EXPERTS AND SOLUTIONS IN SUSTAINABLE DEVELOPMENT
rdcenvironment.be - contact@rdcenvironment.be

Economic impact of switching to reusable options for pallet wrapping

Final report

Authors
Tom Huppertz
Tristan Salmon
Simon Standaert
Pippa Van Wichelen
Bente Wigerinck

Contact
+32 2 420 28 23
contact@rdcenvironment.be

Document for
EuPC

Date
March 2025

Table of contents

Executive summary

Pallet wrapping packaging is designed to protect and stabilise palletised loads during transportation and storage, safeguarding them from dust, moisture, UV exposure, and rain.

Article 29 (1-3) of the Packaging and Packaging Waste Regulation ("PPWR", e.g. Regulation (EU) 2025/40) establishes various reuse targets for pallet wrapping. It also provides for possible exemptions in cases of "particular economic constraints encountered in a specific sector," as outlined in Article 29 (18a).

In this context, EuPC (European Plastic Converters) commissioned RDC Environment to study the economic constraints and costs of switching from the currently single-use plastic wraps and hoods formats to reusable alternatives.

Currently, the most commonly used transport packaging are single use wraps or hoods, which are both made from plastic. Reusable alternatives include options such as pallet boxes, reusable hoods or sleeves and reusable cardboard boxes.

This report provides an economic evaluation of switching from single use to alternative PPWR-compliant pallet wrapping options, for eight representative products across eight industrial sectors in the EU. The study quantifies both per-unit production cost differences and their cumulative impact at an EU-wide level, incorporating detailed cost models and sensitivity analyses. The following summary outlines the study's objectives, methodology, packaging functionalities, most relevant alternatives and key results.

Objectives and scope

The objective of the study is to assess the economic impact of transitioning from single-use plastic pallet wrapping systems (e.g., stretch wraps or hoods, shrink hoods) to reusable solutions. This evaluation covers eight industrial sectors—agriculture, cement, construction, milk, glass, plastic, retail, and water—each represented by a specific product...The analysis proceeds in the following steps:

- Quantifying the per-unit cost difference between current single-use systems and proposed alternative solutions;
- Conducting sensitivity analyses on key parameters to assess sensitivity of the result to parameters with significant variability or uncertainty;
- Extrapolating the per-unit cost differences to determine the cumulative impact at the EU level;
- Describing the short- to medium-term transition costs (e.g., investment costs of machinery, R&D, production line modifications, co-existence of standards).

Selection of the alternative packaging solution to model, based on functionalities and requirements

Single use plastic wrapping fulfils a certain number of key functions that would need to be met or compensated for in an alternative packaging system. These include:

- Pallet stabilisation;
- Protection from rain, UV, insects, dust;

- Flexibility in adapting to many product formats, but also to different industrial processes.

Each product has different requirements of these attributes, i.e. face different constraints during the packing, the transport or the storage of the pallets. Based on the specific requirements that need to be met as well as the functionalities of the alternative solutions, the most feasible alternative is identified for each sector, as set out in the following table.

Table 1: Products and the most relevant alternative options considered in this study

Sector	Representative product	Alternative solution
Agriculture	25 kg bag of fertilizer	Reusable hood
Cement	25 kg bag of cement	Reusable hood
Construction	Insulation roll	Reusable hood
Milk	1L bottle (HDPE), filled	Reusable hood
Glass	▪ 1L empty glass bottle ▪ 1L filled glass bottle	Stacked pallet wide crates with locks[1]
Plastic	25 kg bag of plastic pellets	Reusable hood
Retail	Cardboard box filled with tissue boxes	Reusable hood
Water	1.5 PET bottle, still water, filled	Reusable hood

There are currently few alternative pallet packaging options in use, and none were identified as being in use at large scale as of early January 2025 for the studied products.

The analysis considers the long term situation where adapted reusable solutions exist and are used at a large scale, between different entities (not closed loops only) and are compatible with automation. The reusable packaging's analysed in the cost model are inspired by the reusable products in circulation today, more optimised and compatible with automation (which are not currently available). Indeed, given the speed of production, a purely manual solution is not feasible for the sectors studied in his report. In particular, the assumption underlying this report is that the automated solutions are technically possible and will be available in the future.

Methodology and cost modelling approach

Data was principally collected via site visits and interviews across the eight sectors. Specifically, 4 site visits and 31 interviews were conducted to identify: (i) the functionalities that are provided by the different types of pallet packaging, as well as (ii) the costs that are related to their application (CAPEX, OPEX and other key factors such as pace and logistics).

The following steps of the palletisation process are modelled:

- Material purchase (pallet, packaging) and its storage.
  - For reusable options, this includes the return cost of these options (transport, treatment, per use cost).
- The end of the production line:

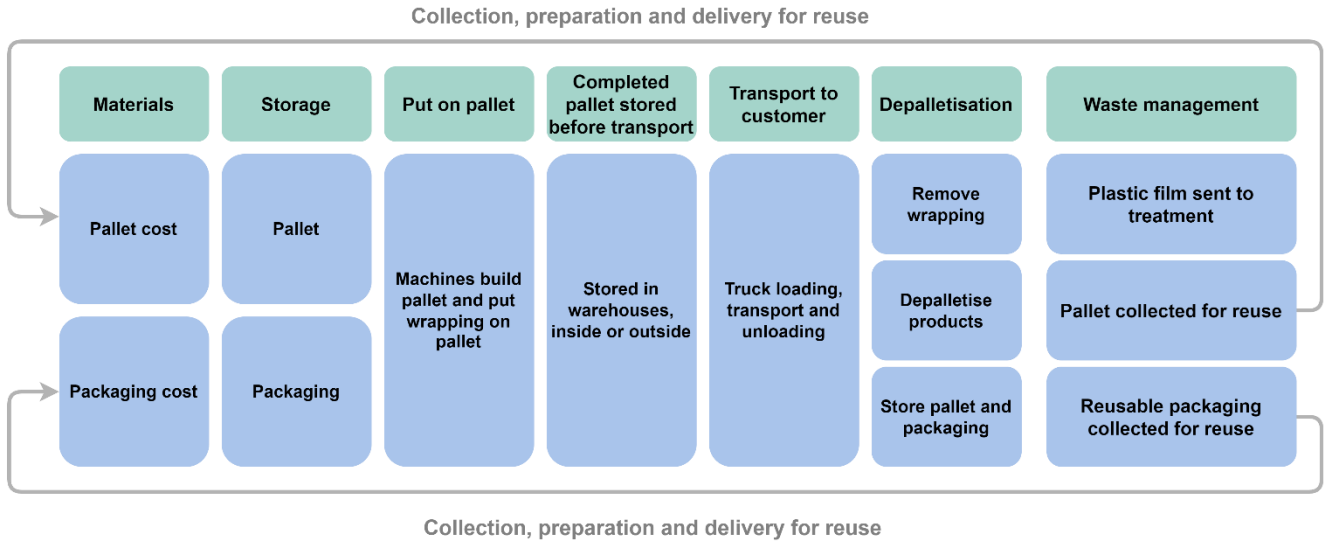
[1] System not currently in existence but conceptualised by RDC Environment based on industry interviews.

- Palletisation of the products on a pallet (stacking products on the pallet)
- Putting the packaging on the pallet

- Completed pallet storage before it is shipped
- Transport of the pallet to its initial destination
- Depalletisation
  - Packaging removed from pallet
  - Products removed from pallet
  - Pallet and packaging storage
- Waste management (cost of disposing of the used packaging).

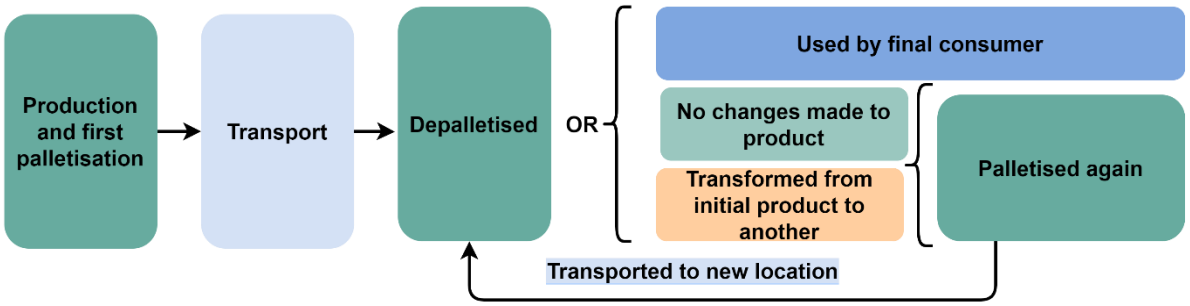
The following figure provides an overview of these stages.

Figure 1: Overview of modelled stages of production and palletisation value chain



Some products may go through this cycle several times before final use, and these multiple cycles are considered in the results. That is, some products are palletised, depalletised and repalletised before arriving at their final customer (i.e. after initial production, and repalletisation in a warehouse for instance). This is illustrated in the figure below.

Figure 2 : Illustration of multiple palletisation cycles per product



Sensitivity analyses then consider the impact of variations in key cost model parameters such as the number of products per pallet, reusability rates, automation levels, and the amount of packaging material used.

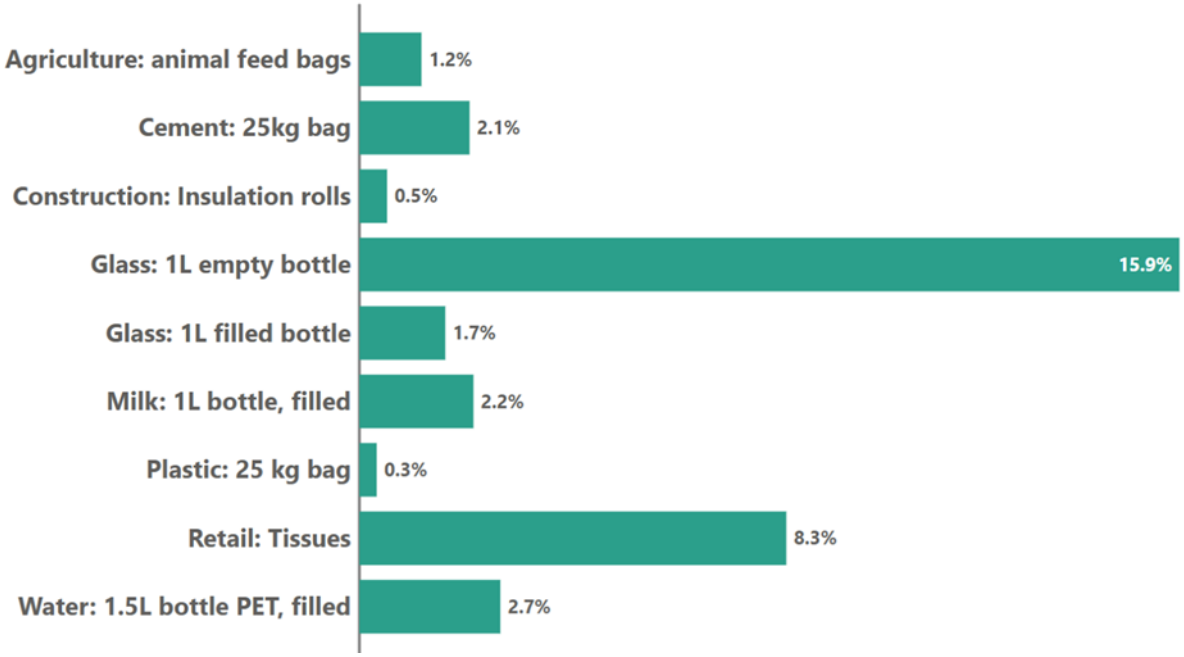
Per-unit cost differences were then extrapolated using production volume data and average prices for each representative product.

Key findings – long term impact

The shift to alternative packaging results in additional costs per unit ranging from 0.3% to 15.9% increases relative to the product price.

The figure below expresses these cost deltas compared to the price of the final product.

Figure 3: Total cost variation by representative product in percentage of product price



The differences in cost **(cost delta)** are primarily driven by:

- The additional machines needed for the automated end of line
- The cost of the reusable packaging itself
- The impact of a reduction of products per pallet (considered in the base model for glass).

These results rely on a number of assumptions, necessary given the lack of deployed automated reusable solutions today, therefore a series of sensitivity analyses are conducted to identify how the cost behaves with variations of these parameters. These find that the most sensitive parameters of the model are:

- The number of products that can be put on a pallet in the alternative scenario. Reducing the number of products that can be put on a single pallet significantly increases the cost per product of the palletisation step.
- The number of additional machines required for automated palletisation and wrapping.
- The amount of additional labour required on the automated lines for the alternative solutions.

Based on these cost delta, the following cost impacts are extrapolated to the EU level.

Table 2: Long term cost impacts at the EU level of switching to alternative wrapping solutions

Sector	Set of products covered by extrapolation	Number of units affected in the EU per year in million	Expected impact on production cost in million €/year	Total impact compared to total value of products at the EU level
Agriculture	25 kg bags of animal feed compound for use in agriculture or equivalent	882	**181**	**1.2%**
Cement	Cement in bags <= 50 kg	655	**95**	**2.1%**
Construction	Rockwool and glass wool insulation rolls produced and consumed in the EU, delivered at retailer or to consumer	267	**79**	**0.5%**
Milk	HDPE bottles of milk, 1 L or equivalent, for household consumption (filled)	15 625	**297**	**2.2%**
Glass	Glass container aimed at containing food or beverage (after filling), filled with food or beverage	61 300	**3 063**	**1.7%**
Glass	Glass container aimed at containing food or beverage (before filling), empty[2]	61 300	**1 756**	**15.9%**
Plastic	25 kg FFS (Form Fill Seal) plastic pellets, delivered to convertor	815	**167**	**0.3%**
Retail	Handkerchiefs and cleansing or facial tissues of paper pulp, paper, cellulose wadding or webs of cellulose fibres	3 562	**109**	**8.3%**
Water	Bottled water in PET bottles < 3L produced and sold in the EU, filled.	44 400	**947**	**2.7%**
Total across studied sectors (counting filled bottles only)		**127 506**	**4 936**	

The expected impact on production costs at the EU level varies between 79 and 3 063 million € per annum, depending on the representative product category, if all products sold in the EU are affected by the switch to reusable pallet packaging systems (total of 4 936 million across these eight product sectors). The main drivers of this range are the number of products in scope (similar enough to the representative products modelled), and the cost delta between the current and alternative solutions.

To be clear, these figures relate only to the set of products selected for this study, which represent only a sample of the product categories put on pallets in the EU. The degree to which each sector is affected may differ, but this does mean that the total estimated overall EU impact would be much more than listed in the table above.

It should be noted that if the adoption of reusable solutions increases production costs, this could have a knock-on effect on the competitiveness of EU-based industries compared to industries based outside the EU, in particular for cost-sensitive exports. Economic operators exporting in and out of the EU will also likely have to maintain the single-use palletising systems currently in use throughout the world for exports. This will require the simultaneous maintenance of two production line ends in some facilities.

[2] Once produced, glass containers can go to many different bottle and food fillers, so there is a large range of potential customers and end products that result from this empty glass container product.

These costs may be passed on to the final customer. This degree of pass on will fundamentally depend on the producers' market power in a specific industry and the market structure.

Key findings – short to medium term impacts

The results above consider the long run scenario. However, the shift from the current setup to the alternative will also imply economic costs in the short and medium run which are discussed only qualitatively in this study, other than a quantitative estimation of investment costs in new machinery. The immediate challenges include R&D costs and extensive modifications to existing production processes. Key areas of focus are:

- **R&D**: Major investments in research and development are needed to create automated and optimised alternatives, especially for reusable systems.
- **Capacity**: Expected demand variation for boxes may result in building new production lines and closing them shortly later. There may also be challenges in meeting the demand for adapted machinery for end of lines if a switch to reusable options is required by 2030 (given that these relevant automated machineries do not appear to be available at large scale today).
- **Production line modifications:** Existing lines must be adapted or reconfigured, requiring new machinery and process adjustments.
- **Investment costs of installing new wrapping lines, :** Capital expenditure (excluding R&D) for the installation of new packaging lines for the reusable options (palletisation and depalletisation lines) is estimated at 8.4 billion € in the EU (for the products of interest). This expenditure would be incurred once the shift to reusable options takes place, and the machines would be amortised over their lifetime (approximately 15 years). Note that investment expenditures would also be needed in the absence of transition to reusable option, but to a lesser degree and an adapted pace. This is because the remaining lifespan of single use packaging machinery currently in operation is variable, so some replacement would be needed.
- **Co-existence of different packaging standards within the European market**:
  - Manufacturers will likely need to operate both single-use and reusable systems simultaneously across facilities in the short to medium run, complicating logistics and reverse logistics.
  - Multiple competing reusable standards are also likely to co-exist in the short to medium run, involving logistical difficulties.

1 Context, objectives and scope

1.1 Context

Article 29 (1-3) of the Packaging and Packaging Waste Regulation (PPWR, e.g. Regulation (EU) 2025/40) states that "flexible formats or pallet wrappings or straps for stabilization and protection of products put on pallets during transport "shall ensure that: must be managed as part of a reuse system from 2030:

- (§1) At least 40 % of the total packaging listed in Art. 29 (1) is reusable within a reuse system in 2030, and 70% in total from 2040, when economic operators trade between two different Member State within the territory of the EU;
- (§2) If these packaging formats are used between different operators' sites or sites of affiliated companies within the territory of the EU, they must be completely, i.e. 100% reusable as of 2030;
- (§3) If these packaging formats are used between different economic operators within the same Member State, they must be completely, i.e. 100% reusable as of 2030.

Article 29 also sets different types of exemptions for transport packaging and sales packaging:

- (§4) exempts; transport packaging or sales packaging used for the transportation of dangerous goods, large-scale machinery and other equipment or commodities that require custom-designed packaging, or when the packaging is in direct contact with food and feed, as well as cardboard boxes;
- (§18 a) also states that the Commission is empowered to adopt delegated acts establishing exemptions for economic operators "due to particular economic constraints encountered in a specific sector".

Single-use plastic pallet wrapping systems (e.g. shrink hoods, stretch hoods and wraps) dominate across most sectors. Current packaging systems provide some key functions including stability, hygiene protection and flexibility. In this context, EuPC commissioned RDC Environment to study the economic impact of switching from single use to reusable pallet wrapping.

1.2 Objectives

The objective of this study is to assess the economic impact of transitioning from single-use plastic pallet wrapping systems to a reusable alternative solution for 8 sectors.

1.3 Scope of the study

1.3.1 Sectors and representative products

The table below presents the studied sectors and the chosen representative product for the study. The representative product was selected based on its representativity of the packaging switch challenge and on data availability.

Table 3: Studied sectors and representative products within each sector

Economic sector	Representative product
Agriculture (agriculture)	25 kg bag of animal feed
Cement production (Cement)	25 kg bag of cement
Construction (Construction)	Insulation roll of glass wool or rockwool
Milk production (Milk)	1L bottle (HDPE) of milk, filled
Plastic raw material production (Plastic)	25 kg bag of plastic pellets
Bottled water production (Water)	1.5L PET bottle of water, filled
Glass containers production (Glass)	1L glass bottle: results presented for filled and empty glass containers
Retail (Retail)	Tissue boxes packed in cardboard boxes

1.3.2 Reference packaging items: pallet wrap, hood, accessories

This study focuses on the replacement of the following pallet packaging items: the film wraps, the hoods, the caps, the possible accessories. These items are part of the tertiary packaging.

Currently, two different types of single use plastic transport packaging are commonly used: wrap and hood.

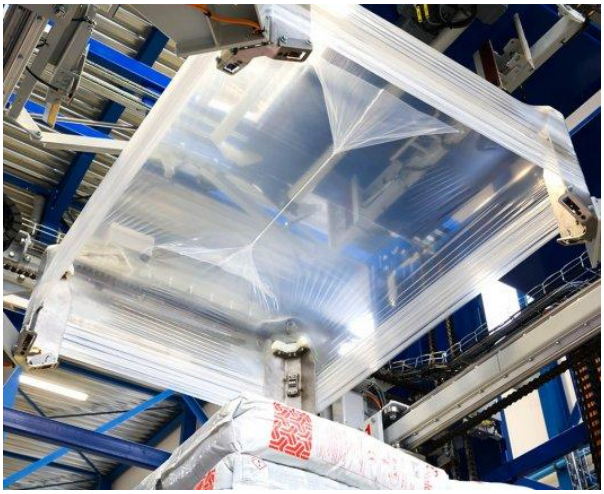
- The wrap comes as a stretch wrap, where a foil is wrapped sideways around the pallet and cut from the roll once the wrapping is complete. Since the stretch wrap only covers the sides, an additional plastic sheet can be integrated to protect the top of the pallet load.
- A hood on the other hand is a one piece is placed from above over the entire pallet load. This hood is either heat shrunk (shrink hood) or stretched out before being pulled over the pallet (stretch hood) to properly fit the product.

  There is a trend in some sectors to move away from shrinking the hood to save on gas costs.

The pictures below show the application of stretch wrap and stretch hood.

Table 4 : Illustrations of single use wrap and hood options

Stretch wrap application	Wrapped pallet
 https://www.packaging-labelling.com/products/atlas-for-industry/stretch-wrap	 https://www.raniplast.com/product/ranistretch/

Hood application	Hooded pallet
 https://www.arodo.in/products/stretch-hooders.html	 Alibaba.com

2 Methodology

2.1 General approach

2.1.1 Assess the difference in production cost for 8 representative products

In order to assess the economic impact of switching from **single use** to an **reusable** pallet wrapping, this study:

- Focusses on the impact on representative products for 8 industrial sectors (i.e. 8 case studies);
- Examines the difference in total production cost of the product between the current system and the best alternative packaging solution, to ensure fair comparability.

2.1.2 Long-term cost quantification and a qualitative description of short-run transition costs

In the case of an industrial shift driven by the regulation, there are two sets of cost impacts:

- **Short run impacts (assessed qualitatively)**, i.e., the transition costs, which can be significant. The industry must develop new solutions, adapt or replace production lines before amortisation, deal with the potential co-existence of different technical standards and adopt solutions having not yet reached their economies of scale.
- **Long run impacts (assessed quantitatively)**: In the long run, we assume that the alternative packaging solutions are **mature, established and optimised**. This means that these alternative solutions could be used in high cadence automated wrapping lines, are optimised to maximise the products per pallet and transport is also optimised.

Comparing the costs using long term assumptions allows for a fair comparison, focused on the technical characteristics of the solutions.

It is important to note that large scale automated and optimised reusable solutions do not appear to exist today for the products studied in this report.

2.2 The methodology in practice

The approach outlined above requires a significant amount of qualitative and quantitative data in each of the sectors analysed. To collect this information and process it, the following steps were taken (from November 2024 to February 2025):

- **Site visits (4) and interviews (31)**, with the following objectives:
  - To understand how the pallet wrapping systems currently work along the supply chain and the key functionalities of current solutions;
  - To identify the most representative product for each sector, based on sales, pallet packaging challenges and information availability;
  - To understand challenges associated with a shift, based on industry experience;
  - To discuss alternative packaging solutions;

- To collect data for the quantitative cost modelling.

- Based on the input above, for each representative product, the best alternative pallet packaging solution was determined based on the sector specific requirements and the functionalities of each possible solution.
- A cost model was built on this foundation, with a common approach for each sector and specific sector parameters. The model was built with an iterative approach, that is:
  - The model structure and parameters are based on the interviews, literature review, and RDC Environment's own expertise.
  - Assumptions were made to complete missing data in the first instance in order to identify the key parameters influencing results;
  - Further data collection and interviews after this first step were used to reduce the range of possible values for each parameter;
  - A sensitivity analysis is presented on the results of the cost model to deal with the remaining uncertainty.
- The assessed difference in total production cost is expressed in three ways, the latter two to allow for easier interpretation:
  - The cost in € per unit of product of the current and alternative solutions, together with the cost delta between the two.
  - This same delta, expressed as a percentage of the sale price of the product (to put the delta in perspective of the magnitude of the total value added or of the consumer price) ;
  - This cost delta is then extrapolated to the European level, i.e. multiplied by the volume of products potentially affected by the PPWR regulation that are reasonably similar to the specific representative product modelled. This gives an overview of the total cost for a subset of sectors and products in the EU.

2.3 Structure of the report

The report includes the following sections:

- Context and objectives of the study
- Methodology
- Selection of the reusable packaging solution to model, based on a the analysis of the functionalities of the different packaging solutions;
  - Sectoral specificities;
  - Choice of the current and alternative package to be considered in the model for each representative product.
- Cost model – approach
  - Description of the cost items covered, and key general assumptions
  - Data: presentation of the key assumptions for each representative product, i.e. case study
  - Limitations and remaining uncertainties

- Study results
  - Quantitative results: total cost differences per sector and per value chain stage
  - Qualitative results: transition costs and challenges
- Conclusion

3 Selection of the alternative packaging solution to model, based on functionalities and requirements

3.1 Objective and approach

The objective of this chapter is to select an alternative packaging option for each of the representative products to be modelled in the cost model.

The selection criteria for the alternative packaging solution are:

- To be reusable;
- To fulfil the product-specific packaging functionality requirements;

The section unfolds as follows:

- Identification of the functionalities provided by the currently used pallet packaging, and product category specific requirements;
- Description of the possible alternative packaging solutions;
- Selection of the best alternative packaging solutions to consider in the model.

3.2 Packaging functionalities and sector specificities

3.2.1 Functionalities of pallet packaging

Besides ensuring transport efficiency and limiting losses, key pallet packaging functions include: logistical functions, product protection functionalities and others. In summary:

- **Logistical Functionalities:**
  - **Stability:** Ensures the pallet load stays secure during transport and is suited to wrap relatively unstable loads.
  - **Adaptability:** Accommodates different product formats, pallet sizes, and depalletisation processes.
- **Protection functionalities:**
  - Shields products from environmental factors (rain, humidity, UV, condensation).
  - Prevents contamination by sealing out unwanted substances.
- **Other features** may include additional protections such as puncture resistance and product visibility.

These functionalities are described in more detail below.

3.2.1.1 Logistical functionalities

A. Ensure pallet stability

Stability concerns the ability to maximise the number of products put on a pallet, while avoiding losses due to pallet movements during transport in truck and forklifts. It arose as a general constraint that is encountered across all sectors. Particularly for lighter products and smaller secondary packaging, additional stabilisation is required.

In the context of pallet stability for safe transport and warehousing, a series of tests (referred to as EUMOS-tests) have been developed. These tests assess the ability of pallets to maintain their integrity and prevent shifting, tipping, or damage to the goods when subject to various conditions such as vibrations, handling or changes in the environment[3]. Complying with EUMOS-regulation is not currently mandatory across all regions or industries.

In a similar vein, some products categories stacked on the pallet are very unstable before the cover is applied, and so the packaging solution must be compatible for that issue. For example, shrink hoods fulfil this function for empty glass products. Stretch wraps would not work (at least not as well) in these instability cases, as the wrapping phase applies a force on the pallet. The packaging choice depends on the stability of the pallet load prior to the application of the packaging.

B. Adapt to various product formats and pallet sizes

Manufacturers palletise products of different formats and pack pallets with variable dimensions and heights, on the same palletisation line. Adaptability to different formats of products and pallets is a key feature of the pallet packaging solutions. Plastic wrap is a versatile solution because it allows to palletised different shapes of loads on pallets and to add layers depending on the products put on a pallet.

As an example, a plant can pack its products on pallets with different length and width depending on the pallet's recipient. The pallet height can vary and depends on the product formats and their secondary packaging.

In some cases, such as for bottled water or milk bottles, products first go on half pallets (suited to be directly placed in supermarkets), then are grouped onto one full size master pallet. The exact set up varies from case to case, but the same film is generally used across these stages.

Note: for simplicity, in the remainder of the report only full pallets are modelled and considered, but the existence of half pallets is likely to complexify the use of reusable options.

Current wrapping solutions are adapted to these various formats and pallet sizes.

C. Adapt to various infrastructures at destination

Adaptability concerns the ability of the products to be depalletised by different types of customers. Removing single use plastic transport packaging from the pallet load is a simple process that can be automated, but it can also be cut manually.

3.2.1.2 Protection functionalities

A. Protect against environmental factors and condensation

Pallets are exposed to various environmental factors (such as rain, humidity and UV radiation) against which the load must be protected (especially when stored outside). Moreover, some products are subject to condensation, e.g., empty glass bottles and containers.

Pallet packaging can protect the products in different ways:

- A hood with an underlayer that is sealed creates an airtight cover to protect against rain and condensation.

[3] https://eumos.eu/quality-standards/

- Hoods or wraps used with a pallet cap keep out rain.
- Anti-UV film blocks harmful UV rays.
- Perforated film lets air in to reduce moisture buildup.

Additionally, the level of protection required can vary across seasons and across regions.

B. Protect against contamination

Contamination refers to the presence of unwanted substances or microorganisms in a product that can compromise its purity, safety or quality. Contamination includes the presence of bacteria and insects, but also odours and allergens. A hood combined with an underlayer sealed with the hood can provide a hermetic sealing to protect against contamination.

3.2.1.3 Other possible features of the packaging solutions

These other features include:

- Puncture protection
- Visibility of the products through the pallet packaging

3.2.2 Sector specific requirements

Each product requires varying levels of the functionalities presented above, as set out in the following tables. The relative importance of each functionality is presented per product in the tables below.

The importance is to be interpreted in a comparative way. For example, stabilisation is a basic need for all pallets. However, for glass bottles, there is a relatively higher stabilisation requirement than for cement bags - which are intrinsically more stable when stacked onto the pallet.

It is also important is to distinguish the product and the sector in what is presented below. Not all of the following products can be considered equally representative for the entirety of their sector.

- In the bottled water sector for example, product variety is relatively limited, therefore the modelled product can be considered more representative for the sector.
- In agriculture, construction and retail sectors, there is a wider variety of products which differ in their characteristics, as compared to the representative product. Thus, the product coverage in each sector is the same across industries for these representative products.

The functionalities are assessed only for the representative product and variants sharing the same characteristics (that can be manufactured at the same plant and packed on the same line). The criteria are not assessed for the sector as a whole. For example, in the milk sector where a 1L HDPE bottle was defined as the representative product, other packaging formats (e.g. cartons, milk bags) are also considered. Other products, e.g. butter, cheese, are not considered.

3.2.2.1 Agriculture: 25 kg bag of animal feed

Table 5 : Functionalities requires for animal feed bags (agriculture)

Functionality	Product needs with respect to functionality	Importance
Pallet stability	▪ The bags provide already provide a certain amount of stability when stacked onto a pallet. ▪ The additional stability requirements are mainly for pallet handling and truck transport.	Moderate
Format flexibility	▪ Limited need as product is standardised.	Limited
Depalletisation flexibility	▪ Needs to be unpackable at destinations without strong infrastructure, e.g. at a small farm.	Strong
Protect against environmental factors and condensation	▪ Limited requirements	Limited
Protect against contamination and dust	▪ Limited requirements.	Limited

3.2.2.2 Cement: 25 kg bag of cement

Table 6 : Functionalities requires for cement 25kg bags (cement)

Functionality	Product needs with respect to functionality	Importance
Pallet stability	▪ The bags provide already provide a certain amount of stability when stacked onto a pallet. ▪ The additional stability requirements are mainly for pallet handling and truck transport.	Moderate
Format flexibility	▪ Limited product format variety: three different bag sizes (25 kg, 35 kg, 50 kg) represent the vast majority of the market.	Moderate
Depalletisation flexibility	▪ The pallets need to be unpackable without infrastructure, e.g. on a small construction site.	Strong
Protect against environmental factors and condensation	▪ Water hardens cement, rendering it unusable. ▪ Primary packaging (bags) mitigate this issue especially if plastic, but the pallet wrapping is still needed. If paper bags, stronger reliance on pallet packaging for protection against rain.	Strong
Protect against contamination and dust	▪ No specific requirement.	Limited

3.2.2.3 Construction: insulation rolls

Table 7 : Functionalities requires for insulation rolls (construction)

Functionality	Product needs with respect to functionality	Importance
Pallet stability	▪ Light product which is stacked high, so stabilisation is important. ▪ Products can fall over (rarely) during the wrapping process.	Moderate
Format flexibility	▪ Insulation rolls exist in variety of formats, depending on thickness, material and compression but are relatively modulable via compression.	Limited
Depalletisation flexibility	▪ The pallets need to be unpackable without infrastructure, e.g. on a small construction site.	Strong
Protect against environmental factors and condensation	▪ The primary and secondary packaging do not provide a complete water barrier. Pallet packaging currently must ensure total water protection and UV protection (stored outside for up to 6-9 months).	Strong
Protect against contamination and dust	▪ No specific requirements.	Limited

3.2.2.4 Glass: 1L empty glass bottle

Table 8 : Functionalities requires for empty glass bottles (glass)

Functionality	Product needs with respect to functionality	Importance
Pallet stability	▪ Strong need of stabilisation, fragile product that can tilt. ▪ Products cannot move during palletisation and after due to significant breakage risk. ▪ A hood is placed over the pallet to ensure its stability, and the products cannot move.	Strong
Format flexibility	▪ A glass plant typically produces many different container formats (over 150 variations), so flexibility of packaging is key.	Strong
Depalletisation flexibility	▪ The vast majority of products are depalletised at beverage production sites, many with automated glass receiving systems.	Moderate
Protect against environmental factors and condensation	▪ Strong need for protection against rain, humidity and condensation. Glass products on a pallet are not protected by intermediate packaging	Strong
Protect against contamination and dust	▪ Strong need for protection against contamination (incl. insects) and dust ▪ Glass products are often used as the primary packaging for food products and need to be delivered free of contamination (not always cleaned before being filled).	Strong

3.2.2.5 Milk: 1L HDPE bottle

Table 9 : Functionalities requires for 1L HDPE milk bottle (milk)

Functionality	Product needs with respect to functionality	Importance
Pallet stability	▪ Moderate need for stabilisation depending on the intermediary packaging size. Product weight contributes to good pallet stability.	Moderate
Format flexibility	▪ Limited variety of secondary packaging formats and full pallet dimensions. ▪ Milk products can be packed onto half-pallets: requires packaging that can be applied to full pallets as well as to half pallets.	Moderate
Depalletisation flexibility	▪ Need to be unpackable by a small distribution site or supermarket, without specific infrastructure.	Strong
Protect against environmental factors and condensation	▪ Low need for protection as milk is usually stored inside due to its sensitivity to environmental factors.	Limited
Protect against contamination and dust	▪ Most of the protection is provided primary packaging ▪ For commercial purposes, protection of the secondary packaging against dust is required.	Moderate

3.2.2.6 Plastic: 25 kg bag of plastic pellets

Table 10 : Functionalities requires for 25kg bag of plastic pellets (plastic)

Functionality	Product needs with respect to functionality	Importance
Pallet stability	▪ The bags provide already provide a certain amount of stability when stacked onto a pallet. ▪ The additional stability requirements are mainly for pallet handling and truck transport.	Moderate
Format flexibility	▪ Limited need as product is standardised.	Limited
Depalletisation flexibility	▪ Need to be unpackable by a small distribution site.	Strong
Protect against environmental factors and condensation	▪ UV radiation can degrade plastics, leading to discolouration, surface cracking or loss of strength. ▪ Rain: pellet bags can be perforated, which requires the tertiary pallet packaging to protect from rain when storing outside.	Strong
Protect against contamination and dust	▪ A proportion of the bags are perforated to ensure stability, so pallet packaging needs to ensure protection against dust.	Moderate

3.2.2.7 Retail: Tissue boxes in cardboard secondary packaging

Table 11 : Functionalities requires for tissue boxes in cardboard secondary packaging (retail)

Functionality	Product needs with respect to functionality	Importance
Pallet stability	▪ Tissue boxes are light products. Pallet packaging must provide stability.	Strong
Format flexibility	▪ Limited variety of secondary packaging formats and full pallet dimensions.	Limited
Depalletisation flexibility	▪ Need to be unpackable by a small distribution site or supermarket, without specific infrastructure.	Strong
Protect against environmental factors and condensation	▪ No specific requirement as cardboard boxes are stored inside.	Limited
Protection against contamination and dust	▪ No specific requirement as secondary packaging ensures protection.	Limited

3.2.2.8 Water: 1.5L PET bottle of still water

Table 12 : Functionalities requires for 1.5L PET bottle of still water (water)

Functionality	Product needs with respect to functionality	Importance
Pallet stability	▪ Moderate need for stabilisation depending on the intermediary packaging size. Product weight contributes to good pallet stability.	Moderate
Format flexibility	▪ Limited variety of secondary packaging formats and full pallet dimensions. ▪ Bottled water products are sent to supermarkets and can be packed onto half-pallets.	Moderate
Depalletisation flexibility	▪ Need to be unpackable by a small distribution site or supermarket, without specific infrastructure.	Strong
Protect against environmental factors and condensation	▪ UV radiation degrades plastic, the primary packaging of water, leading to contaminated water. Especially during the summer when the UV radiation is more intense, optimal protection needs to be ensured.	Strong
Protect against contamination and dust	▪ Most of the protection is provided by primary packaging ▪ For commercial purposes, protection of the secondary packaging against dust is required.	Moderate

3.2.3 Functionalities of pallet packaging across products

The table below sums up the importance of the needs explained above, using the same colour code.

Table 13: Functionalities of pallet packaging across products

Functionality	Agriculture	Cement	Construction	Glass	Milk	Plastic	Retail	Water
Pallet stability	Moderate	Moderate	Moderate	Strong	Moderate	Moderate	Strong	Moderate
Format flexibility	Limited	Moderate	Limited	Strong	Moderate	Limited	Limited	Moderate
Depalletisation flexibility	Strong	Strong	Strong	Moderate	Strong	Strong	Strong	Strong
Protect against environmental factors and condensation	Limited	Strong	Strong	Strong	Limited	Strong	Limited	Strong
Protect against contamination and dust	Limited	Limited	Limited	Strong	Moderate	Moderate	Limited	Moderate

3.3 Description of the alternative packaging solutions and their logistics

3.3.1 Overview of existing alternative solution systems

The section below lists alternatives to single use packaging considered in this study.

3.3.1.1 Reusable pallet boxes and pallet cages

Reusable pallet boxes and pallet cages	
Description	▪ **Pallet box:** Pallet boxes are large plastic or wooden boxes integrated with a pallet. The built-in pallet allows forklift transport. Foldable versions exist.

<table>
<tr><td></td><td>


Source: https://www.export.kaiserkraft.com/containers-for-storage/pallet-boxes-rectangular-containers/pallet-box/capacity-610-l-6-feet-and-runners-on-the-long-sides/p/M76360/
Metal cage pallet: Metal frame and wire mesh, integrated with a pallet.


Source: https://www.loscam.com/en/products/steel-stillage-cages-pallets-loscam</td></tr>
<tr><td>Sectors where used</td><td>Pallet box: bulk transport in B2B
Metal cage pallet: bulk transport in B to B + suitable for exposition in supermarkets</td></tr>
<tr><td>Existence of automation</td><td>Possible automation of use of pallet boxes.</td></tr>
<tr><th colspan="2">Packaging solution features with respect to functionalities</th></tr>
<tr><th>Functionality</th><th>Degree of fulfilment</th></tr>
<tr><td>Ensure pallet stability</td><td>Complete stability due to integration if the pallet in the box/cage.</td></tr>
<tr><td>Adapt to various product formats and pallets sizes</td><td>Moderate adaptability can only be achieved by using adaptable internal separators.</td></tr>
<tr><td>Adapt to various infrastructures at destination</td><td>Yes.</td></tr>
</table>

Protect against environmental factors	▪ Pallet box: good protection if equipped with a lid ▪ Metal cage: no protection
Protect against contamination and dust	▪ Pallet box: good protection if equipped with a lid ▪ Metal cage: no protection

3.3.1.2 Crate systems

Crates systems	
Description	▪ **Foldable or stackable crates** typically used for fresh food (vegetable, fish, meat)  Source: https://naeco.com/en/info/fruit-and-vegetables-processing/ **Crates for glass bottles:** Specific crates ensuring optimal protection of the glass bottles. As an example, 24 filled bottles are packed into a crate, which are directly put onto the pallet.  Source: https://www.dreamstime.com/stock-illustration-drink-crates-beer-bottles-wooden-pallet-d-renderin-rendering-white-background-image83370190
Sectors where used	Crates for fruits & vegetables, meat & fish, crates for glass bottles in the beverage industry
Existence of automation	Fully automated crate system in the beverage industry.
Packaging solution features with respect to functionalities	
Functionality	**Degree of fulfilment**
Ensure pallet stability	▪ **Crates with filled glass bottles:**

	○ Initial stability due to design of the crates that fit into each other; ○ Heaviness of the filled bottles contributes to the complete stability of the stacked crates. ■ **Foldable and stackable crates:** ○ Initial stability due to design of the crates that lock into each other; ○ Additional stability related to the heaviness of the load.
Adapt to various product formats and pallets sizes	■ **Crates with filled glass bottles:** Limited adaptability, need to use adaptable internal separators to ensure adaptability ■ **Foldable and stackable crates**: Limited adaptability, fits products in bulk
Adapt to various infrastructures at destination	Yes, for existing systems. Moderate adaptability for bigger and more complex crate systems.
Protect against environmental factors	Yes if closed and equipped with a lid.
Protect against contamination and dust	Yes if closed and equipped with a lid.

3.3.1.3 Reusable hoods and sleeves

Reusable hoods and sleeves	
Description	■ **Reusable hood:** A one-piece unit placed over the goods from above, similarly to its single-use counterpart (hood). They are equipped with straps that can be tightened.  Source: https://www.indiamart.com/proddetail/ecowrap-reusable-pallet-cover-22477167533.html

	▪ **Reusable sleeve:** Reusable alternative of stretch wrap. The sleeves are also equipped with straps to tighten them around the pallet.  Source: https://www.thecarycompany.com/pallet-wraps-37w4gw
Sectors where used	No industrial (high volume) use identified.
Level of automation	No currently existing automated system identified for the application of the hoods and sleeves on the pallet.
Packaging solution features with respect to functionalities	
Functionality	**Degree of fulfilment**
Ensure pallet stability	▪ Stability is ensured by the straps system, that needs to be adapted to the load requirements ○ good stability if regular, beam-shaped load[4] ○ Solution not applicable if no beam-shaped load.
Adapt to various product formats and pallets sizes	▪ Adaptable for beam-shaped loads ▪ Not adaptable to different height ranges. One hood type per height ranges. ▪ Not adaptable to different pallet dimensions. One hood type per pallet dimension.
Adapt to various infrastructures at destination	Yes.
Protect against environmental factors	▪ Hood: ○ Good protection at the top and sides;

[4] Beam Shaped Load: A long, narrow load with weight concentrated along its length, often requiring extra securing measures for safe transport.

	○ Does not provide a hermetical seal. ■ Sleeve ○ No protection as the top of the load is not covered
Protect against contamination and dust	■ Hood: ○ Good protection at the top and sides; ○ Does not provide a hermetic seal. ○ Protection against dust but not against contamination ■ Sleeve: ○ No protection as the top of the load is not covered.

3.3.1.4 Reusable straps

Reusable straps	
Description	Reusable straps are used to directly secure goods on the pallets or to secure cardboard boxes packed with products. Possible use in combination with reusable hoods or sleeves.  **Source:** https://www.packmile.com/pallet-straps/
Sectors where used	Not currently used in sectors surveyed during this study.
Level of automation	No currently existing automated system for the application of straps on the pallet.
Packaging solution features with respect to functionalities	
Functionality	**Degree of fulfilment**
Ensure pallet stability	Yes, if the load is composed of large enough products or secondary packages and accepts compression.

Adapt to various product formats and pallets sizes	Adjustable and can be tightened or loosened to fit various load sizes.
Adapt to various infrastructures at destination	Yes.
Protect against environmental factors	No protection.
Protect against contamination and dust	No protection.

3.3.1.5 Other possible packaging solutions

- **Palletising glue:** Certain products (e.g. cardboard boxes are paper bags) can be glued together to enhance the stability of the load on the pallet. This reduces the use of single use plastics, but these might still be needed depending on the stability of the load after gluing and for meet other requirements that are not met by the glue (e.g. protection from dust).
- **Octabins**: Octabins are large containers made of thick corrugated cardboard with an octagonal shape. These bins are used for storing and transporting bulky materials. Due to their cardboard composition, the bins cannot be stored outside unprotected from the rain. Octabins are currently used for some applications for plastic pellets.

Source: https://www.quadwall.co.uk/demos/

- **IBC:** Intermediate Bulk Containers are large containers that are used to transport bulk liquids, powders or granules. IBC are commonly used in the chemical and pharmaceutical industries.

Source: https://www.tanks-direct.co.uk/water-tanks/ibc-containers/ibc-tanks/c915

- **Big bags:** Big bags are large, strong bags made from a polypropylene fabric that fit neatly on a standard-sized pallet. They typically have lifting loops, making them easy to handle using forklifts and cranes.

Source: https://www.shutterstock.com/image-illustration/big-bulk-bag-on-wooden-pallet-1099727663

3.4 Selection of the best alternative solution to consider in the model

No automated and optimised pallet packaging solution was identified in this study for the studied products. This section assumes that these systems could be developed and would take a similar format to the (mostly manual) solutions that do exist today.

Based on the previously mentioned requirements of the representative products, as well as the functionalities of the reusable solutions, the most feasible alternative solution to single use plastics was selected for each sector by RDC Environment.

- In all sectors except glass, the reusable hood was identified as the most feasible solution. Unlike reusable sleeves, the hood integrates protection at the top of the pallet. This contiguous packaging over the entire load ensures that the requirements are met to a better extent compared to the sleeves.

- In the glass sector, a specific system was designed for the purpose of this study, but it is currently not implemented. This system consists of pallet-wide crates with locks and is based on the crate system, that is already used in the beverage sector (as described in section 3.3). Empty bottles (as modelled in the glass sector) are less stable compared to filled once, hence the development of a new system that ensure maximal product stability – and protection, also to avoid breakage or movement of the bottles during transit.

The table below summarises for each sector: the representative product, the single use plastic solution, the most feasible alternative solution and the justification for the alternative solution.

Table 14: Summary of the representative product, the single use plastic solution, the most feasible alternative and the justification for this alternative for each sector

Sector	Representative product	Single use plastic solution[5]	Alternative solution	Justification
Agriculture	25 kg bag of fertilizer	Stretch hood	Reusable hood (including straps)	The reusable hood is expected to meet the key requirements for these products: ■ **Stability**: The reusable hood ensures sufficient stability for these products: ○ The representative products characteristics provide intrinsic stability and extra stabilisation is mostly needed for pallet handling and transport. ○ The loads are beam shaped which is adapted to reusable hoods use. ■ **Protection**: the hood integrates a protection at the top of the pallet. This contiguous packaging over the entire load ensures that the most important requirement in each sector is met: ○ Protection against rain and dust is required for all representative products; ○ UV protection is required in water and plastic sector. ○ Hermetic seal is not required for these products.
Cement	25 kg bag of cement	Stretch hood		
Construction	Insulation roll	Stretch hood		
Milk	1L bottle (HDPE)	Stretch hood		
Plastic	25 kg bag of plastic pellets	Stretch hood		
Retail	Cardboard box filled with tissue boxes	Stretch wrap		
Water	1.5L PET bottle, still water	Stretch wrap		

[5] Note: For some products, depending on the facility or even the line, multiple single use packaging types can be used. The ones selected here are the most frequent ones identified for that product in that sector, based on the interviews.

Glass	1L empty glass bottle	Shrink hood	Stacked pallet wide crates with locks, to be developed[6]	The crate system is expected to meet the key requirements of empty glass bottles logistics, and to provide limited adaptability to formats: ■ Stability: Stability is ensured as follows ○ Each glass container is securely locked, so it does not move in any direction. ○ Each crate is stacked on top of another and locked, ensuring pallet stability. The first crate has fork entries so the whole pallet forms one locked unit. ■ Adaptability to formats: The crate provides moderate adaptability. One crate system has to be capable to fit a format category using adaptable separators. ■ Adaptability to infrastructure at destination: the destinations are industrial plants and can be equipped with adapted infrastructure. ■ Protection ○ The crates are hermetically sealed on one another with a lid on top, ensuring protection against environmental factors, condensation, contamination. ○ The crates are cleaned and dried at every return loop, ensuring no contamination of the crate itself.

[6] See further details in section 4.4.4.

4 Cost modelling approach

4.1 Objective

The objective of the cost modelling is to assess **the difference or delta** in production cost for a product, between value chains using either the first or the second of the following options:

- Single use pallet packaging
- The best alternative packaging option (in compliance with the PPWR regulation).

4.2 General principles

4.2.1 Compare apples with apples

To ensure comparability amongst scenarios, the costs modelling considers the costs of different solutions for a same product, using the same system boundaries. All costs considered along the value chain are expressed per unit of product.

Accordingly, all general parameters are common amongst scenarios: labour cost, transport cost, space cost, transport distances, real interest rate, etc.

4.2.2 Focus on cost differences, along the value chain

The cost assessment focusses on production stages that are different amongst scenarios, in terms of cost per unit of product.

4.2.3 Assess a European scenario in 2025 prices

The cost modelling must reflect the average situation in the EU. The reference year for the value of one Euro is 2025.

Hence, all cost parameters are expressed in average European price levels for 2025, using Eurostat's purchasing power parities data where relevant, as well as European inflation data to adjust across countries where relevant.

4.2.4 Sensitivity analysis on main differentiating parameters

Interviews, literature research and RDC's own experience guided the definition of base case parameters that are representative of the European average.

However, the results of the representative case can differ from reality for two main reasons:

- **Uncertainty**: several parameters, such as the possible number of rotations/uses of a reusable package, the folded volume of the reusable package or the complexity of the automation are uncertain.
- **Variety of real-world situations**: A variety of situations exist amongst the plants active in a given sector and amongst the products in a product category. In other words, not all plants are equal, they can do things differently site to site. This can manifest through different line speeds and sizes, or different capacity or efficiency levels.

As a result, a sensitivity analysis is also presented to mitigate the impact of this uncertainty and variety.

4.2.5 Quantify total production cost difference, not impact on price and sold quantities

The total difference or cost delta in production cost is the target of the cost model. No assumptions are made as to which stakeholders would incur this difference in cost. The cost difference may be absorbed by the producers, the intermediaries and the final consumer. Price variations may in turn influence sold quantities, depending on price elasticities. Redistributive effects amongst actors of the value chain and impacts on sold quantities are not part of this assessment.

It should be noted that if the adoption of reusable solutions increases production costs, this could have a knock-on effect on the competitiveness of EU-based industries compared to industries based in the US or Asia for example. This is particularly the case for those reliant on cost-sensitive exports.

These costs may be passed on to the final customer. This degree of pass on will fundamentally depend on the producers' market power in a specific industry and the market structure.

4.3 Costs items modelled along the value chain

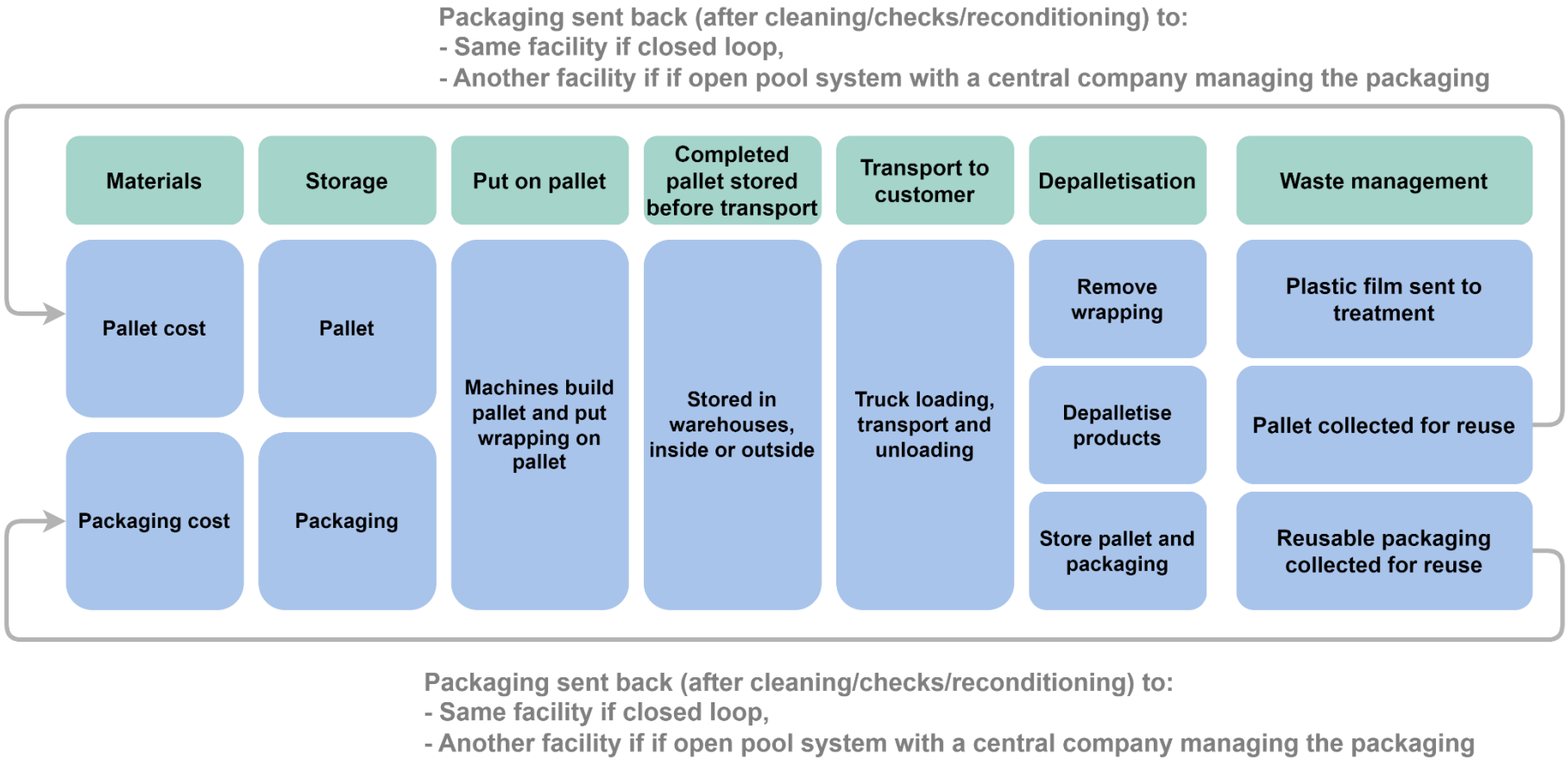
4.3.1 General description of cost items considered

The costs items taken into account in the assessment are listed in two tables presented in this section:

- The cost items along the product production value chain
- The cost of the reusable packaging.

The production value chain considered is summarised in the figure below.

Figure 4: Overview of modelled stages of production and palletisation value chain



4.3.1.1 Cost items along the product production value chain

Table 15: Cost items along the value chain for the stages shared by the compared scenarios

<table>
<tr><th rowspan="2">Production stage</th><th colspan="3">Cost item considered</th></tr>
<tr><th>Single use solution</th><th>Reusable hood</th><th>Reusable pallet-crate for glass bottles</th></tr>
<tr><td rowspan="2">Packaging solution supplied at producer's gate</td><td rowspan="2">Hood / wrap
Pallet</td><td>Reusable hood, including straps, clean and ready to use
Pallet</td><td>Pallet-crate set, clean and ready to use</td></tr>
<tr><td colspan="2">Note: see next table for the explanation of the cost model for the return logistics of reusable pallet, used to compute the cost of a reusable package ready to use at gate.</td></tr>
<tr><td>Unloading time</td><td colspan="3">Forklift use and labour time to unload the packaging solutions</td></tr>
<tr><td>Storage space</td><td colspan="3">Storage space needed to store the packaging solutions ready to use. Pallets are stored outside. Other solutions are stored inside.</td></tr>
<tr><td rowspan="2">End of production line
See separate note on the number of operations below.</td><td colspan="3">Investment in machines, installation, footprint of the line, energy consumption and labour associated with the "end of line". The "end of line" includes the following operations for each compared system:</td></tr>
<tr><td colspan="2">1. <u>Stage 1: Palletisation machine</u>: layers of products are assembled and then pushed or dropped on the pallet, layer per layer. Accessories can be added beneath the first layer, between layers and above the pallet.</td><td></td></tr>
</table>

Production stage	Cost item considered		
	Single use solution	**Reusable hood**	**Reusable pallet-crate for glass bottles**
	2. Depending on the product, either **a wrap or a hood is applied on the pallet:** ▪ **Wrapping machine:** a strip of plastic film is wrapped around the pallet. Depending on the technology, either the pallet is turning on a turntable or the machine is turning around the pallet. The wrap is made of plastic. ▪ **Hooding machine:** A plastic hood is applied on the pallet from above. This implies **two** automation machines **(two operations)** (see note below).	2. Reusable hood preparation: Machine to be developed, capable of unfolding and preparing the reusable hood before application. 3. Reusable hood application machine: Machine to be developed, capable of applying the reusable hood on the pallet. 4. Reusable strapping machine: Machine to be developed, capable of strapping the pallet using reusable straps. This implies **four** automation machines **(four operations)** (see note below).	1. **Reusable crates preparation machine**: machine to be developed, unfolding the crates and preparing them to welcome the bottles 2. **Reusable crates filling machine**: robot to be developed, picking a layer of bottles and filling the crate with bottles 3. **Reusable crates stacking machine:** machine to be developed, stacking the crates on one another to form a full pallet-crate. This implies **three** automation machines **(three operations)** (see note below).
Storage before shipping	Storage space, inside or outside depending on the product.		
Truck loading	▪ Forklift use and labour time to load the pallets in the truck. ▪ Time of immobilisation of the truck.		

<table>
<tr><th rowspan="2">Production stage</th><th colspan="3">Cost item considered</th></tr>
<tr><th>Single use solution</th><th>Reusable hood</th><th>Reusable pallet-crate for glass bottles</th></tr>
<tr><td>Transport to customer</td><td colspan="3">Transport cost of a full truck, maximal load limited by volume or weight depending on the product characteristics.</td></tr>
<tr><td>Truck unloading</td><td colspan="3">■ Forklift use and labour time to load the pallets in the truck.
■ Time of immobilisation of the truck.</td></tr>
<tr><td rowspan="2">Depalletisation</td><td colspan="3">As for the end of production line, investment in machines, installation, footprint of the line, energy consumption and labour are considered. The following operations apply:</td></tr>
<tr><td>Depending on the sector and the plant, the depalletisation can be automatised, or manual.

<u>Automatised depalletisation:</u>

1. The machine removes the single use wrap or hood and the robot picks the products, product per product or layer per layer.

This is considered as one machine or operation.

<u>Manual depalletisation:</u>

■ The operator removes the wrap or hood and has direct access to the products.</td><td><u>Automatised depalletisation:</u>

1. The machine unstraps the pallet and removes the reusable hood and folds it the reusable hood.

2. The robot picks the products, product per product or layer per layer.

This is considered as two machines or operations.

<u>Manual depalletisation:</u>

■ The operator unstraps and removes the hood;
■ The operator folds the hood;
■ The operator has direct access to the products.</td><td><u>Automatised depalletisation line:</u>

1. The robot picks the bottles out of each crate, to place them on the bottle filling line.

2. A machine, to be developed, folds the crates and stacks them on pallets.

This is considered as two machines or operations.</td></tr>
</table>

Production stage	Cost item considered		
	Single use solution	Reusable hood	Reusable pallet-crate for glass bottles
Waste management	▪ Cost of space for waste storage (film waste compressed in container) ▪ Cost of transport to waste recycling facility ▪ Gate fee for the waste at recycling facility		
Empty packaging storage at receiver	Space needed outside to store the pallets, the hoods and the crates, before the pooler comes to pick them up (included in the depalletisation results).		

The table below provides a correspondence between the stages described above and their reporting in Section 5.1.

Table 16: Correspondence table between stages and reported results

Detailed stage	Stage in results
Packaging cost pre palletisation	1 – Per use packaging cost (incl. return logistics)
Packaging storage pre palletisation	
Pallet cost pre palletisation	2 - Pallet cost
Pallet storage pre palletisation	
End of line	3 - End of line
Storage after pallet wrapping	
Pallet transport	4 - Pallet transport
Depalletisation cost	5 - Depalletisation costs
Packaging storage cost after depalletisation	
Pallet storage costs after depalletisation	
Waste management	6 - Waste management

Note on the number of operations

The table above introduces the concept of the number of operations necessary to put transport wrapping on a pallet. Each operation corresponds to a specific step in the process, involving dedicated machinery. The number of operations is introduced to be able **to model the cost of** machinery in the reusable scenario (as the data does not exist today). This is also based on the assumption that the same speed (pallets per minute) is achievable with these solutions as the single use options. **The cost of automation is inherently uncertain, and so a sensitivity analysis** on the number of operations is included in the results.

In the **single-use scenario, two operations** are considered when the product reaches the end of line**:**

- **Palletisation**: Stacking the products on a pallet.
- **Pallet wrapping**: A machine then cuts the necessary amount of film to wrap the pallet and applies it.

For reusable packaging solutions, as the machines that would allow automation and optimisation are not currently in circulation to the knowledge of the authors, assumptions are made as to the number of necessary operations. Technically, putting reusable options on a pallet is more complicated than the current system as more steps need to happen for it to work.

In the **reusable hood** scenario, **four operations are considered:**

- **Palletisation**: Stacking the products on a pallet.
- **Unfolding the reusable hood**: Preparing the hood for application (it must always be folded and prepared in the same way)
- **Hood application**: Placing the reusable hood over the pallet.
- **Strapping**: Applying and tightening straps to secure the load.

In the reusable crate system (for glass products), three operations are considered:

- **Reusable crates preparation** machine that unfolds the crates and prepares them for the bottles.
- **Reusable crates filling** machine that picks up a layer of bottles and fills the crate with bottles
- **Reusable crates stacking machine** that stacks the crates on one another to form a full pallet-crate

4.3.1.2 Reusable packaging cost items (per use)

The table below lists cost items used to assess the per use cost of a reusable packaging, i.e. the price of a reuse package ready to use, delivered at the gate of the producer. The parameters values have been calibrated based on actual values from the literature and interviews. The results are presented in Section 5.1.1.[7]

Note: no model is needed to assess the price of a pallet as we know the actual market price (per use).

Table 17: Cost items for the per use cost of the reusable packaging (crate and reusable hood)

Stage	Main parameters
Production cost of a new packaging	▪ Cost price of a new unit of package ▪ Number of uses/year ▪ Lifespan ▪ Cost of capital immobilisation of packaging in stock
Sorting, cleaning, drying process	▪ Assumptions on CAPEX for one processing line ▪ Lifespan and real interest rate ▪ Yearly number of packaging treated ▪ Forklift costs ▪ Labour: operators for the monitoring and operating the line, forklift operators, administration ▪ Footprint, inside ▪ Other costs and overhead

[7] The reusable packages under discussion can be used several times. Each use implies logistics for the packaging to arrive at the correct location to be used again, after it has been collected from the previous use, cleaned and repaired (potentially). These steps all imply costs. For the purposes of the quantitative cost model, a per use cost of the reusable option is computed, which accounts for these costs. Therefore, the cost used in the cost model is not the outright cost of the reusable option, but rather how much each use costs for the user.

Storage of dirty package	▪ Space, outside
Storage of clean package	▪ Space, inside
Transport for “dirty” package collection	▪ 12t box truck costs/km and /h ▪ Number of collection points ▪ Loading and unloading times ▪ Distance ▪ % empty outbound ▪ Folded volume of the empty package
Transport for clean package delivery	▪ 26t articulated truck costs/km and /h ▪ Number of delivery points ▪ Loading and unloading times ▪ Distance ▪ % empty outbound ▪ Folded volume of the empty package
Waste management	▪ Transport, pre-treatment, treatment[8]

4.4 Scenarios and key data per sector

The tables below often contain ranges. **These ranges are <u>not</u> minimum and maximum values.**

They are rather included to ensure confidentiality of the data received by RDC Environment during this study. **The true used value is included in these ranges,** but the **min and max are set** so that it is impossible to reverse engineer the actual value.

[8] This cost is very small in comparison with the cost categories, when considered per use of the reusable option and per product on a pallet.

4.4.1 Agriculture (product: 25kg bags of animal feed)

	Reference scenario	Reusable scenario
Assessed packaging solutions		
Packaging option	▪ Pallet and stretch hood	▪ Pallet and reusable hood
Picture of a pallet	 Source : https://npp.ie/product/stretch-hood-tubing/	 Source : https://www.indiamart.com/proddetail/ecowrap-reusable-pallet-cover-22477167533.html (no agriculture images available)
Key parameters		
Number of products per pallet	▪ 36 – 42 products/pallet	▪ 36 – 42 products/pallet

Cost of packaging solution per use	▪ Pallet: 5 €/pallet ▪ Stretch hood: 2 – 2.7€/pallet	▪ Pallet: 5 €/pallet ▪ Hood: 7 €/pallet
Volume of packaging when folded	▪ Pallet: 0.134 m^3	▪ Pallet: 0.134 m^3 ▪ Hood: 0.04 m^3
Number of end of line[9] operations *See Table 15 for details*	▪ 2 operations / machines	▪ 4 operations / machines
Investment cost of the machine for one operation	▪ 84 - 114K €/operation	
Number of extra persons needed on one end of line		▪ 0.15-0.26 people present/end of line
% of automation of depalletisation lines	▪ 0%	
Transport distance	▪ 250 km	

[9] End of line includes stacking the products onto the pallet as well as applying the pallet packaging.

4.4.2 Cement (product: 25kg bag of cement)

	Reference scenario	Reusable scenario
Assessed packaging solutions		
Packaging option	▪ Pallet and stretch hood	▪ Pallet and reusable hood
Picture of a pallet	 Source: https://balcan.com/products/shrink-hood-shroud	 Source : https://www.indiamart.com/proddetail/ecowrap-reusable-pallet-cover-22477167533.html (no cement specific images available)
Key parameters		
Number of products per pallet	▪ 52 – 63 products/pallet	▪ 52 - 63 products/pallet
Cost of packaging solution per use	▪ Pallet: 5 €/pallet ▪ Stretch hood: 1.7 - 2.5 €/pallet	▪ Pallet: 5 €/pallet ▪ Reusable hood: 7 €/pallet

Volume of packaging when folded	▪ Pallet: 0.134 m^3	▪ Pallet: 0.134 m^3 ▪ Reusable hood: 0.04m^3
Number of end of line operations *See Table 15 for details*	▪ 2 operations / machines	▪ 4 operations / machines
Investment cost of the machine for one operation	▪ 68 - 92K €/operation	
Number of extra persons needed on one palletisation line		▪ 0.16 - 0.31 people present/end of line
% of automation of depalletisation lines	▪ 0%	
Transport distance	▪ 500 km	

4.4.3 Construction (product: insulation rolls (12-15kg))

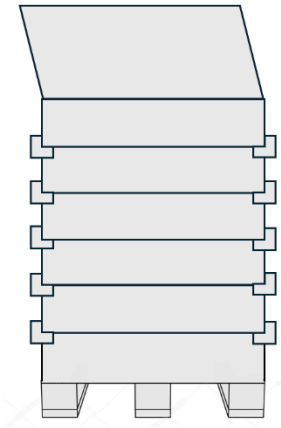
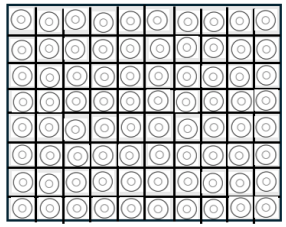
	Reference scenario	Reusable scenario
Assessed packaging solutions		
Packaging option	▪ Pallet and stretch hood	▪ Pallet and reusable hood
Picture of a pallet	 Source: https://www.varleyinsulation.com/catalog/product/view/_ignore_category/1/id/597/s/knauf-factory-clad-40-sold-in-pallets-of-24-rolls-choose-a-thickness/	 Source: https://www.indiamart.com/proddetail/ecowrap-reusable-pallet-cover-22477167533.html (no construction specific images available)
Key parameters		
Number of products per pallet	▪ 16 – 23 products/pallet	▪ 19 – 23 products/pallet
Cost of packaging solution per use	▪ Pallet: 5 €/pallet ▪ Stretch hood: 3 - 4.2 €/pallet	▪ Pallet: 5 €/pallet ▪ Reusable hood: 7 €/pallet
Volume of packaging when folded	▪ Pallet: 0.134 m^3	▪ Pallet: 0.134 m^3 ▪ Reusable hood: 0.04m^3

Number of end of line operations *See Table 15 for details*	▪ 2 machines/operations	▪ 4 machines/operations
Investment cost of the machine for one operation	▪ 99 - 134K €/operation	
Number of extra persons needed on one palletisation line		▪ 0.16 - 0.31 people present/end of line
% of automation of depalletisation lines	▪ 9 - 11%	
Transport distance	▪ 500 km	

4.4.4 Glass (product: 1L empty glass bottle)

	Reference scenario	Reusable scenario
Assessed packaging solutions		
Packaging option	▪ Pallet. ▪ Shrink hood and underlayer to be totally hermetically sealed. ▪ Cardboard cap and interlayers.	<u>System of pallet-crate + stackable crates + lid:</u> The full pallet is composed of: ▪ First layer: A crate of the same surface as a pallet (e.g. 1 x 1.2m), capable of storing glass bottles inside, with fork entries to be carried by a forklift. Layers 2 to 6[10]: crates capable of storing glass bottles inside, stackable on one another and lockable for stability. ▪ Last layer: lockable lid. Note: all crates are foldable while empty. A system of separators and packing pieces adapted to the bottle format are foreseen in each crate to block each bottle.

[10] The number of layers is fixed here for the example, but can differ in function of the format of the carried bottles.

Picture of a pallet	 https://www.plasticosreca.com/en/pallet-wrap/	**RDC Environment representation of crate system** **Side view:**  **Top view:** 
Key parameters		
Number of products per pallet	▪ 1 075 - 1 274 products/pallet	▪ 781 - 936 products/pallet

Cost of packaging solution per use	▪ Pallet: 5 €/pallet ▪ Shrink hood: 2.4 - 4.1 €/pallet	▪ Pallet: no longer relevant so 0 €/pallet ▪ Reusable plastic box: 22 €/pallet
Volume of packaging when folded	▪ Pallet: 0.134 m^3	▪ System of pallet-crate + stackable crates + lid: 0.7 m^3
Number of end of line operations *See Table 15 for details*	▪ 2 machines/operations	▪ 3 machines/operations
Investment cost of the machine for one operation	▪ 199 - 270K €/operation	
Number of extra persons needed on one palletisation line		▪ 0.48 – 0.53 people present/end of line
% of automation of depalletisation lines	▪ 90-100%	
Transport distance	▪ 500 km	

4.4.5 Milk (product: 1L bottle (HDPE))

Reference scenario	Reusable scenario
Assessed packaging solutions	
Packaging option ▪ Pallet and stretch hood	Packaging option ▪ Pallet and reusable hood
Picture of a pallet  Source: https://daddytypes.com/archive/milk_jug_pallet_nyt.jpg	Picture of a pallet  Source: https://www.indiamart.com/proddetail/ecowrap-reusable-pallet-cover-22477167533.html (no milk specific images available)
Key parameters	
Number of products per pallet ▪ 656 –795 products/pallet	Number of products per pallet ▪ 656 – 795 products/pallet

Cost of packaging solution per use	▪ Pallet: 5 €/pallet ▪ Stretch hood: 2.1 - 3.2 €/pallet	▪ Pallet: 5 €/pallet ▪ Reusable hood: 7 €/pallet
Volume of packaging when folded	▪ Pallet: 0.134 m^3	▪ Pallet: 0.134 m^3 ▪ Reusable hood: 0.04 m^3
Number of end of line operations *See Table 15 for details*	▪ 2 machines/operations	▪ 4 machines/operations
Investment cost of the machine for one operation	▪ 105 - 141K €/operation	
Number of extra persons needed on one palletisation line		▪ 0.18-0.31 people present/end of line
% of automation of depalletisation lines	▪ 9 – 11%	
Transport distance	▪ 250 km	

4.4.6 Plastic (product: 25 kg bag of plastic pellets)

	Reference scenario	Reusable scenario
Assessed packaging solutions		
Packaging option	▪ Pallet and stretch hood	▪ Pallet and reusable hood
Picture of a pallet	 Source: https://d2n4wb9orp1vta.cloudfront.net/cms/Vistamaxx%20PBE%20for%20thinner-1%20lores.jpg;maxWidth=400	 Source: https://www.indiamart.com/proddetail/ecowrap-reusable-pallet-cover-22477167533.html (no plastic pellet specific images available)
Key parameters		
Number of products per pallet	▪ 49 – 55 products/pallet	▪ 49 – 55 products per pallet
Cost of packaging solution per use	▪ Pallet: 5 €/pallet ▪ Stretch hood: 1.2 - 1.6 euro/pallet	▪ Pallet: 5 €/pallet ▪ Reusable hood: 7 €/pallet

Volume of packaging when folded	▪ Pallet: 0.134 m^3	▪ Pallet: 0.134 m^3 ▪ Reusable hood: 0.04 m^3
Number of end of line operations *See Table 15 for details*	▪ 2 machines/operations	▪ 4 machines/operations
Investment cost of the machine for one operation	▪ 134 - 181K €/operation	
Number of extra persons needed on one palletisation line		▪ 0.24-0.32 people present/end of line
% of automation of depalletisation lines	▪ 6 – 11%	
Transport distance	▪ 500 km	

4.4.7 Retail: product (box of paper tissues – in cardboard boxes)

Reference scenario	Reusable scenario
Assessed packaging solutions	
Packaging option	▪ Pallet and stretch wrap	▪ Pallet and reusable hood
Picture of a pallet	 Source: https://bhpackaging.net/products/stretch-wrap-pallet-wrap/	 Source: https://www.indiamart.com/proddetail/ecowrap-reusable-pallet-cover-22477167533.html (no plastic pellet specific images available)
Key parameters		
Number of products per pallet	▪ 323 – 395 products/pallet	▪ 323 – 395 products/pallet

Cost of packaging solution per use	▪ Pallet: 5 €/pallet ▪ Stretch wrap: 1.6 - 2.2 €/pallet	▪ Pallet: 5 €/pallet ▪ Reusable hood: 7 €/pallet
Volume of packaging when folded	▪ Pallet: 0.134 m^3	▪ Pallet: 0.134 m^3
Number of end of line operations *See Table 15 for details*	▪ 2 machines / operations	▪ 4 machines/operations
Investment cost of the machine for one operation	▪ 96 - 130K €/operation	
Number of extra persons needed on one palletisation line		▪ 0.21-0.30 present/end of line
% of automation of depalletisation lines	▪ 0%	
Transport distance	▪ 250 km	

4.4.8 Water (product: 1.5L bottle of water)

	Reference scenario	Reusable scenario
Assessed packaging solutions		
Packaging option	▪ Pallet and stretch wrap.	▪ Pallet and reusable hood.
Picture of a pallet	 Source:https://www.h2odirectlink.com/cheap-bulk-generic-label-bottled-water-ok-tx	 Source: **https://www.indiamart.com/proddetail/ecowrap-reusable-pallet-cover-22477167533.html** (no water bottle specific images available)
Key parameters		
Number of products per pallet	▪ 478 – 529 products/pallet	▪ 478 – 529 products/pallet
Cost of packaging solution per use	▪ Pallet: 5 €/pallet ▪ Stretch wrap: 1.2 – 1.8 €/pallet	▪ Pallet: 5 €/pallet ▪ Reusable hood: 7 €/pallet

Volume of packaging when folded	▪ Pallet: 0.134 m^3	▪ Pallet: 0.134 m^3 ▪ Reusable hood: 0.04 m^3
Number of end of line operations *See Table 15 for details*	▪ 2 machines / operations	▪ 4 machines / operations
Investment cost of the machine for one operation	▪ 168 - 228K €/operation	
Number of extra persons needed on one palletisation line		▪ 0.18 - 0.26 people present/end of line
% of automation of depalletisation lines	▪ 8 - 11%	
Transport distance	▪ 250 km	

4.5 Quantities and values of the representative products

4.5.1 Information required

In order to extrapolate the computed production cost difference per unit of representative product to the EU market, and to express the cost difference in terms of price difference for the consumer, the following estimations are needed:

- Total quantity of the representative product categories sold in the EU;
- Average price paid by the consumer;
- Number **of palletisation cycles** of the product along the value chain (see description below in Section 4.5.3). The cost difference assessed by the model by product and palletisation is incurred once or several times depending on the value chain.

4.5.2 Collection method

The following data sources were consulted:

- All relevant European federations were contacted.
- Interviews and site visits
- European federations annual reports were consulted
- Eurostat's Prodcom database
- Complementary web scraping for product prices, corrected for PPP using Eurostat data

4.5.3 Number of cycles per representative product's value chain

A key element, as noted above – is **the number of palletisation cycles** a product goes through.

The number of palletisation cycles rather refers to how many times a product will have to be put on a pallet before reaching the final consumer.

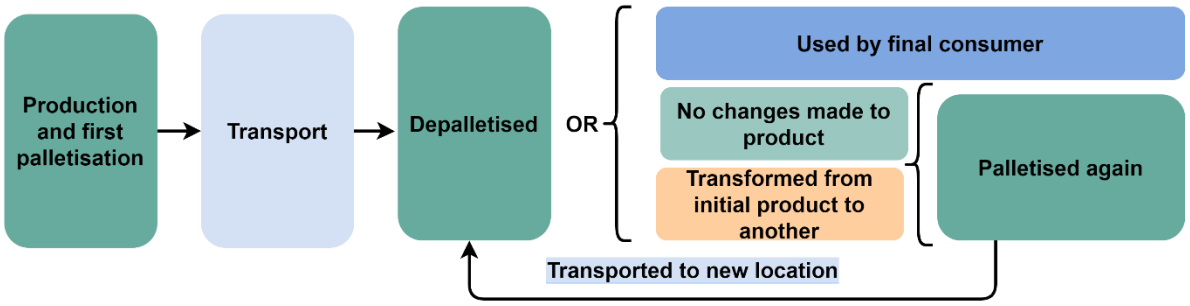
To prevent any confusion, this is a different topic to the number of operations for the end of line (which refers to the complexity of the machinery needed at the end of line). It also does not refer to how many times a reusable option can be used.

The following figure shows the illustrative case modelled in this study:

- A product is first produced and palletised.
- It is then sent to its initial destination, where it is depalletised.
- After this, there are three possibilities:
    - **If it is the final product:**
        - The product can be sent for its final use by the consumer
        - The product can be repalletised to be sent to a new location. This is for example in the case of the composition of mixed pallets and/or to meet specific orders that cannot be met by the initial pallet).
    - **If it is an intermediary product**: it can be transformed into another product (e.g., empty glass bottles are filled) and then repalletised.

The cycle then repeats for the latter two options after the product is repalletised.

Figure 5 : Illustration of multiple palletisation cycles per product

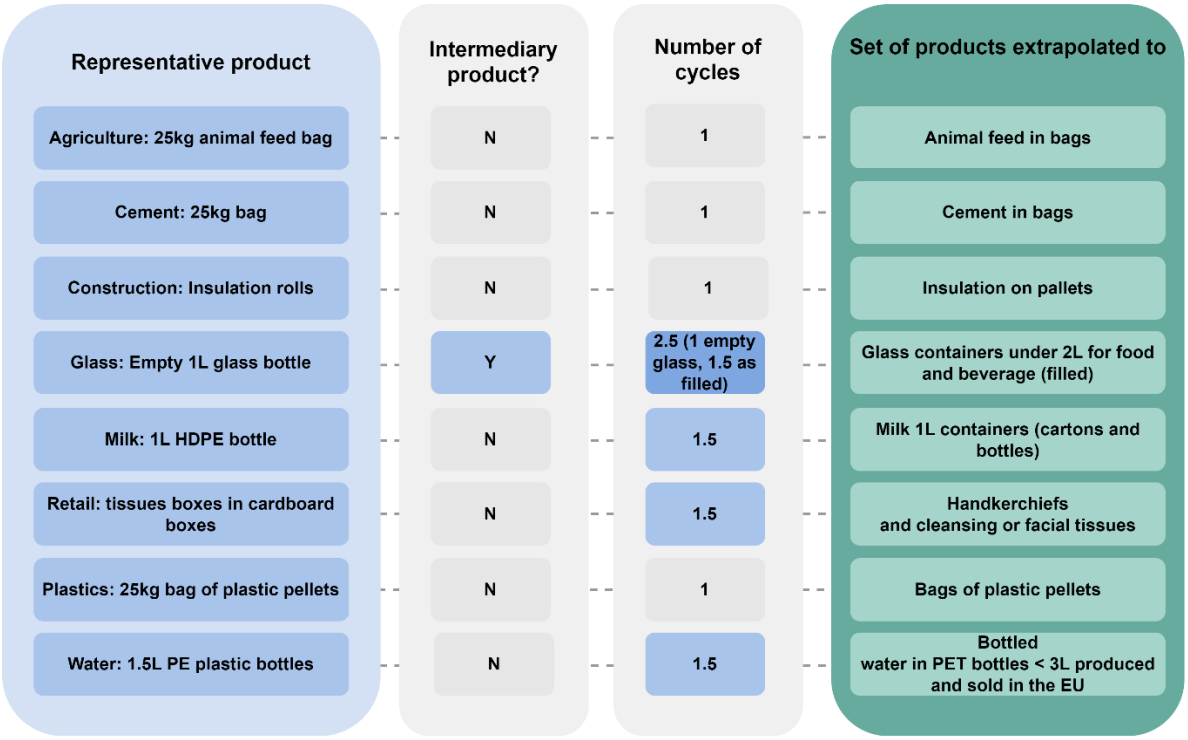


The next figure, from left to right, shows:

- **The representative product** used in the cost modelling for one cycle (the first cycle).
- Which of these products **are considered intermediary products** (only empty glass bottles), i.e. require a further transformation before their final use.
- **The number of cycles** a product can go through before its final use.
  - 1 means only one palletisation and depalletisation (one cycle before final use)
  - 1.5 means one cycle and then another one in half of cases for that product.
  - 2.5 is specific to glass and means indicates that a glass bottle is: (i) Produced, palletised as empty bottles, transported and depalletised (1 cycle), (ii) Filled, palletised as filled bottles, transported and depalletised (1.5 cycles).

    Note: a half palletisation cycle (0.5) is included in some cases as an average, to allow for variation in the number of palletisation cycles a product goes through. For example, in some sectors, part of the products may go straight from production to use (so only one palletisation cycle), while another part a may go through an intermediary palletisation cycle in a warehouse. For the sectors where this can occur, an average number of 0.5 palletisation cycle is considered.
- What set of products the results from the specific representative products are extrapolated to.

Figure 6 : Number of cycles per product and product set extrapolated to



4.5.4 Data

The table below shows the value considered for each representative product.

Table 18: Data relevant to the extrapolation to the EU level and comparisons to prices

Sector	Products considered	Parameter	Value	Source / Comment
Agriculture	25 kg bags of animal feed compound for use in agriculture or equivalent	Quantities	882 million bags	Based on FEFAC[11] production information and the assumption that 15% of the production is delivered in bags.
		Price excl. VAT	17 €/bag	Web scraping
		Number of cycles	1	RDC assumption
Cement	Cement in bags <= 50 kg	Quantities	655 million bags	Estimation based on Cembureau's key facts and figures 2024
		Price excl. VAT	0.27 €/kg	Web scraping
		Number of cycles	1	RDC assumption

[11] European Feed Manufacturers' Federation.

Sector	Products considered	Parameter	Value	Source / Comment
Construction	Rockwool and glass wool insulation rolls and slabs produced and consumed in the EU, delivered at retailer or to consumer	Quantities	3.6 million tons	Estimate based on JRC's BREF for manufacture of glass
		Price excl. VAT	4.1 €/kg	Web scraping
		Number of cycles	1	RDC assumption
Milk	HDPE bottles or cartons of milk, 1 L or equivalent, for household consumption	Quantities	15.6 billion litres	Estimation based on sector interviews
		Price excl. VAT	0.86 €/litre	Web scraping
		Number of cycles	1.5	Estimation based on sector interviews
Glass (delivered to filler)	Empty glass container aimed at containing food or beverage, delivered to filler	Quantities	61.3 billion containers	Estimation based on sector data
		Price excl. VAT	0.18 €/container	Estimation based Eurostat's Prodcom
		Number of cycles	1	Delivery to filler
Glass (delivered to retailer)		Quantities	61.3 billion containers	Estimation based on sector data

Sector	Products considered	Parameter	Value	Source / Comment
	Food and beverage in glass container, single use and reusable, delivered to retailer.	Price excl. VAT	3€/unit	RDC assumption
		Number of cycles	1 cycle as empty container + 1.5 cycles as filled container	Pallet opened at the filler, 50% times at the distributor and finally at the retailer. A simplified assumption that the extra cost computed for water applies for the transports from filler to retailer, as no specific model is developed for these logistic steps.
Plastic	25 kg FFS (Form Fill Seal) plastic pellets, delivered to convertor	Quantities	815.4 million bags	Based on market information from EU federations.
		Price excl. VAT	61 €/bag	Estimation based on Plastics Europe "The plastic transition"
		Number of cycles	1	Delivery to convertors.
Retail	Handkerchiefs and cleansing or facial tissues of paper pulp,	Quantities	589.9 million kg	Estimation based on Eurostat data (Prodcom)

Sector	Products considered	Parameter	Value	Source / Comment
	paper, cellulose wadding or webs of cellulose fibres (Prodcom 17221140)	Price excl. VAT	2.22 €/kg	Estimation based on Eurostat data (Prodcom)
		Number of cycles	1.5	Estimate based on the assumption that 50% of products get depalletised and repalletised at distribution centres.
Water	Bottled water in PET bottles < 3L produced and sold in the EU.	Quantities	44.4 billion litres	RDC estimate based on interviews with sector experts and volume data from GlobalData
		Price excl. VAT	0.52 €/L	RDC estimate based on interviews with sector experts and web research
		Number of cycles	1.5	Estimate based on the assumption that 50% of products get depalletised and repalletised at distribution centres.

4.6 Limits

The following limits and uncertainties, inherent to our approach, are identified.

- **Uncertainty on the alternative packaging solutions chosen by the market** and **the possible shift to bulk logistics**
  - There will always be uncertainty while trying to anticipate future choices and technical options, especially as the alternative large-scale solutions for this case are not clear today.
  - This study only compares two options for each representative product (except for retail).
  - It is likely that several alternative solutions, similar or not, will co-exist. A transfer from pallet to bulk can be expected for some products, such as animal feed, plastic pellets and cement. This shift is likely to be – to an extent – proportional to the additional cost of the reusable pallet packaging option, also depending on the extent to which the other parts of the PPWR affect bulk transport.
- **Uncertainty on the level of optimisation of the reusable pallet packaging solutions**
  - **Developing a reusable pallet hood** with straps that can be **automatically applied, tightened and removed**, while **fulfilling the same functionalities** as the current solutions, is a significant technical challenge. This study makes a strong assumption that it is technically possible and will be optimised in the future, while also making assumptions on how it will be optimised. A reusable hood is also less customisable than the current plastic film. Therefore, changing pallet dimensions may become more challenging.
  - **Developing a reusable** glass crate system that can carry and protect empty glass containers is also a significant technical challenge. This crate system would have to:
    - Be operated automatically by machines on the end of line and palletisation line
    - Allow for some level of format adaptation so as to limit the number of different co-existing crates.
    - Be foldable to minimise storage space and transport costs.
  - In addition, some sectors may have very specific or variable product formats which makes packing them with reusable options difficult.
  - The consequence of this is that the data for the reusable solutions used in the cost modelling, is inherently uncertain.
- **Potential additional costs linked to the co-existence of different systems**, e.g. single use for export outside of the EU together with reusable for intra-EU trade, are not taken into account in the long-term quantitative cost model. This tends to **underestimate** the cost of the alternative scenarios.
- **The potential price effects on exchanged volumes** are not considered.
- **The extrapolation method** is subject to the following limitations:
  - The cost differences modelled for one specific product are applied to a product category assuming identical per unit extra costs.

- The data in terms of total production and consumption, as well as average prices, are subject to associated assumptions.

- **Multiple interviews were conducted across product types in the context of this study to try to get the most representative set of data possible**. However, there can be significant variability from one plant to another, and from one size of plant to another. This study does not capture the heterogeneity of these situations.
- **Some specificities as not directly considered in the results for simplicity**. This includes, for example, that many of the pallets with water or milk bottle are actually half pallets grouped on a single master pallet.

5 Results

5.1 Quantitative assessment: long term impact on production cost – analysis at product level

As described above, the alternative solutions modelled are **reusable hoods for every representative product except for glass.** The solution for the **glass** sector is the **reusable plastic crate** system.

The results are presented in two steps: first (i) the return model constructed to estimate the cost of using a reusable option for one palletisation cycle, which then serves as an input to the following steps, (ii) for the first cycle of palletisation (**"first cycle"**) then (ii) after all subsequent palletisation cycles up until the final use of the product **("all cycles")**.[12] For the avoidance of doubt, "all cycles" includes all cycles including the first.

For each product category, the following sets of results are presented:

- **For the first cycle:** The estimated cost difference of pallet wrapping in € per unit of representative product, between single use and alternative options. These results are presented for the sake of clarity only. Final results include all cycles (see below).
- **For all cycles:**
  - The cost impact across all cycles with respect to the product price.
  - A sensitivity analysis with respect to the parameters involving the most significant variety of situations and uncertainty.
  - An extrapolation of these results to the EU level and (for some sectors) a wider set of products than the representative product.

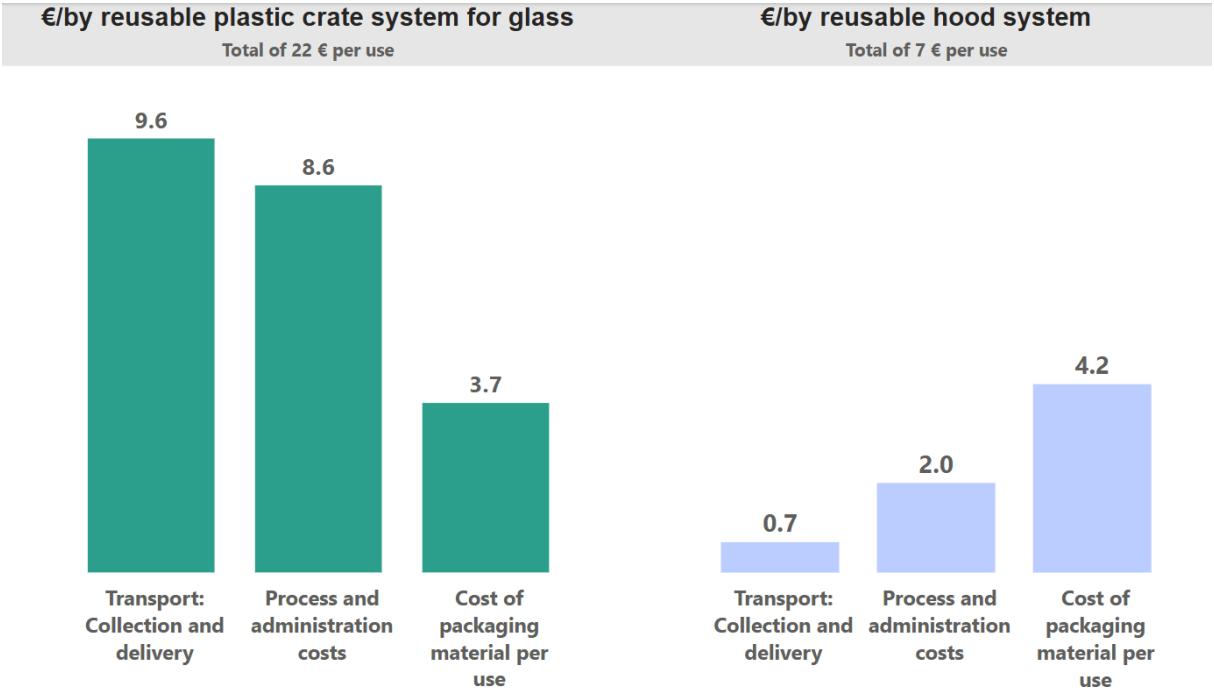
5.1.1 Return cost model

The results of the return cost model described in Table 17 are presented here. These results relate to the cost per use of the reusable options, not the outright cost of purchasing a new reusable option. As such, the cost includes the whole value chain to get the reusable option ready for a new use, including, inter alia, logistics and cleaning as well as its initial cost. This is then an input to the cost pallet cost modelling.

The figure below shows the main cost components for the reusable crate system and the reusable hood system.

[12] For a detailed explanation of these cycles, see Section 4.5.3.

Figure 7: Cost items in reusable solution return model



For the reusable plastic crates, given that they take more volume and is a more complex system, the transport costs are the largest cost category driving the return cost. The reusable hoods are compressible – more empty packaging can be transported in a truck, so the main cost per use comes from the cost of the packaging itself (spread over the uses of the packaging).

These costs are then plugged into the main cost model.

5.1.2 Analysis of cost impact per cycle – first pallet wrapping cycle only

The results in this section consider only the costs for the first palletisation of a product or the first cycle[13].

That is, even if a product is palletised multiple times before it is used, this section considers the first palletisation once the representative product is produced.

These are shown separately to provide the results of a single palletisation first for transparency purposes.

5.1.2.1 Results in cost € per unit of representative product – for the first cycle

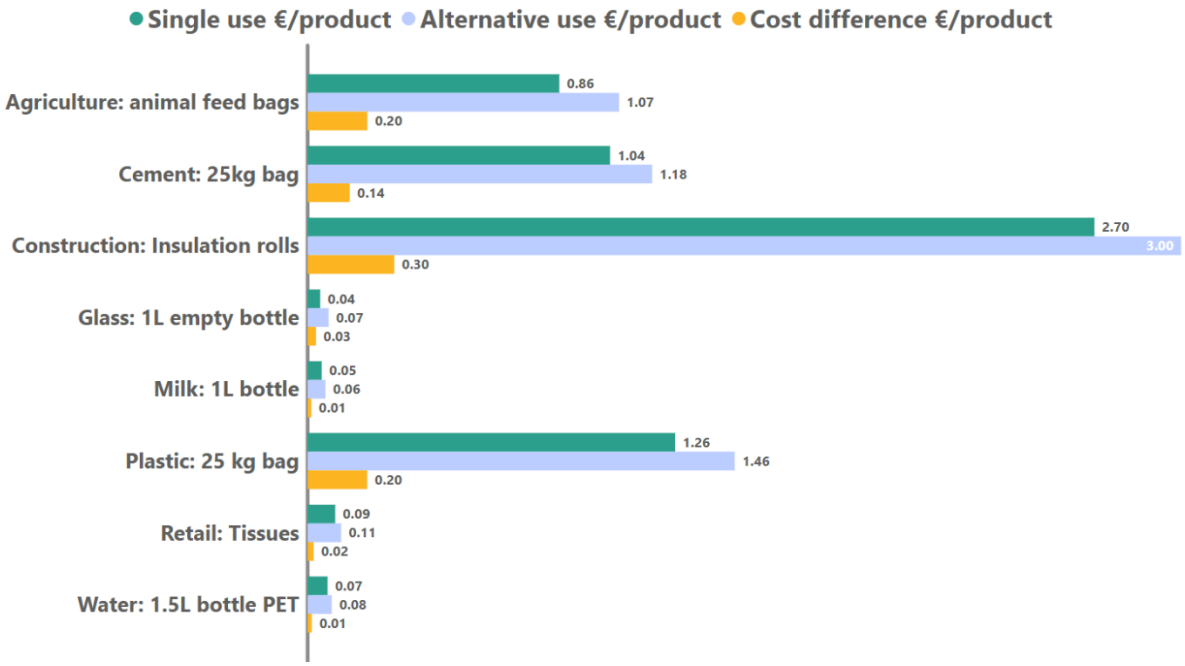
A. Total cost difference per unit of representative product per cycle

In the long run, using a reusable packaging (reusable hood, reusable crate system) instead of a single use option (stretch hood, wrap or shrink hood), results in an average cost increase in the range of 0.01-0.30 € per unit of product for the first cycle.

[13] Ibid.

The figure below shows the costs incurred for each of the reference and alternative scenarios defined above for one cycle. For example, for animal feed bags (representative product for agriculture), the cost of preparing, sending and depalletizing a product is estimated at 0.86 € per bag for single use, and 1.07 € per bag for the reusable hood option, or an extra cost of +0.20 € per unit per cycle.

Figure 8: Total costs per product per cycle for the single use option, the alternative option and the absolute difference between the two – first cycle only



Note: this only considers the first cycle, as such, filled glass bottles are not presented (they are filled after the first palletisation cycle).

The cost difference is strongly influenced by the number of products per pallet as well as the choice of alternative option. For example, the cost per glass bottle is lower than the cost per insulation roll, because of the higher number of products per pallet for glass bottles.

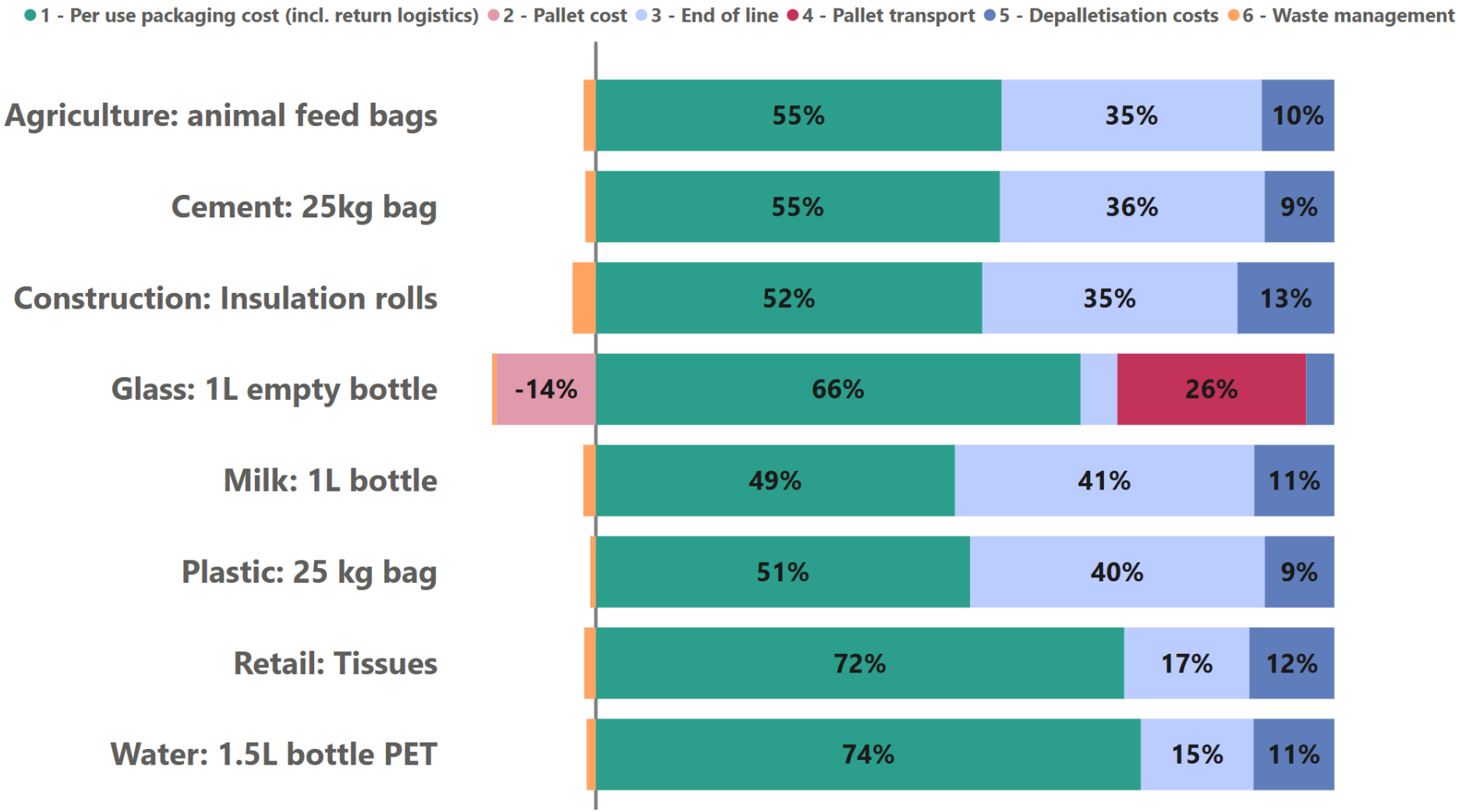
B. Cost delta per stage in €/product – first cycle only

The results are now presented by stage for each sector, including only the cost delta between the single use and alternative solution. The packaging cost (i.e. the cost of the single use film, reusable hood or reusable plastic crate) is the systematically the largest contributor to the total cost delta. This includes the return logistics (transport, cleaning, etc.) for the reusable options.

The figure below shows how much each stage contributes to the total cost variation for a given product.

- For example, for animal feed bags, 55% of the cost variation comes from the cost of reusable packaging, 35% from increase in costs of the end of line.
- Empty glass bottles are the only representative product for which the transport cost differs amongst compared scenarios, making up 26% of the total cost variation.
    - This is because, as set out above, it is assumed that an optimised reusable hood solution does not impact the number of products per pallet.
    - On the other hand, the reusable crate system reduces the space available for glass, thereby increasing the number of trucks necessary to ship an equal amount of products.

Figure 9: Cost variation by sector and stage in % of the total cost variation – first cycle only



Note: The per use packaging cost (incl. return logistics) includes the return logistics (transport, cleaning, etc.) for the reusable options. See details in Figure 7.

The key differences between the results for each of the representative products are linked to, inter alia:

- **The number of products per pallet** (as already noted)**,** and whether **that changes with the reusable system**. In the table above, only the reusable packaging for glass bottles implies a reduction in products per pallet, which strongly affects the cost delta across stages (for example transport, per use packaging cost, end of line due to the loss of efficiency).
- **The capacity and cost of the automation machines** used in each sector for the various products. There are different speeds of production for these products, which means that the wrapping and palletisation machines also have different speed capacities (and costs) to match.
- **The amount of plastic film used in the single use option**. This varies depending on the product and the type of wrapping (shrink hood, stretch/shrink wrap), which affects the single use costs.

For the sake of clarity: the figure above shows the cost delta per stage of the value chain. This means that, if there is no cost delta for a given stage (no change in cost), then the figure will not show that stage as the cost delta is zero. This is why, for example, the pallet cost and transport cost do not appear except for glass. These are only affected if the pallet itself changes or if the number of products per pallet changes.

Individual figures by stage and representative product can be found in Annex B (Section 8).

C. Summary table of costs in €/product for the first cycle

The following table provides more detailed results of the single use, alternative and cost delta by stage and product category[14].

[14] Table 16 provides a description of what costs are included in each stage.

Table 19: Detailed single use and alternative costs by sector – for the first cycle, by product[15]

Sector and product	Stage	Single use €/product	Reusable use €/product	Cost variation in absolute terms in €/product unit	Delta in % of compared single use cost
Agriculture: 25kg bags of animal feed	1 - Per use packaging cost (incl. return logistics)	0.056	0.171	0.114	203.0%
	2 - Pallet cost	0.127	0.127	0.000	0.0%
	3 - End of line	0.071	0.144	0.073	103.8%
	4 - Pallet transport	0.459	0.459	0.000	0.0%
	5 - Depalletisation costs	0.146	0.167	0.020	14.0%
	6 - Waste management	0.003	0.000	-0.003	-100.0%
	7 - Total	**0.863**	**1.068**	**0.205**	**23.7%**
Cement: 25kg bag of cement	1 - Per use packaging cost (incl. return logistics)	0.034	0.114	0.080	236.7%
	2 - Pallet cost	0.085	0.085	0.000	0.0%
	3 - End of line	0.061	0.113	0.052	86.6%
	4 - Pallet transport	0.758	0.758	0.000	0.0%
	5 - Depalletisation costs	0.098	0.112	0.014	14.1%
	6 - Waste management	0.002	0.000	-0.002	-100.0%
	7 - Total	**1.037**	**1.181**	**0.144**	**13.9%**
Construction: Insulation rolls (12-15kg)	1 - Per use packaging cost (incl. return logistics)	0.157	0.318	0.161	102.0%
	2 - Pallet cost	0.237	0.237	0.000	0.0%
	3 - End of line	0.179	0.285	0.106	59.2%
	4 - Pallet transport	1.864	1.864	0.000	0.0%
	5 - Depalletisation costs	0.251	0.291	0.040	16.0%
	6 - Waste management	0.010	0.000	-0.010	-100.0%
	7 - Total	**2.698**	**2.995**	**0.297**	**11.0%**
Glass: 1L empty glass bottle	1 - Per use packaging cost (incl. return logistics)	0.003	0.025	0.022	731.9%
	2 - Pallet cost	0.004	0.000	-0.004	-100.0%

[15] Waste management of the reusable option is accounted for in the *1 – per use packaging cost (incl. return logistics)* cost. See Figure 7 for what is included in this category.

	3 - End of line	0.003	0.004	0.002	58.5%
	4 - Pallet transport	0.032	0.040	0.009	26.9%
	5 - Depalletisation costs	0.001	0.002	0.001	153.2%
	6 - Waste management	0.000	0.000	0.000	-100.0%
	7 - Total	**0.043**	**0.072**	**0.029**	**66.5%**
Milk: 1L bottle (HDPE), filled	1 - Per use packaging cost (incl. return logistics)	0.004	0.010	0.006	175.4%
	2 - Pallet costs	0.007	0.007	0.000	0.0%
	3 - End of line	0.005	0.010	0.005	100.7%
	4 - Pallet transport	0.024	0.024	0.000	0.0%
	5 - Depalletisation costs	0.008	0.009	0.001	17.6%
	6 - Waste management	0.000	0.000	0.000	-100.0%
	7 - Total	**0.048**	**0.061**	**0.013**	**26.3%**
Retail: Box of paper tissues - professional hygiene	1 - Per use packaging cost (incl. return logistics)	0.005	0.020	0.015	278.7%
	2 - Pallet cost	0.015	0.015	0.000	0.0%
	3 - End of line	0.008	0.011	0.004	44.7%
	4 - Pallet transport	0.049	0.049	0.000	0.0%
	5 - Depalletisation costs	0.017	0.020	0.002	13.8%
	6 - Waste management	0.000	0.000	0.000	-100.0%
	7 - Total	**0.095**	**0.115**	**0.020**	**21.5%**
Plastic: 25 kg bag of plastic pellets	1 - Per use packaging cost (incl. return logistics)	0.026	0.130	0.104	405.0%
	2 - Pallet cost	0.097	0.097	0.000	0.0%
	3 - End of line	0.122	0.205	0.082	67.1%
	4 - Pallet transport	0.908	0.908	0.000	0.0%
	5 - Depalletisation costs	0.106	0.125	0.019	18.3%
	6 - Waste management	0.002	0.000	-0.002	-100.0%
	7 - Total	**1.260**	**1.465**	**0.204**	**16.2%**
Water: 1.5L PET bottle, still water, filled	1 - Per use packaging cost (incl. return logistics)	0.003	0.014	0.011	362.4%
	2 - Pallet cost	0.010	0.010	0.000	0.0%
	3 - End of line	0.005	0.007	0.002	45.0%
	4 - Pallet transport	0.040	0.040	0.000	0.0%
	5 - Depalletisation costs	0.011	0.012	0.002	14.9%
	6 - Waste management	0.000	0.000	0.000	-100.0%
	7 - Total	**0.068**	**0.083**	**0.014**	**20.8%**

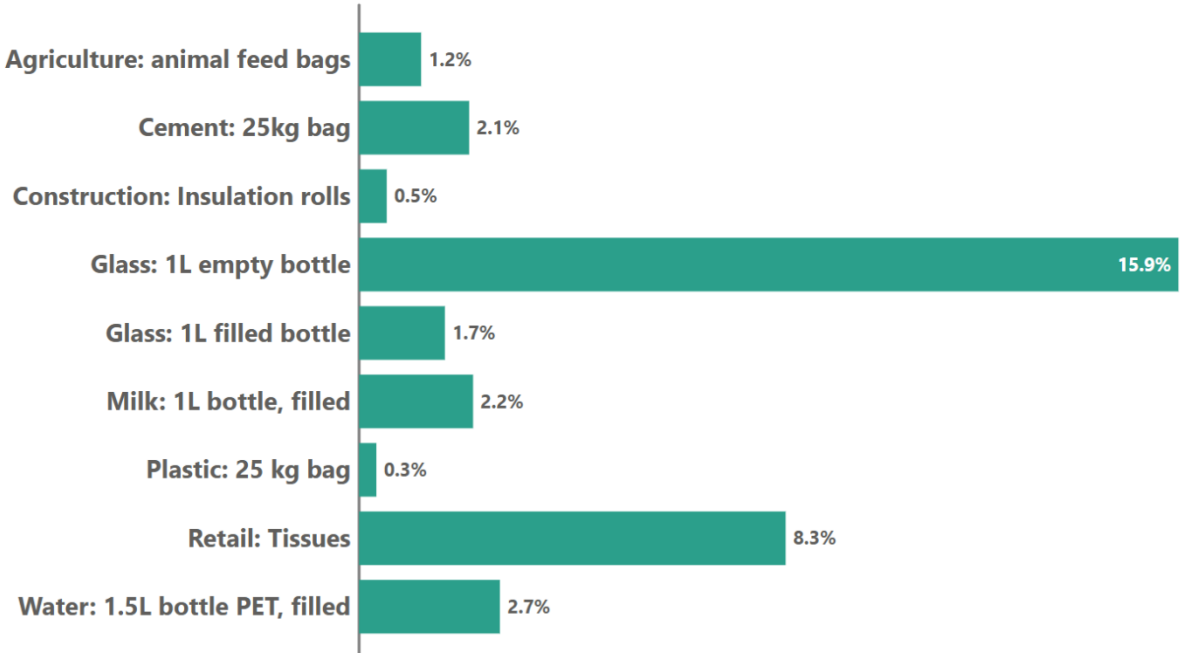
5.1.3 Analysis of the total cost impact – including all pallet wrapping cycles (all cycles)

The results in this section (5.1.3) now consider all palletisations of a product after its production and before its final use (all cycles). In some cases, only one palletisation cycle occurs before the product's use, so the results in this section and the previous one are equivalent for those. For others, the cost delta is greater as there are more cycles. For glass only, results including all upstream value chain are shown for both the intermediary product and the final product (namely: empty glass bottles delivered to the fillers and filled glass bottles delivered to retailers).[16]

5.1.3.1 Results expressed in share of the product price

The figure below sets out the cost delta of all cycles relative the product price.

Figure 10: Total cost variation by sector in percentage of product price – all cycles



Note: empty glass bottles and filled glass bottles are to be considered as two separate case studies. Both include all upstream value chain.

The figure below above that the cost impact as a share of price varies between 0.3% of the price for plastic pellet bags and 15.9% for empty glass bottles.

The parameters of the cost model are based on the long-term view, with assumptions that the solution would be optimised (automated). However, as already discussed, uncertainties exist on what form the reusable solution would take, as well as how much additional effort it would take from an automation perspective. As a result, the following section presents sensitivity analyses around the key parameters, affecting different stages of the compared scenarios.

[16] As set out in Section 4.5, for glass bottles: 1 empty glass cycle is considered, followed by 1.5 cycles for filled bottles using the cost increase estimated for water as a proxy for the cost of palletising filled glass bottles.

5.1.4 Sensitivity analysis – on all cycles

In the following, "**baseline**" and "**base parameters**" are used interchangeably, to denote the set of data and calculations resulting in the cost deltas presented above in the sections above.

This section presents (i) the key parameters with intrinsic variation and/or uncertainty that has an influence on the total cost delta, which are therefore relevant to include in a sensitivity analysis and (ii) how sensitive the cost delta calculated in the previous section are to changes in these parameters.

5.1.4.1 Parameters selected for sensitivity analysis

The most influential and variable or uncertain factors identified in the analysis are:

- **Number of extra operations:** How many extra automation steps are required at the end of the production line (e.g., palletisation and depalletisation) in the alternative scenario compared to the reference single use scenario.[17]
- **Reusable packaging cost per use:** This cost includes not only the packaging itself but also its transportation, cleaning, and other related expenses.[18]
- **Number of products per pallet:** The difference in number of products that can be loaded on each pallet, between scenarios.

Other parameters for which there is significant uncertainty or variation include:

- **Plastic film (single use):** the amount of plastic film used on a pallet.[19]
- **Level of depalletisation automation:** The proportion of depalletisation processes that are automated once the pallet is received by the customer (this varies significantly by sector).
- **Transport distance:** Various transport distances are considered for each sector depending on the product. The impact may vary according to the distance the product is sent, when the reusable option means fewer products per pallet. This is the case for glass in the analysis below. The variability is driven by the differences in distances across different facilities and firms (some may export across the EU, some may be national). In the below, two sensitivities: one with half the transport distance and the other with double.

5.1.4.2 Sensitivity analysis: results

The table below presents the sensitivity of the cost delta to variations in key parameters. Specifically, it provides the coefficient of variation, which indicates the extent to which the total cost delta varies compared to the value calculated with the base parameters as presented above, for a given change in a parameter.

[17] For a discussion of this point, see section 4.3.

[18] See Annex C in Section 9 for more detail.

[19] The variation here stems from differences in the amount of plastic used for a same type of product. This difference can occur across production facilities, due to different wrapping types (shrink hood, stretch or shrink wrap), as well as to differences in palletisation techniques and habits specific to a given facility.

Reading guide based on an example: If **the number of product units per pallet** in the **alternative** packaging option is **10% lower** than in the baseline scenario (fourth column from the right), the additional cost of insulation roll production (+0.3 €/unit) increases by 112.0%, reaching +0.63 €/unit.

Table 20: Percentage difference cost impact as share of price increase, compared to baseline scenario – all cycles

Product	Alternative	Cost difference with base parameters (€/unit)	Return cost		Amount of plastic used	Number of operations	Amount of extra labour	Products per pallet	Share of automation		Transport distance	
			Reusable options take 10% more space when folded	Reusable options can be used 10% more times	10% more single use plastic is used than currently estimated	One more operation is necessary to palletise and depalletise a pallet	One more person is needed on the palletisation line for the reusable option	10% fewer products per pallet can be put on the reusable option	0% of depalletisation is automated	100% of depalletisation is automated	Double	Half
For each representative product, if the key parameter changes as described above, the cost difference is to be multiplied by (1+the percentage below).												
Animal feed	Reusable hood	0.20	1.1%	-5.0%	-2.9%	11.3%	27.7%	57.9%	0.0%	12.0%	0.0%	0.0%
Cement	Reusable hood	0.14	1.0%	-4.7%	-2.5%	12.7%	23.0%	91.0%	0.0%	13.8%	0.0%	0.0%
Insulation roll	Reusable hood	0.30	1.4%	-6.4%	-5.6%	12.4%	30.2%	112.0%	-0.9%	7.8%	0.0%	0.0%
Milk bottle	Reusable hood	0.02	1.0%	-4.6%	-3.0%	17.0%	25.1%	53.4%	-1.7%	15.5%	0.0%	0.0%
Empty glass	Reusable crate	0.03	5.1%	-1.4%	-1.1%	5.1%	2.8%	27.8%	4.6%	0.0%	26.4%	-13.2%
Filled glass	Reusable crate	0.05	3.4%	-3.3%	-1.6%	5.9%	4.4%	43.5%	2.7%	-0.3%	15.1%	-7.6%
Plastic pellet	Reusable hood	0.20	0.8%	-3.8%	-1.3%	17.2%	22.2%	79.6%	-1.9%	16.7%	0.0%	0.0%
Tissue	Reusable hood	0.03	1.3%	-5.9%	-2.8%	6.9%	15.3%	62.7%	0.0%	1.4%	0.0%	0.0%
Bottled water	Reusable hood	0.02	1.3%	-5.7%	-2.2%	7.1%	6.6%	64.5%	0.1%	-0.7%	0.0%	0.0%

*Note: **colour coding** in this chart is **across products** (the colours compare the values with a row and across rows).*

The exact same results are displayed in different units in the two following tables. The table below shows the influence of parameter changes in € per unit.
Reading guide based on an example: if the alternative packaging can be used 10% more times than with the base parameters (fifth column from the left), the extra cost of animal feed production decreases from + 0.20 €/unit to + 0.19 €/unit.

Table 21: Cost variation in absolute terms in each sensitivity - €/product – all cycles

Product	Alternative	Cost difference with base parameters (€/unit)	Return cost		Amount of plastic used	Number of operations	Amount of extra labour	Products per pallet	Share of automation		Transport distance	
			Reusable options take 10% more space when folded	Reusable options can be used 10% more times	10% more single use plastic is used than currently estimated	One more operation is necessary to palletise and depalletise a pallet	One more person is needed on the palletisation line for the reusable option	10% fewer products per pallet can be put on the reusable option	0% of depalletisation is automated	100% of depalletisation is automated	Double	Half
For each representative product, if the key parameter changes as described above, the cost difference in €/product varies from the amount in the base parameter column to the amount in the relevant column.												
Animal feed	Reusable hood	0.20	0.21	0.19	0.20	0.23	0.26	0.32	0.20	0.23	0.20	0.20
Cement	Reusable hood	0.14	0.15	0.14	0.14	0.16	0.18	0.28	0.14	0.16	0.14	0.14
Insulation roll	Reusable hood	0.30	0.30	0.28	0.28	0.33	0.39	0.63	0.29	0.32	0.30	0.30
Milk bottle	Reusable hood	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
Empty glass	Reusable crate	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.02
Filled glass	Reusable crate	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.05	0.05	0.06	0.05
Plastic pellet	Reusable hood	0.20	0.21	0.20	0.20	0.24	0.25	0.37	0.20	0.24	0.20	0.20
Tissue	Reusable hood	0.03	0.03	0.03	0.03	0.03	0.04	0.05	0.03	0.03	0.03	0.03
Bottled water	Reusable hood	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02

*Note: **colour coding** in this chart is **product specific** (the colours compare the values within a row but not across rows).*

The table below shows the influence of parameter changes on the cost delta as a share of the product price. **Reading guide based on an example:** if one more operation is necessary to palletise and depalletise a pallet (column 7 from the left), the extra cost of cement bags with the alternative packaging solutions increases from 2.1% of the unit price to 2.4% of the unit price.

Table 22: Cost variation compared to price of product in each sensitivity – cost delta in €/product compared to product price – all cycles

Product	Alternative	Cost difference with base parameters (€/unit)	Return cost		Amount of plastic used	Number of operations	Amount of extra labour	Products per pallet	Share of automation		Transport distance	
			Reusable options take 10% more space when folded	Reusable options can be used 10% more times	10% more single use plastic is used than currently estimated	One more operation is necessary to palletise and depalletise a pallet	One more person is needed on the palletisation line for the reusable option	10% fewer products per pallet can be put on the reusable option	0% of depalletisation is automated	100% of depalletisation is automated	Double	Half
For each representative product, if the key parameter changes as mentioned above, the cost difference in % of the product price varies from the amount in the base parameter column to the amount in the relevant column.												
Animal feed	Reusable hood	1.2%	1.2%	1.1%	1.2%	1.3%	1.5%	1.9%	1.2%	1.3%	1.2%	1.2%
Cement	Reusable hood	2.1%	2.2%	2.0%	2.1%	2.4%	2.6%	4.1%	2.1%	2.4%	2.1%	2.1%
Insulation roll	Reusable hood	0.5%	0.5%	0.5%	0.5%	0.6%	0.7%	1.1%	0.5%	0.6%	0.5%	0.5%
Milk bottle	Reusable hood	2.2%	2.2%	2.1%	2.1%	2.6%	2.8%	3.4%	2.2%	2.6%	2.2%	2.2%
Empty glass	Reusable crate	15.9%	16.7%	15.7%	15.7%	16.7%	16.4%	20.3%	16.6%	15.9%	20.1%	13.8%
Filled glass	Reusable crate	1.7%	1.7%	1.6%	1.6%	1.8%	1.7%	2.4%	1.7%	1.7%	1.9%	1.5%
Plastic pellet	Reusable hood	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.6%	0.3%	0.4%	0.3%	0.3%
Tissue	Reusable hood	8.3%	8.4%	7.8%	8.1%	8.9%	9.6%	13.5%	8.3%	8.4%	8.3%	8.3%
Bottled water	Reusable hood	2.7%	2.8%	2.6%	2.7%	2.9%	2.9%	4.5%	2.7%	2.7%	2.7%	2.7%

*Note: **colour coding** in this chart is **product specific** (the colours compare the values within a row but not across rows).*

5.1.4.3 Sensitivity analysis : key take-aways – based on all cycles

The most influential parameters on the cost model include:

- **The number of units of product per pallet in the alternative scenario**.
  - For every product except glass, the use of reusable hood is expected to have no impact on the number of products per pallet.
  - If this assumption does not hold in reality, the reusable solution's extra cost would be significantly higher (an increase in the cost delta of between 28% and 112%).

  Note: For glass, the baseline cost model considers that the pallet can carry 21% fewer bottles in the reusable than in the reference scenario – due to the use of the crate system. This assumption is a major contributor to the cost difference for glass bottles, together with the cost of the crate system and its logistical return scheme.
- **The optimisation of the palletisation and depalletisation process and its automation.** Three of the parameters selected for the sensitivity analysis refer to the complexity of the palletisation of depalletization processes:
  - **The number of operations**, which defined the number of machines on the end of production line;
  - **The number of extra personnel** needed for manual operations on the palletisation line;
  - **The share of facilities using automatised** processes for depalletisation.
- **Transport distances:** if switching to the reusable solution means fewer products per pallets, then the transport distance has a strong impact on the total cost impact of this switch. For example:
  - For glass : If the transport distance for a product is twice the distance considered as base parameter, the cost delta increases by 26% for the first cycle of empty glass bottles only, and 15% for the all-cycles filled glass bottles case.
  - For other products: no sensitivity to transport distance as there is no difference in number of products per lorry.

The following parameters are influential, but to a lesser extent:

- **Increased reusability:** If the reusable packaging can be used 10% more times: the cost impact **decreases** by **1–6%** (depending on the sector).

  For example, for construction:
  - The total cost delta drops from **0.30 €/product** to **0.28 €/product** (a reduction in cost delta between single use and alternative of 0.02 €).
  - This translates to a **6% relative decrease** in the cost delta. A 10% increase in the number of reusable option uses per packaging – compared to the baseline – for the construction sector, results in a 6% lower total cost delta between single use and reusable. A similar effect would be achieve if considering a 10% lower price for the reusable option.
- **Other packaging sensitivities:**
  - **Increased folded volume:** A 10% increase in the space taken by the folded reusable option raises the cost delta by 1 – 5%.

- **Single-use plastic film:** Increasing the amount of plastic film used per pallet by 10% reduces the cost delta by 1 – 6% compared to the reusable hood.

5.2 Economic impact at EU level

This section uses the results from the previous section and extrapolates up to the EU level. This considers all palletisation cycles (all cycles).

The cost impacts above are at the product level. Here, results at the EU level are presented. The product categories may be wider than those in the cost analysis to cover as wide a basket of similar goods as possible, i.e. what set of products can these results be reasonably extended to.[20]

The representative products used have significant variation in the number of products produced and sold in the EU. In part because of this, total impacts for some representative products are much higher than others. The table below shows the estimated total impact per set of products extrapolated to from the representative product.

[20] See Section 4.5 for more context.

Table 23: Long term cost impacts at the EU level of switching to alternative wrapping solutions – all cycles

Sector	Set of products covered by extrapolation	Number of cycles	Cost delta per product for first cycle €/product	Number of units affected in the EU per year in million	Expected impact on production cost in million €/year	Total impact compared to total value of products at the EU level
Agriculture	25 kg bags of animal feed compound for use in agriculture or equivalent	1.0	0.20	882	**181**	**1.2%**
Cement	Cement in bags <= 50 kg	1.0	0.14	655	**95**	**2.1%**
Construction	Rockwool and glass wool insulation rolls produced and consumed in the EU, delivered at retailer or to consumer	1.0	0.30	267	**79**	**0.5%**
Milk	HDPE bottles of milk, 1 L or equivalent, for household consumption	1.5	0.01	15 625	**297**	**2.2%**
Glass	Glass container aimed at containing food or beverage (after filling)[21]	2.5	0.03	61 300	**3 063**	**1.7%**
	Glass container aimed at containing food or beverage, delivered to filler (empty)	1.0			**1 756**	**15.9%**
Plastic	25 kg FFS (Form Fill Seal) plastic pellets, delivered to convertor	1.0	0.20	815	**167**	**0.3%**
Retail	Handkerchiefs and cleansing or facial tissues of paper pulp, paper, cellulose wadding or webs of cellulose fibres	1.5	0.02	3 562	**109**	**8.3%**
Water	Bottled water in PET bottles < 3L produced and sold in the EU.	1.5	0.01	44 400	**947**	**2.7%**
Total across studied sectors (counting filled bottles only)				**127 506**	**4 937**	**-**

[21] For the glass sector, 1 cycle with the glass cost delta and 1.5 with the water cost delta are considered. This is to approximate the differential impact on palletisation for an empty and a filled glass product. The total results excludes empty glass bottles (they cannot be summed up to the results of filled glass bottles because the second includes the first).

If the reusable solution were to be used, the total cost impact varies between 0.3% and 15.9% of the total value of products sold in the EU in a year, across all of these representative product sectors in the EU.

It is important to note that this table shows the impact if all pallets switch to reusable options. If only a subset switch to reusable options, the total cost would be lower. That being said, the co-existence of single use and alternative solutions also implies compatibility related costs as well as increase logistical coordination costs.

Finally, this analysis could also be extended by considering substitution effects (from using pallets to selling more bulk for instance), which is more or less feasible depending on the product, client and sector.

5.3 Short to medium term impact: transition costs and challenges

The modelling above looks at the long-term equilibrium solution, notably making assumptions about the existence of an automated efficient solution to place alternative packaging solutions on pallets. This does not directly consider the short-term impact of a regulation-induced shift, which is discussed qualitatively here.

The main sources of negative economic impact on the industry considered below are:

- **R&D costs** to invent and scale up new packaging solutions, along with their associated automation processes and logistic schemes;
- **Expected demand variation** for boxes may result in building new production lines and closing them shortly later ;
- **Sunk costs of premature replacement of non-amortised capital** (machines);
- **Investment costs of purchasing new machinery**
- **Reduced scale economies.**

5.3.1 R&D cost to invent and scale up new packaging solutions

The interviews conducted for this study noted a lack of industrialised pallet packaging solutions complying with the PPWR, at least for the products analysed. Their development represents a R&D cost ultimately borne by the industries.

Intense R&D activity will be necessary for:

- **The packaging solution itself**: this means the reusable hood and straps solution, the stackable crates option. Currently, the solutions on the market are aimed at closed loop and manual applications or are in testing phases.
- **Machinery:** Automation requires machines that can handle these new packaging solutions:
  - At the producer's facility, i.e. the end of line process to put on the packaging.
  - At the receiver's facility, i.e. the depalletisation phase to remove the packaging.
- **Other impacts:** other aspects of the production process are also affected by the new packaging solution, namely:
  - **Modifying the size and/or set-up of the production line** to integrate the new alternative packaging format.

- **Adapting the supply chain** to compensate for the potential loss of functionality of the alternative packaging. For example, if the alternative packaging does not allow some functionalities that are currently covered by single use packaging (e.g. climate control inside the pallet to avoid condensation or contamination).

The key identified challenging functions to replicate for alternative reusable functions are the following:

- Robustness and resistance over time and reuses;
- Adaptability to different product formats;
- Protection of the product and loss minimisation;
- Minimised volume when folded (i.e., does not take much space to transport or store while empty);
- Manoeuvrability by the palletisation and depalletisation machines.

As of early 2025, no automated large-scale reusable pallet wrapping system are identified as having reached commercial maturity for the studied products. Achieving widespread deployment by 2030 – the regulatory deadline – may prove challenging given the technical developments still required.

5.3.2 Expected demand variation for reusable packaging may result in building new production lines and close them shortly later

The application of the PPWR is likely to create a significant increase in demand for crates, boxes and other reusable packaging items to be used as a reusable substitute to single use packaging.

This demand shock is all the more significant that the full reusable packaging stocks are to be built in a few years, before the demand decreases to reach a level high enough to replace old stocks and feed normal growth.

Given the limited production capacity, the plastic convertors could have to open new lines and facilities to meet this variation in demand and shut them down a few years later[22].

There may also be challenges in producing and installing sufficient machinery to meet the demand for automated palletisation solutions.

5.3.3 Sunk cost of premature replacement of not-amortised capital (machines)

There is a significant amount of variation in the age and level of amortisation of the existing palletisation and wrapping machines.

- These machines can be used from anywhere between 10-30 years, with amortisation over 10-15 in most cases.
- While some machines may be due for replacement at the same time as the machines for the alternative solution are installed, may will not be fully paid off.

[22] Analysis pointed out by EUPC, as reported in EC 2008, *Study to analyse the derogation request on the use of heavy metals in plastic crates and plastic pallets.*

- Replacing these machines before the end of their lifespan represents a sunk cost for the industry (which will vary based on how old the current machines are). The loss on the cost of the machine itself is unlikely to be compensated by the re-sale on the second-hand market.

In some cases, this change in machinery will have a broader impact on plant infrastructure and costs. If the effect of the adoption of a new packaging solution is the trigger a broader re-organisation of the plant, a significant part of the plant's capital will be subject to premature replacement. An extreme version of this is that the entire plant would need to be move due to the increased need for space, in the case of the adoption of a reusable crate system.

5.3.4 Quantification of the investment expenditures

Upfront investments are expected for industries transitioning to reusable packaging systems. This subsection provides an indication of the potential investment cost incurred by buying and installing these new machinery systems. The automation machines used today vary in cost depending on the sector and the size of the production line. The cheapest palletisation and wrapping lines can start from around 100K € but range up to above 1 million €.

The table below provides an approximation of the total cost of the current machines (over their lifetime).[23]

Table 24: Estimated costs for palletisation and wrapping machines, total cost, by sector

Sector	Palletisation machine cost in K€ (including installation)	Wrapping machine total cost in K€ (including installation)
Agriculture	[355 - 394]	[340 - 420]
Cement	[327 - 392]	[332 - 367]
Construction	[380 - 439]	[380 - 426]
Glass	[950 - 1 074]	[1 045 - 1 262]
Milk	[760 - 947]	[760 - 840]
Plastic	[712 - 813]	[712 - 787]
Retail	[391 - 472]	[206 - 240]
Water	[1 375 - 1 575]	[1 314 - 1 711]

The table below shows the estimated capital investment costs for end-of-line palletising and depalletising equipment. This expenditure would be incurred once the shift to reusable options takes place, and the machines would be amortised over their lifetime (approximately 15 years). The investment costs for the single use option are shown for comparison purposes as not all machines in use have a remaining life of 15 years. Consequently, some of the machines would also need to be replaced if the single-use solution is maintained.

[23] The tables below often contain ranges. These ranges are not minimum and maximum values. They are rather included to ensure confidentiality of the data received by RDC Environment during this study. The true used value is included in these ranges, but the min and max are set so that it is impossible to reverse engineer the actual value.

Table 25: Investment costs across products, considering a 15-year horizon[24]

Sector	Set of products covered by extrapolation	Single use solution (Shown for comparability)		Reusable solution	
		Capex for End of line - in million € (lifespan 15 years)	Capex Depalletisation- in million € (lifespan 15 years)	Capex for End of line - in million € (lifespan 15 years)	Capex Depalletisation- in million € (lifespan 15 years)
Agriculture	25 kg bags of animal feed compound for use in agriculture or equivalent	197	0	394	0
Cement	Cement in bags <= 50 kg	127	0	255	0
Construction	Rockwool and glass wool insulation rolls produced and consumed in the EU, delivered at retailer or to consumer	76	6	153	11
Milk	HDPE bottles of milk, 1 L or equivalent, for household consumption	676	34	1 352	68
Glass	Glass container aimed at containing food or beverage, after filling	944	225	2 775	571
Glass	Glass container aimed at containing food or beverage, delivered to filler	300	225	1 143	571
Plastic	25 kg FFS (Form Fill Seal) plastic pellets, delivered to convertor	275	21	550	41
Retail	Handkerchiefs and cleansing or facial tissues of paper pulp, paper, cellulose wadding or webs of cellulose fibres	74	0	149	0
Water	Bottled water in PET bottles < 3L produced and sold in the EU.	987	49	1 973	99
Total across studied sectors (counting filled bottles only)		**3 357**	**335**	**7 601**	**790**

[24] This table does not account for costs linked to restructuring facilities and R&D to get there.

5.3.5 Reduced scale economies

The shift towards the use of an alternative packaging is likely to involve a period where the infrastructure costs cannot be distributed on as many products as in business as usual.

In particular, the following sub-optimal situations are expected:

- **Competing standards for reusable options:** The new standard packaging has not emerged yet: several different standards co-exist, leading to increased storage space needs, incompatibility of machines, underused transport volume, etc. There may also be different packaging requirements depending on the region to accommodate differing climates, or differences in products.
- **Co-existence single use and reuse systems:**
  - leading to the need to duplicate depalletisation lines
  - the poolers have not yet reached their optimal market size: their cleaning and sorting facilities are underused and are too few, leading to high treatment and transport costs.

The latter scenario can also occur for industries that send pallets both within and out of the EU. They are likely to face the added complexity of operating two separate systems:

- one for reusable packaging for EU trade; and
- another for single-use options for non-EU exports.

This dual-system requirement could result in higher operational costs, increased logistical complexity, and inefficiencies.

6 Conclusions

Single use plastic packaging (current solution) fulfils a range of functionalities, including stabilisation load adaptability (flexibility) and protection against rain, UV, condensation as well as contamination.

Alternative reusable packaging solutions, sometimes together with process adaptations, need to fulfil the same features. Uncertainty exists on the nature of the alternative solution preferred by the market.

There is also still a significant amount of uncertainty about the scaling up process of the alternative pallet packaging solutions currently on the market, notably to move from a manual to an automated and optimised system in the long run. The modelled cost difference relies on a number of assumptions in the absence of directly applicable automated systems currently existing for the reusable pallet packaging options.

The alternative options identified during this study for the representative products modelled are:

- Reusable hoods;
- Reusable stackable crates / pallet boxes

Conclusion 1. The switch from single use to alternative pallet packaging options is likely to result in transition costs (R&D efforts, co-existence of standards, production line modifications) in the short to medium run.

- **R&D:** Major investments in research and development are needed to create automated and optimised alternatives for reusable systems. No automated and optimised reusable system was identified by this study as being available today for use and deployment for the studied products.
- **Production line modifications:** Existing lines must be adapted or reconfigured, requiring new machinery and process adjustments.
- **Co-existence of different packaging standards :** Manufacturers will likely need to operate both single-use and reusable systems simultaneously across facilities in the short to medium run, complicating logistics and reverse logistics. Multiple competing reusable standards are likely to co-exist in the short to medium run, involving logistical difficulties.

Conclusion 2. The switch from single use to alternative solutions is likely to result a in long run increase in production costs, depending on the representative product category, varying between 0.3-15.9% of the product price.

The key stages of the pallet wrapping supply chain that contribute to this cost delta are expected to be:

- The cost of the packaging itself, per use (including the cost of collecting, cleaning and sending back for its next use).
- The increased expected cost of machinery, labour and maintenance for end of line pallet preparation.
- If there is a reduction in the number of products per pallet and per truck, this significantly impacts transport (more trucks for the same number of products), storage and, palletisation and depalletisation processes.

Conclusion 3. The expected impact on production costs at the EU level varies between 25 and 3 063 million € per annum (total of 4 936 million across the eight sectors), depending on the representative product category.

The main drivers of this range are the number of products in scope (similar enough to the representative products modelled), and the cost delta between the current and alternative solutions.

The table below provides the estimated impact for the product sets evaluated in this study. This considers the cost impact if 100% of pallets are affected.

Table 26: Long term cost impacts at the EU level of switching to alternative wrapping solutions

Sector	Set of products covered by extrapolation	Number of units affected in the EU per year in million	Expected impact on production cost in million €/year	Total impact compared to total value of products at the EU level
Agriculture	25 kg bags of animal feed compound for use in agriculture or equivalent	882	**181**	**1.2%**
Cement	Cement in bags <= 50 kg	655	**95**	**2.1%**
Construction	Rockwool and glass wool insulation rolls produced and consumed in the EU, delivered at retailer or to consumer	267	**79**	**0.5%**
Milk	HDPE bottles of milk, 1 L or equivalent, for household consumption (filled)	15 625	**297**	**2.2%**
Glass	Glass container aimed at containing food or beverage (after filling), filled	61 300	**3 063**	**1.7%**
Glass	Glass container aimed at containing food or beverage (before filling), empty	61 300	**1 756**	**15.9%**
Plastic	25 kg FFS (Form Fill Seal) plastic pellets, delivered to convertor	815	**167**	**0.3%**
Retail	Handkerchiefs and cleansing or facial tissues of paper pulp, paper, cellulose wadding or webs of cellulose fibres	3 562	**109**	**8.3%**
Water	Bottled water in PET bottles < 3L produced and sold in the EU, filled.	44 400	**947**	**2.7%**
127 506			**4 936**	

7 Annex A: Cost data

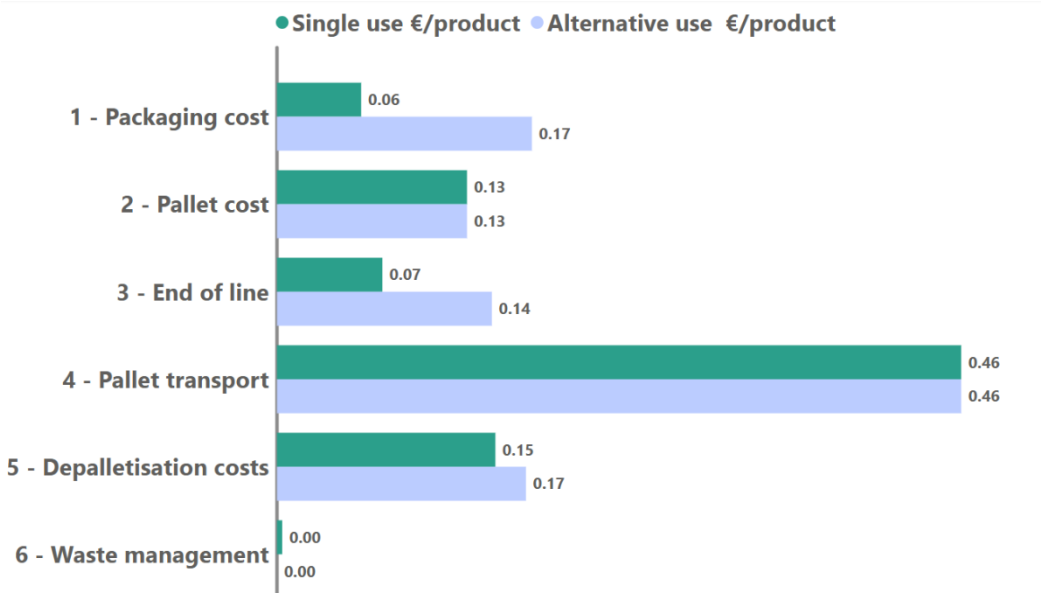
Available upon request

8 Annex A – Detailed results: €/product by sector and stage – first cycle only

This annex presents detailed results by stage, in €/product, of the cost delta between the single use and alternative packaging solutions. This provides a sector-by-sector view of the analysis presented in Section 5.1. This only considers the first palletisation cycle.[25]

Note: "1 – Packaging cost" refers to the same stage as above, i.e. "1 – Per use packaging cost (incl. return logistics)". It is presented with a different label here purely for readability.

Figure 11: Total costs per product for the single use option, the alternative option, by stage, for the Agriculture sector (product: 25kg animal feed bags)



[25] See description in Section 4.5.3.

Figure 12: Total costs per product for the single use option, the alternative option, by stage, for the Cement sector (product: 25kg cement bags)

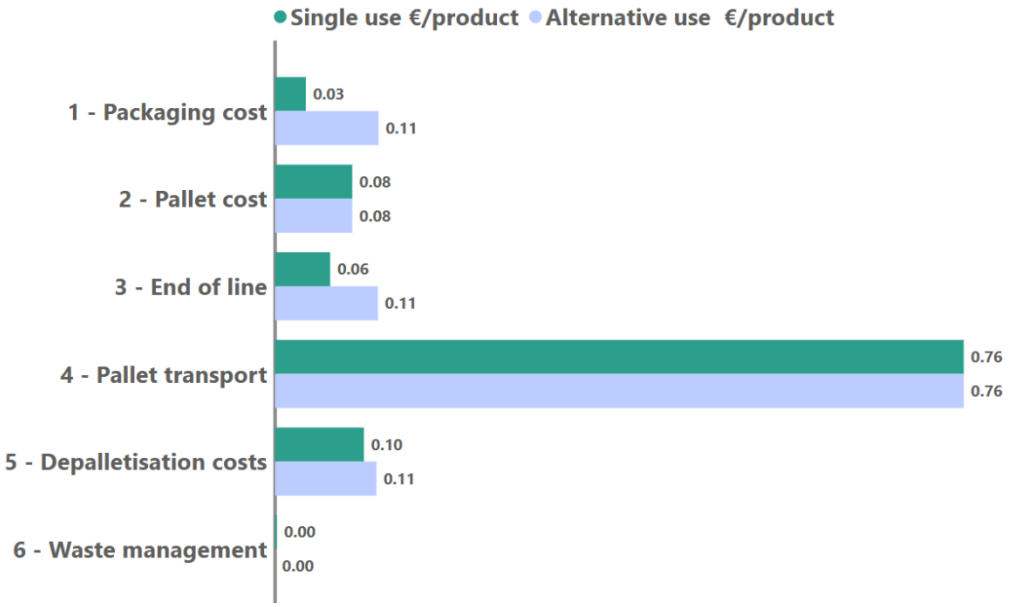


Figure 13: Total costs per product for the single use option, the alternative option, by stage, for the Construction sector (product: Insulation rolls – 12 to 15 kg)

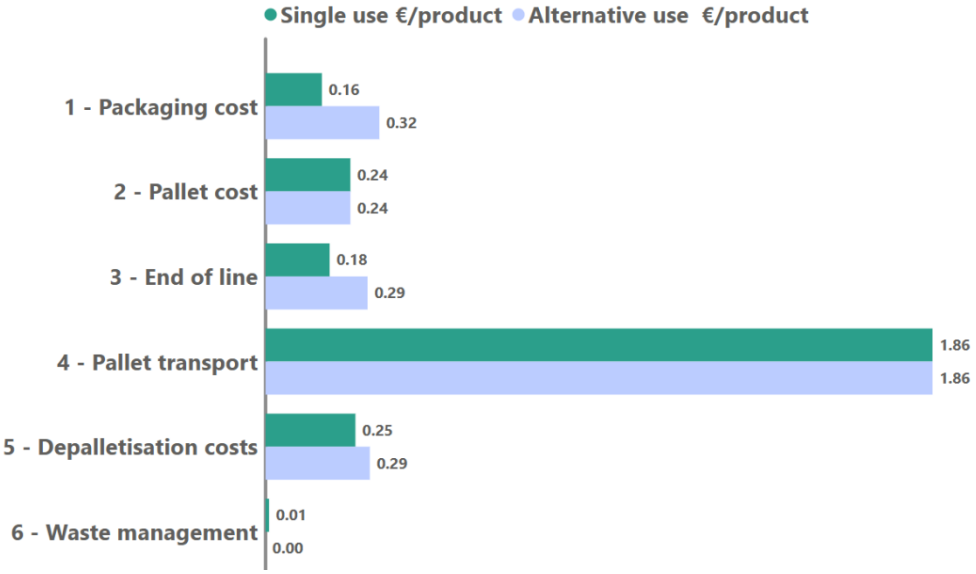
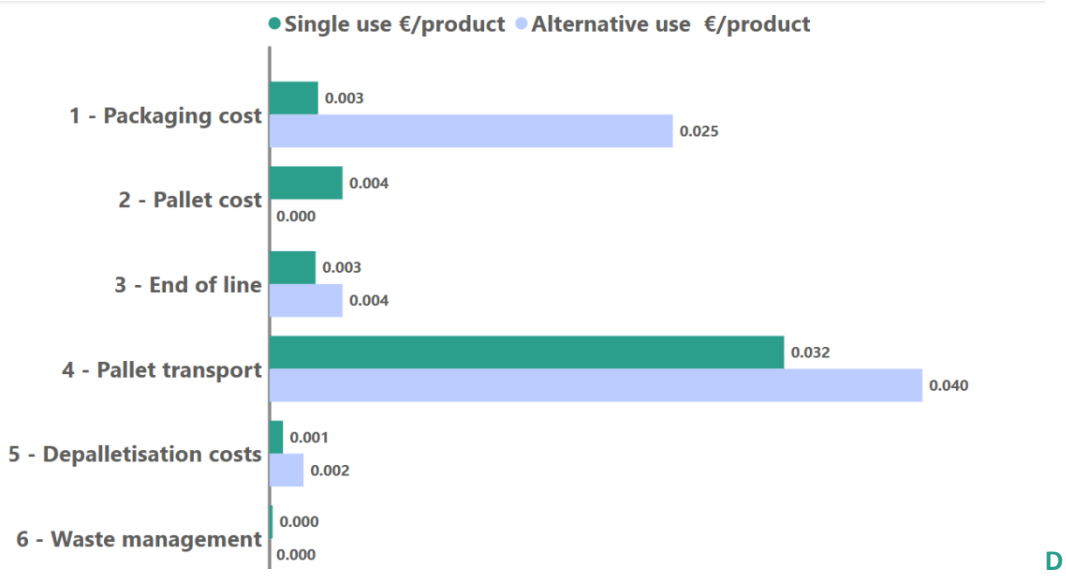


Figure 14: Total costs per product for the single use option, the alternative option, by stage, for the glass sector (product: 1L empty glass bottle)



D

Figure 15: Total costs per product for the single use option, the alternative option, by stage, for the Milk sector (product: 1L HDPE bottle)

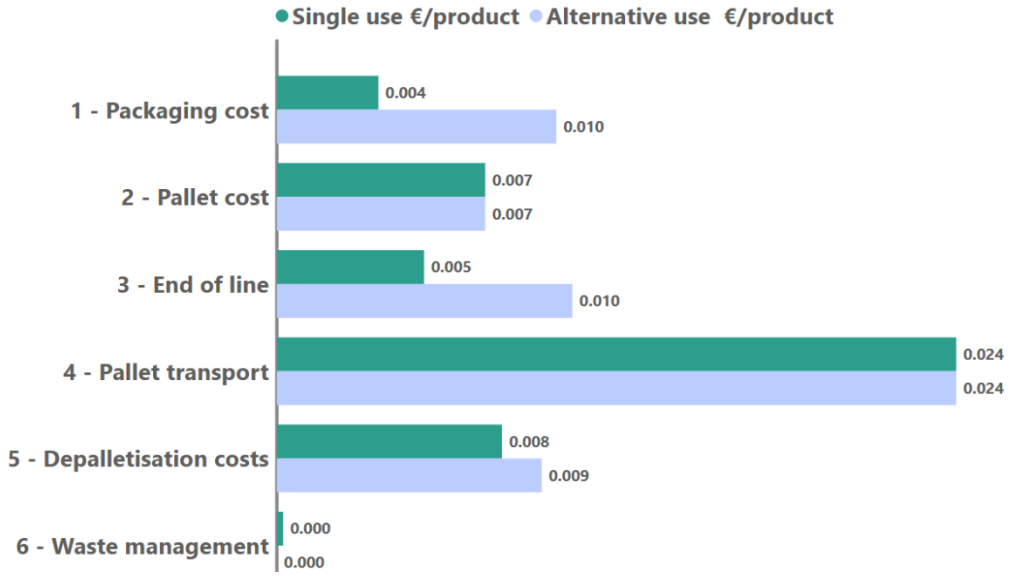


Figure 16: Total costs per product for the single use option, the alternative option, by stage, for the Plastic sector (product: 25kg plastic pellet bags)

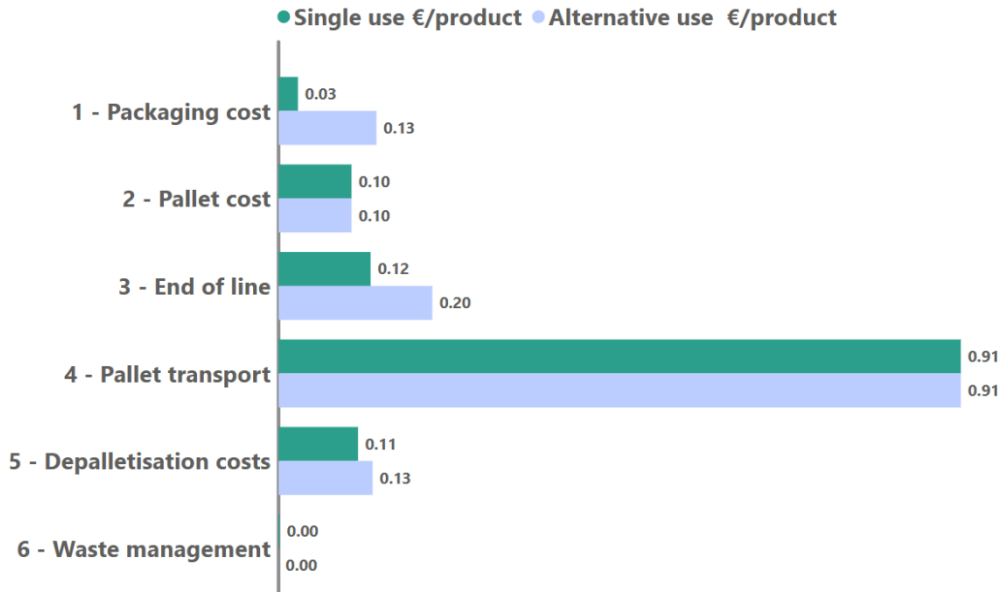


Figure 17: Total costs per product for the single use option, the alternative option, by stage, for the Retail sector (product: tissue boxes in cardboard boxes)

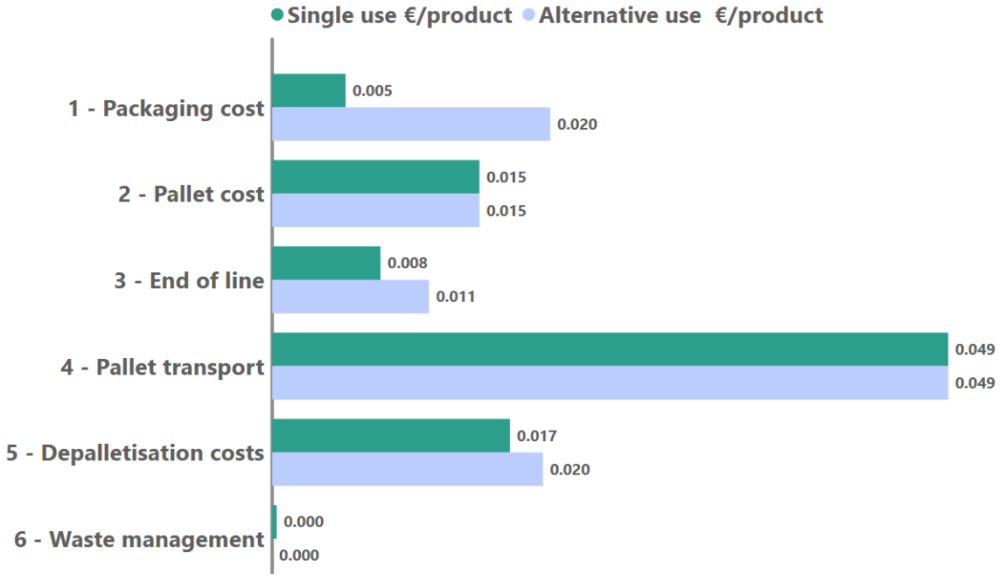


Figure 18: Total costs per product for the single use option, the alternative option, by stage, for the Water sector (product: 1.5L plastic water bottles)

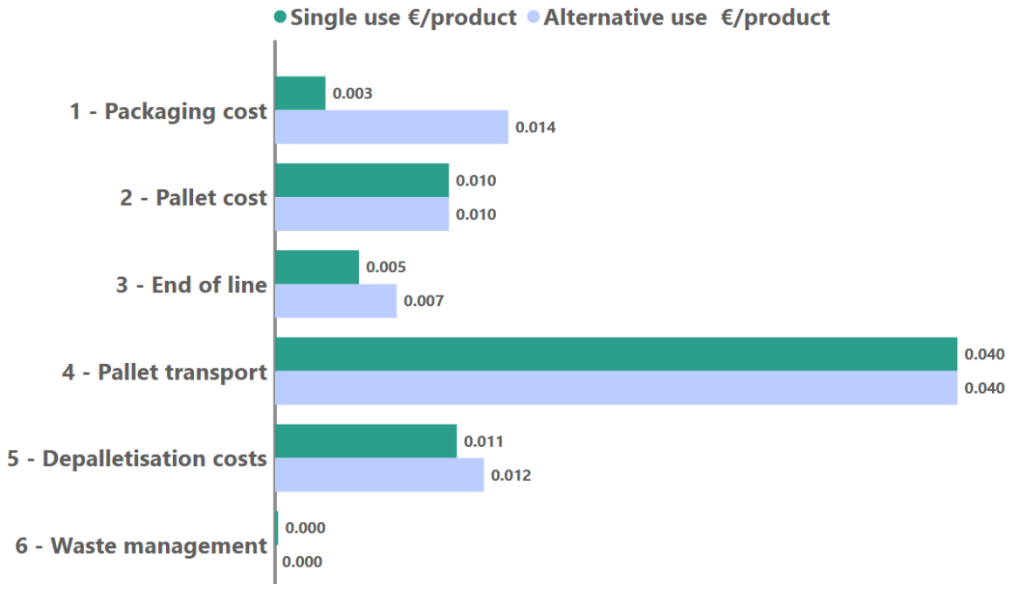


Table of tables

Table of figures

RDC environment

Research Development & Consulting Environment

EXPERTS AND SOLUTIONS IN SUSTAINABLE DEVELOPMENT
rdcenvironment.be - contact@rdcenvironment.be

Address

Av. Gustave Demey, 57

1160 Brussels, Belgium

Contact

+32 2 420 28 23

contact@rdcenvironment.be

Website

www.rdcenvironment.be