthalate (PET) bottles in Mauritius
Authors	Rajendra Kumar Foolmaun & Toolseeram Ramjeeawon
Year	2012
Geographic scope	Mauritian territory
Goal of the study	To carry out the social life cycle assessment of four disposal scenarios of used PET bottles; and

	To determine the disposal option which is socially more attractive/beneficial
Functional unit	Disposal of 1 ton of used PET bottles to the respective disposal facilities
System boundaries	
Methodology	UNEP/SETAC guide (2009)
Social impact assessment method & Scoring system	methodology based on a scoring system and assesses the performance of a company with respect to selected sub-categories. This methodology aims at converting qualitative inventory information into quantitative social and socio-economic inventory data and aggregating them using a scoring system. The idea behind assigning scores to indicators and sub-categories is thus to aggregate the inventory results and convert them into figures that could be eventually summed up and compared with alternative scenarios. The proposed model has three basic steps: - **Conversion of inventory results (indicators) into percentage** Data collected with respect to predefined indicators are expressed in percentage - **Assigning scores to indicators and sub-categories** A score is assigned to each sub-category by classifying the percentages obtained in the previous step in one of the five categories of percentages namely: 0–20 %, 21–40 %, 41–60 %, 61–80 % and 81–100 %. The score allocated to each sub-category ranges from 0 to 4.
Data collection	Questionnaire/survey (simple, with yes/no questions), submitted to a sample of 140 workers (out of 4650). Questionnaires filled on-site during face-to-face interviews.
Stakeholder categories	Workers, Society and Local community

Subcategories	Child labour, fair salary, forced labour, health and safety, discrimination, social benefit/social security Contribution to economic development Community engagement

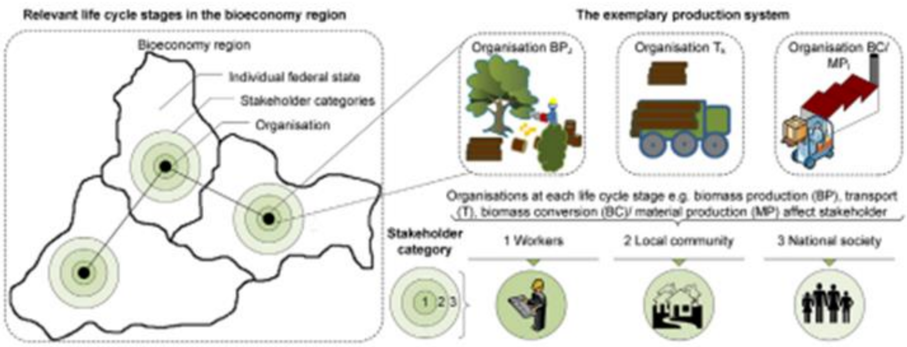
Title	Social Life Cycle Assessment Indices and Indicators to Monitor the Social Implications of Wood-based Products
Authors	Siebert, A. (Helmholtz Centre for Environmental Research), Bezama, A., O'Keeffe, S., Thran, D.
Year	2018
Geographic scope	Regional – in Germany
Goal of the study	To develop indices
Functional unit	n/a this isn't a case study but development of a methodology
System Boundaries	
Methodology	RESPONSA (Regional SPecific cONtexualised Social life cycle Assessment) (based on UNEP guidelines but adapted to be regional) Focusses on foreground processes; social effects outside of system boundary are considered but not in as much detail.
Social impact assessment method and scoring system	Refers to an earlier paper published by same authors in 2016. This paper focusses on developing indices. Scoring system not discussed

Table 5
Final set of social indices and their associated indicators.

Index / Sub-index	Indicator	Unit	Equation/Measure
1. Health & safety			
Accidents[a]	Occupational accidents	Nr	Number of accidents per year per 1000 employees
	Occupational fatal accidents	Nr	Number of fatal accidents per year per 1000 employees
Sick-leave[a]	Sick-leave days	Nr	Sick-leave days per year per employee
	Preventive health measures	Cat.	Health measures (e.g. sick-leave analysis, health activities)
2. Adequate remuneration			
Payment[a]	Payment according to basic wage[1]	y/n	Payment of basic wage
	Average remuneration level	€	Average payment per month per full-time employee
Financial participation[a]	Capital participation[2]	y/n	Existence of a capital participation model
	Profit-sharing and bonuses[3]	y/n	Existence of a profit-sharing and bonuses model
3. Adequate working time			
Working time[a]	Contractual working hours	h	Average contractual working hours per week per full-time employee
	Compensation for overtime	Cat.	Compensation measures (e.g. exclusively payment, payment and free-time, exclusively free-time, any)
Work-life-balance[a]	Access to flexible working time agreements	y/n	Access to flexible working time agreements (e.g. working time accounts etc.)
	Rate of part-time employees	%	Percentage of part-time employees per total employees
4. Employment			
Job conditions[a]	Rate of qualified employees	%	Percentage of employees with professional training per total employees
	Rate of marginally employed (earning max 450€ per month)	%	Percentage of employees earning max 450€ per total employees
Duration of employment[a]	Rate of fixed-term employees	%	Percentage of fixed-term employees per total employees
	Rate of employees provided by temporary work agencies	%	Percentage of employees provided by temporary work agencies per total employees
Job creation[b]	Rate of recruitment	%	Percentage of new hired employees per year per total employees
5. Knowledge capital			
On-the-job training[a]	Employees participated in training	%	Percentage of employees participated in training per total employees
	Support for professional qualification	y/n	Assumption of cost or exemption for training programs
Vocational training[b,c]	Rate of vocational trainees	%	Percentage of trainees per total employees
	Rate of vocational trainees hired	%	Percentage of trainees employed permanently per total trainees
Research & development[c]	Rate of employees in research and development	%	Percentage of employees working permanently or temporally in the research and development section per total employees
6. Equal opportunities			
Gender equality[c]	Rate of female employees in management positions	%	Percentage of female employees in management positions in relation to all employees in management positions
	Measures to improve gender equality	Cat.	Measures for family support (e.g. support for child care, support for female employees)
Older employees[a,c]	Measures to support older employees	Cat.	Measures for older employees (e.g. offer of part-time contracts, special equipment of the workplace)
Minorities[c]	Rate of disabled employees	%	Percentage of disabled employees per total employees
	Rate of foreign employees	%	Percentage of foreign employees per total employees
7. Participation			
Workers participation[a]	Works' council	y/n	Existence of works' councils in the organisation
	Other measures for participation	y/n	Measures to participate in the organisation

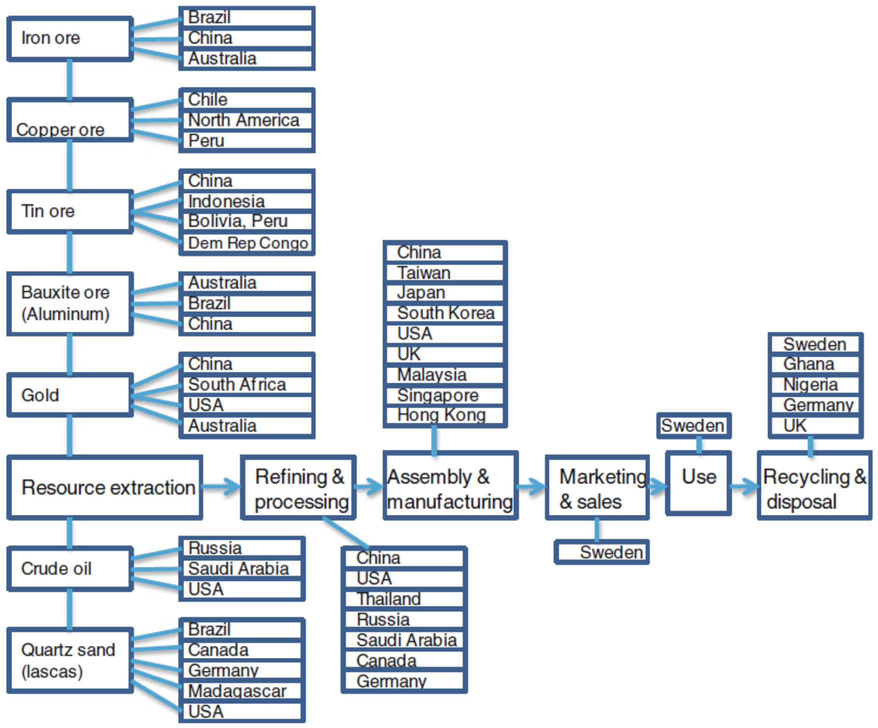
Data collection	Directly from actors in the region.
Stakeholder categories	Workers, local community, national society
Subcategories	See above

Title	Developing a Triple Helix Approach for CO2 Utilisation Assessment
Authors	McCord, S. (University of Sheffield), Armstrong, K., Styring, P.
Year	2021
Geographic scope	Worldwide
Goal of the study	Identify social indicators relevant for carbon dioxide utilisation and develop methodology for assessing them Develop the triple helix – environmental, economic and social life cycle considered on the same system Example: compare social impacts of utilising 1 tonne CO2 for different CDU technologies
Functional unit	See above
System Boundaries	

Methodology	Triple Helix. S-LCA based on UNEP/SETAC guide (2009) using boundaries as for LCA/TEA
Social impact assessment method and scoring system	Qualitative scoring based on quantitative and semi-quantitative data. 5 point scale (0 – 4)
Data collection	Literature and processs data, LCA databses, world bank data
Stakeholder categories	Workers, local community
Subcategories	Delocalisation and migration, local employment, access to MR, safe and healthy living conditions, promoting social responsibility, consumer health and safety, EOL responsibility, child labour, forced labour, equal opportunities, worker health and safety, public commitment to sustainability issues, prevention and mitigation of conflicts, contribution to economic development.

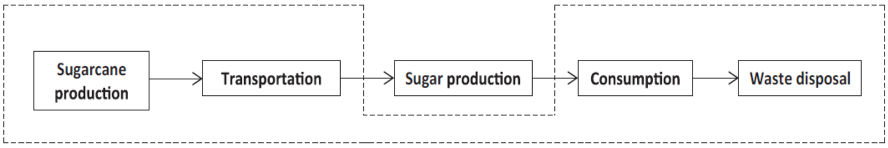
Title	Social Life Cycle Assessment of Product Value Chains under a Circular Economy Approach: A Case Study in the Plastic Packaging Sector
Authors	Reinales, D., Zambrana-Vasquez, D., Saez-de-Guinoa, A.
Year	2020
Geographic scope	global
Goal of the study	Methodology development
Functional unit	n/a
System Boundaries	n/a
Methodology	UNEP/SETAC guide (2009)
Social impact assessment method and scoring system	Qualitative, quantitative & semi-quantitative indicators. 5 point scale (-2 to +2, where 0 = baseline)
Data collection	
Stakeholder categories	Workers, consumer, community, society, value chain actors
Subcategories	Equal opportunities/discrimination, training and education, workers health and safety, Consumers health and safety, EOL responsibility, consumers' well-being, community access to material resources, safe and healthy living conditions, local employment, community engagement, technology development, suppliers' relationship

Title	Potential hotspots identified by social LCA – part 1: a case study of a laptop computer
Authors	Elisabath Ekener-Petersen & Göran Finnveden
Year	2012
Geographic scope	Sweden
Goal of the study	Identify social hotspots of the laptop and to test and evaluate the methodology
Functional unit	A laptop with generalised features and with a typical product system for such a computer
System Boundaries	Craddle-to-grave. Impacts for electricity generation and transports not included



Methodology	UNEP/SETAC guide (2009)
Social impact assessment method and scoring system	Identified the world minimum and maximum values on the indicator, then picked out the countries with values in the highest quartile in the range, indicating severe impacts, as well as the countries with values in the second highest quartile in the range, indicating quite severe impacts Some subcategories were assessed by two or three indicators, others by only one. However, all indicators for a subcategory aimed to assess the same impact for that subcategory and should thus only be counted as one impact. To avoid certain subcategories prevailing in the final result, we summarised the scores for any subcategory having more than one indicator into one score. In this, we chose the most severe score if the indicators scored differently in one and the same subcategory.
Data collection	Country-specific data for the indicators, very little sector-specific information inventoried, using sources suggested in the UNEP guidelines Generic study, performed without information about any specific supply chain, thus testing the availability of generic information.
Stakeholder categories	Workers, consumer, local community, society, value chain actors
Subcategories	Freedom of association/collective bargaining, Child labour, Fair salary Working hours, Forced labour, Equal opportunities/discrimination, Health and safety, Social benefits/social security

	Health and safety, Feedback mechanism, Consumer privacy Transparency, EOL responsibility, Access to material resources, access to immaterial resources, Delocalisation/migration, Cultural heritage, Safe and healthy living conditions, Respect for indigenous rights, Local employment, Community engagement, Secure living conditions Public commitment to sustainability issues, Contribution to economic development, Prevention and mitigation of armed conflicts, Technology development, Corruption Fair competition, Promoting social responsibility, Suppliers' relationship, Respect for intellectual property

Title	Applying Social Life Cycle Asessment in the Thai Sugar Industry: Challenges from the field
Authors	Jittima Prasara-A, Shabbir H. Gheewala
Year	2015
Geographic scope	Thailand
Goal of the study	Assess the social the social performances along life cycle of sugar product
Functional unit	1 tonne of sugar
System Boundaries	Craddle-to-grave. Impacts for Sugar production not included 
Methodology	UNEP/SETAC guide (2009)
Social impact assessment method and scoring system	Reference scale approach Indicators calculated as percentages of stakeholders answering yes/no to the questions designed for each social subcategory.
Data collection	Mostly through interviews, with the objective of 30 answers by stakeholder categories
Stakeholder categories	Workers, consumer, local community, society, value chain actors
Subcategories	Freedom of association/collective bargaining, Child labour, Fair salary Working hours, Forced labour, Equal opportunities/discrimination, Health and safety, Social benefits/social security Health and safety, Feedback mechanism, Consumer privacy Transparency, EOL responsibility, Access to material resources, access to immaterial resources, Delocalisation/migration, Cultural heritage, Safe and healthy living conditions, Respect for indigenous rights, Local employment, Community engagement, Secure living conditions Public commitment to sustainability issues, Contribution to economic development, Prevention and mitigation of armed conflicts, Technology development, Corruption Water and land rights, Fair competition, Promoting social responsibility, Suppliers' relationship, Respect for intellectual property

8.6. Impact subcategories in literature review

Stakeholder categories	Impact subcategories	McCord et al., 2021	Reinales et al., 2020	Yıldız-Geyhan et al., 2017	Ekener-Petersen and Finnveden, 2013	Foolmaun and Ramjeeawon, 2013	Siebert et al., 2018	Prasara-A and Gheewala, 2018
Workers (W)	Freedom of association and collective bargaining			1	1		1	1
	Child labour	1		1	1	1		1
	Fair salary			1	1	1	1	1
	Working Hours			1	1		1	1
	Forced Labor	1		1	1	1		1
	Equal Opportunities & Discrimination	1	1	1	1	1	1	1
	Health and Safety	1	1	1	1	1	1	1
	Social Benefits/Security			1	1	1		1
	Working conditions						1	
	Job satisfaction and engagement			1				1
	Training and Education		1					
Local Community (Lc)	Access to material resources	1	1		1			1
	Access to immaterial resources				1			1
	Delocalization and migration	1			1			1
	Cultural heritage				1			1
	Safe and healthy living conditions	1	1	1	1		1	1

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	Respect of indigenous rights				1			1
	Community engagement		1		1	1	1	1
	Local employment	1	1	1	1		1	1
	Social acceptability			1			1	
	Secure living conditions			1	1			1
Value chain actors (Vca)	Fair competition				1			1
	Promoting social responsibility	1			1			1
	Supplier relationships		1		1			1
	Respect of intellectual property				1			1
Consumer (C)	Health and Safety	1	1		1			1
	Feedback mechanism				1			1
	Consumer privacy				1			1
	Transparency				1			1
	End-of-life responsibility	1	1		1			1
	Service satisfaction			1				
	Responsible communication						1	
	Well-being		1					
Society (S)	Public commitments to sustainability issues	1			1		1	1
	Contribution to economic development	1		1	1	1	1	1
	Prevention and mitigation of armed conflicts	1			1			1
	Technology development		1		1		1	1
	Corruption				1			1