



Fraunhofer-Institut für Materialfluss
und Logistik IML

Presentation of results from 21.05.2026

Comparative analysis of the costs of single-use and reusable transport packaging for fruit and vegetable logistics based on the TCO method



The objective of the project is to conduct a comprehensive analysis of the economic viability of single-use transport packaging **compared** with reusable transport packaging, taking into account various practical application scenarios. The focus of the considerations is in particular on the **logistical processes** and their costs associated with the use of the respective packaging systems. Specifically, the study to be carried out is intended to provide information about the **costs of one circulation**.

Approach

Study Concept

Description and analysis of the observation framework

- (1) Identification and selection of **representative use cases**
- (2) Definition of **packaging alternatives** per product (single-use & reusable)
- (3) Description of the **scenarios and system boundaries** considered: system components, interfaces and processes

Preparation and implementation of the cost comparison

- (4) Development of the **calculation model**
 - Relevant types of costs
 - Reference unit: one cycle
- (5) **Data collection**: Determine relevant costs and process times
- (6) Model calculation: Determine of the **costs for one cycle** of a single-use and reusable scenario

Evaluation and interpretation of the results

- (7) **Evaluation of the results**
 - Comparison of single-use / reusable solutions
 - Breakdown of costs
- (8) **Interpretation** of the results
- (9) Determination of the **need for further investigation requirements**

Use Cases

Selection and exclusion criteria



- Market share
- Product characteristics (e.g. pressure-sensitive)
- Packaging formats & sizes
- Mapping of European cost structure
- Data availability



- Niche products/ low volumes
- Global supply chains and direct sales (e.g. farm shops)
- Packaging with special formats
- Special cases where single use or reusable packaging is excluded

➔ In their entirety, the use cases are representative of the packaging practice in fruit and vegetable logistics.

Use Cases

Types of fruit and vegetables and countries of origin



- With a per-capita consumption of approx. 21 kg in 2024/25, apples are the most widely consumed fruit in Germany by volume
- High degree of self-sufficiency (around 55% in 24/25)



- A key representative of the citrus fruits category, which had a per-capita consumption of around 26.5 kg in 2024/25
- Approx. 29% of Spanish orange exports went to Germany in 2024



- Ranked 4th in terms of per-capita consumption (approx. 5 kg)
- Germany is the most important export market for Italian table grapes (approx. 31% in 2024)



- Poland is the world's largest exporter of fresh/chilled mushrooms
- In 2024, approx. 28% of the export volume went to Germany



- Highest per-capita consumption 2024/25 in Germany (approx. 23 kg)
- In 2024, approx. 38% of Dutch export volume went to Germany



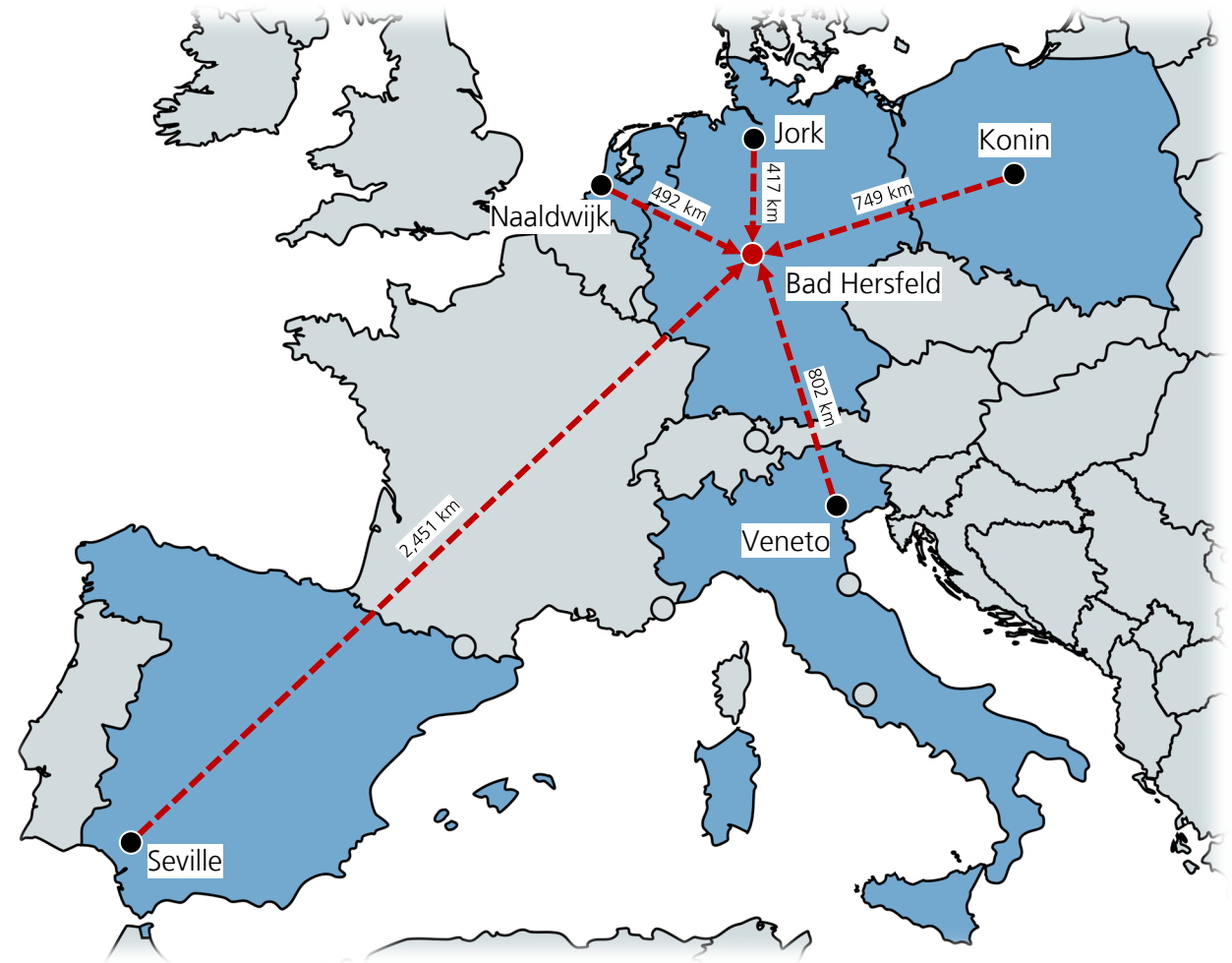
Taking into account country-specific cost and distribution structures

Sources: BMEL Supply Balance, World Integrated Trade Solution (WITS), FEPEX

Use Cases

Transport distances

- Derivation of transport distances by defining a specific production region for each use case
 - Apples → Jork (DE)
 - Oranges → Seville (ESP)
 - Grapes → Veneto (IT)
 - Mushrooms → Konin (PL)
 - Tomatoes → Naaldwijk (NL)
- Destination area: Bad Hersfeld as the geographical centre of Germany
- Representative European distance range from approx. 400 km to approx. 2,450 km
- Coverage of regional and European transport routes



Use Cases

Selection of crates

Selection of reusable crates

- One reference crate from each of three established pooling service providers
- This ensures that differences in the following aspects are considered:
 - Nestability when stacking
 - Volume reduction
 - Available height increments
- Separate cost calculation in the model
- Presentation of average costs of the reusable system in the results

Selection of single-use crates

- One reference crate for each use case
- Assumption: Flexible height gradation per product
- Assumption: Material is corrugated cardboard

Use Case	Fill weight [kg]	Basic dimension [mm]	Height of reusable crates [mm]	Height of single-use trays [mm]
Apples from DE	12	600x400	211-216	210
Oranges from ESP	15	600x400	176-185	174
Grapes from IT	5	600x400	117-123	115
Mushrooms from PL	3	400x300	101-152	100
Tomatoes from NL	5	600x400	152-153	150

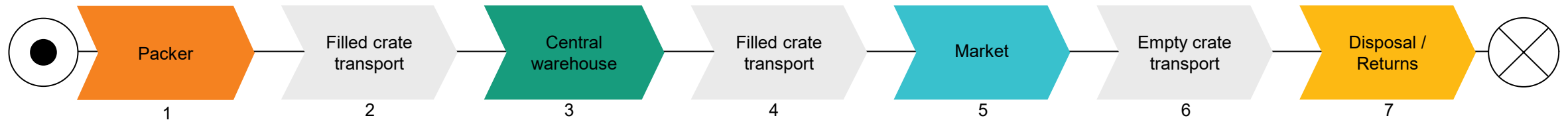


Practical relevant dimensions were chosen for the fruit and vegetable types.

Use Cases

Process chain

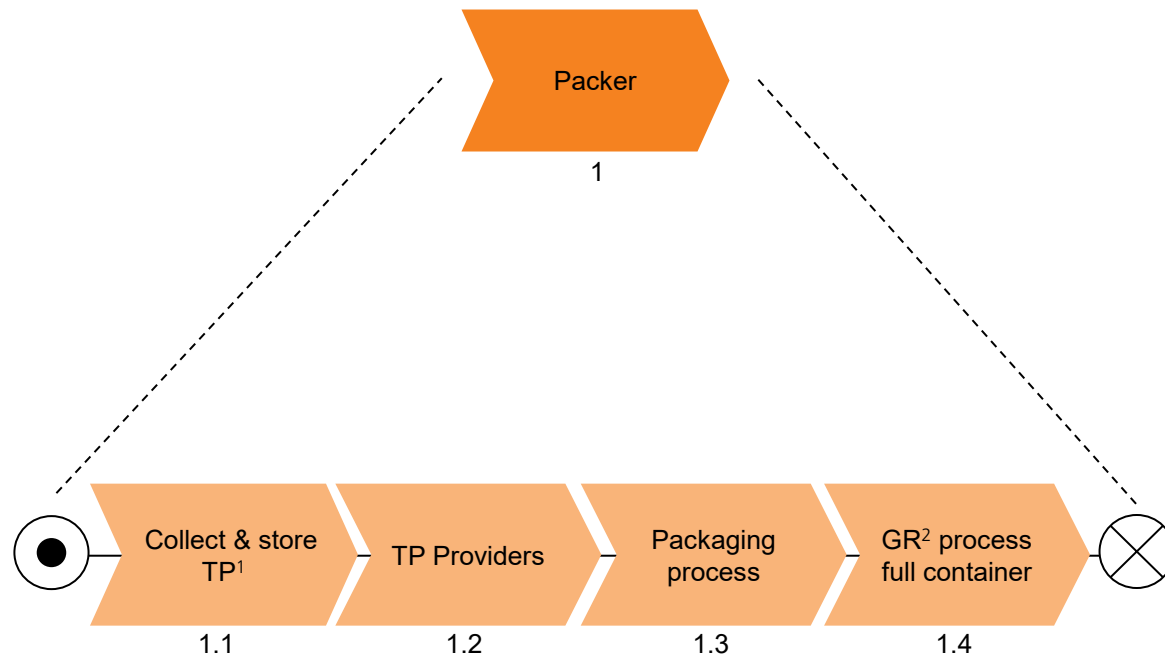
- The process chain describes the selected use cases and makes them comparable with each other
- The focus is on logistics processes
- The overarching processes 1, 3, 5 and 7 are broken down into subprocesses



Process chain

Subprocesses and costs considered

Example subprocess chain:



Costs included in the calculation model:

- Procurement costs/ usage fees³ for crates
- Capital tied-up costs
- Personnel costs
- Storage and space costs
- Machine and equipment costs
- Procurement costs for load unit securing materials
- Fixed and variable vehicle costs / transport costs
- Product loss costs due to packaging damage
- Disposal costs/ revenues

¹ Transport packaging, ² Goods Receipt, ³Assumption: Usage fee for reusable crates includes loss costs

Process chain

Subprocesses considered in detail



Packer

Goods receipt

- Data capture
- Put-away
- Storage

Provide packaging

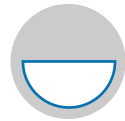
- Retrieve
- Set up/ erect
- Provide for packaging

Packaging process

- Pack
- Palletize
- Secure load unit

Goods issue

- Staging goods
- Loading finished goods



Central warehouse

Goods receipt

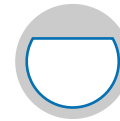
- Unloading
- Data capture
- Put-away
- Storage

Picking

- Picking goods
- Secure load unit

Goods issue

- Staging goods
- Loading finished goods



Market

Goods receipt

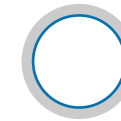
- Unloading
- Data capture
- Storage/buffering

Clearance

- Transport to the shelf
- Shelf replenishment at the POS¹

Empty packaging handling

- Folding the packaging
- Placing packaging on load carriers
- Staging empty packaging
- Loading load carriers with empties



Disposal/ Returns

Empties unloading

- Unloading empties
- Collect empties

Empties handling

- RTP²
 - + Sorting
 - + Stacking and palletizing
 - + Staging
 - + Handing over to service providers
- SuTP³
 - + Sorting
 - + Processing of fractions
 - + Handing over to waste disposal company

The transports between the individual areas were considered separately.

¹ Point of Sale, ² Reuse Transport packaging, ³ Single-use Transport packaging

Basics for calculating the comparison

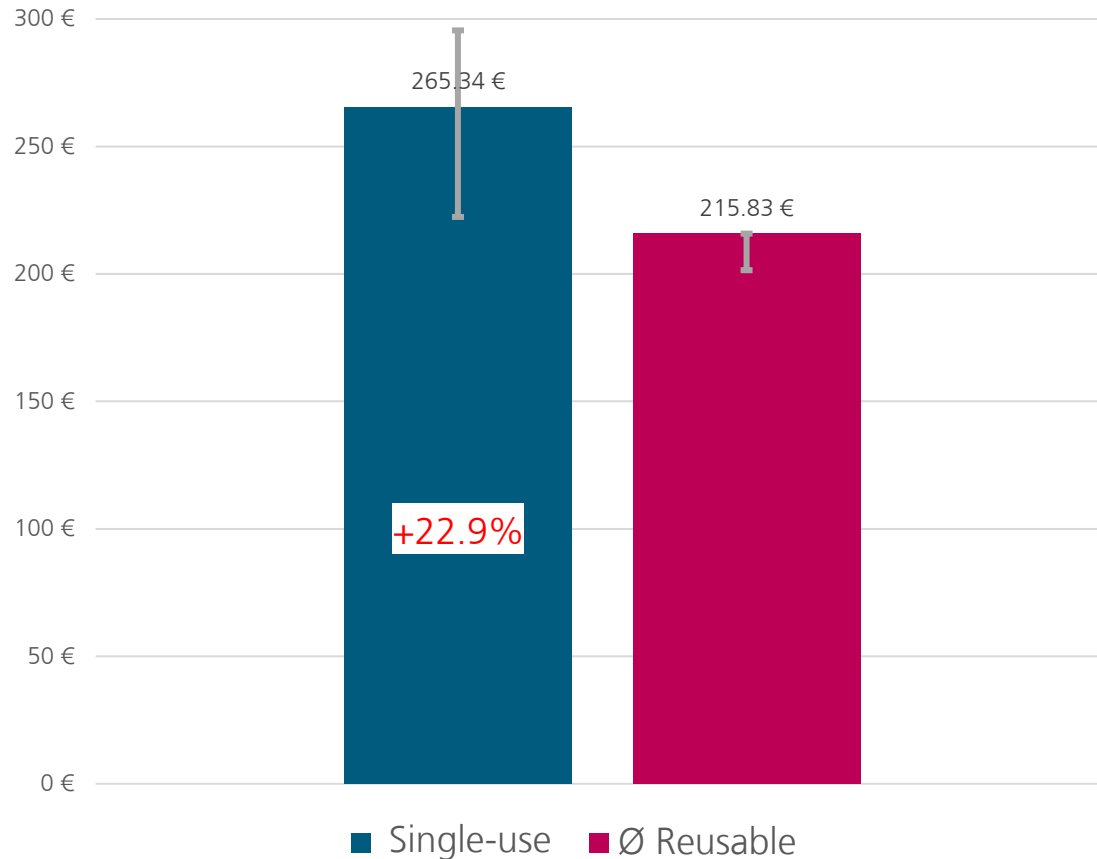
Baseline scenario and impact of influencing parameters

- The **costs for a cycle** of single-use or reusable crates were calculated according to the process chain
- A baseline scenario has been defined for the use cases
- Due to common market price fluctuations, the diversity of processes in practice, etc., it is useful to conduct a scenario analysis for selected parameters of the calculation model.
- The following influencing parameters were systematically varied:
 - Procurement costs of single-use crates, circulation costs of reusable crates
 - Loading height pallets/ roll containers
 - Number of pallets/roll containers loading positions per truck
 - Transport distance warehouse → market (full units) and market → warehouse (empties)
 - Compaction factor of single-use crates when disposed of
 - Revenues from recovered paper
- This resulted in 18 realistic scenarios

Critical influencing parameters	Bandwidths	
Procurement costs disposable	Apples Oranges Tomatoes	€0.85–1.15
	Grapes Mushrooms	€0.63-0.77
Load carriers for market supply	Roll container / pallet	
Compaction of waste paper	25-75 %	
Waste paper revenues	0-120 €/t	

Calculation results

Total costs basic scenario apples from GER (€/1,000 kg)



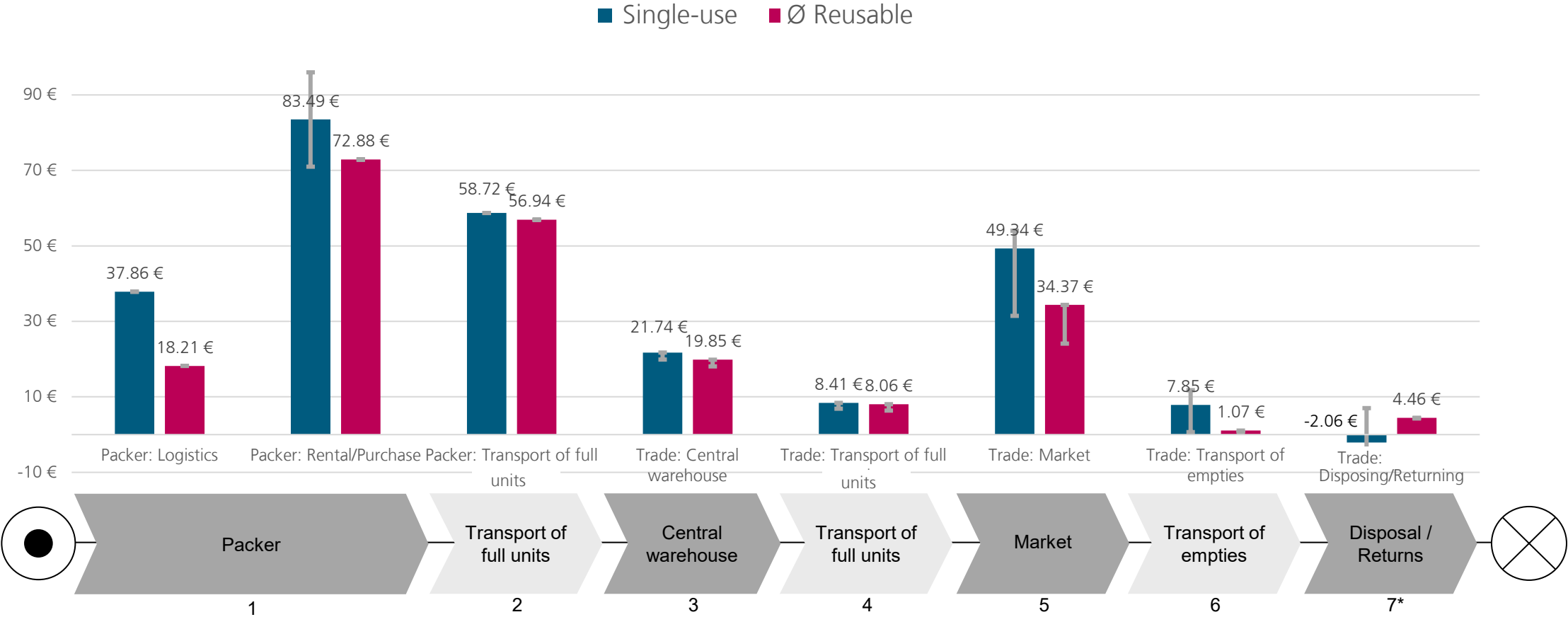
Reusable packaging is more cost-effective than single-use packaging. The advantage results from savings across the entire process chain.

In detail

- In the present use case, reusable packaging is more cost-effective than single-use in almost all process steps.
- The advantage is particularly evident in the processes
 - at the packer
 - in the market
 - for the return transport of empties or crates for disposal
- The profitability is strongly determined by
 - the costs of using or procuring the packaging
 - the transport processes from the packer to the central warehouse
 - the market-side processes
- Overall, single-use costs are 22.9% higher

Calculation results

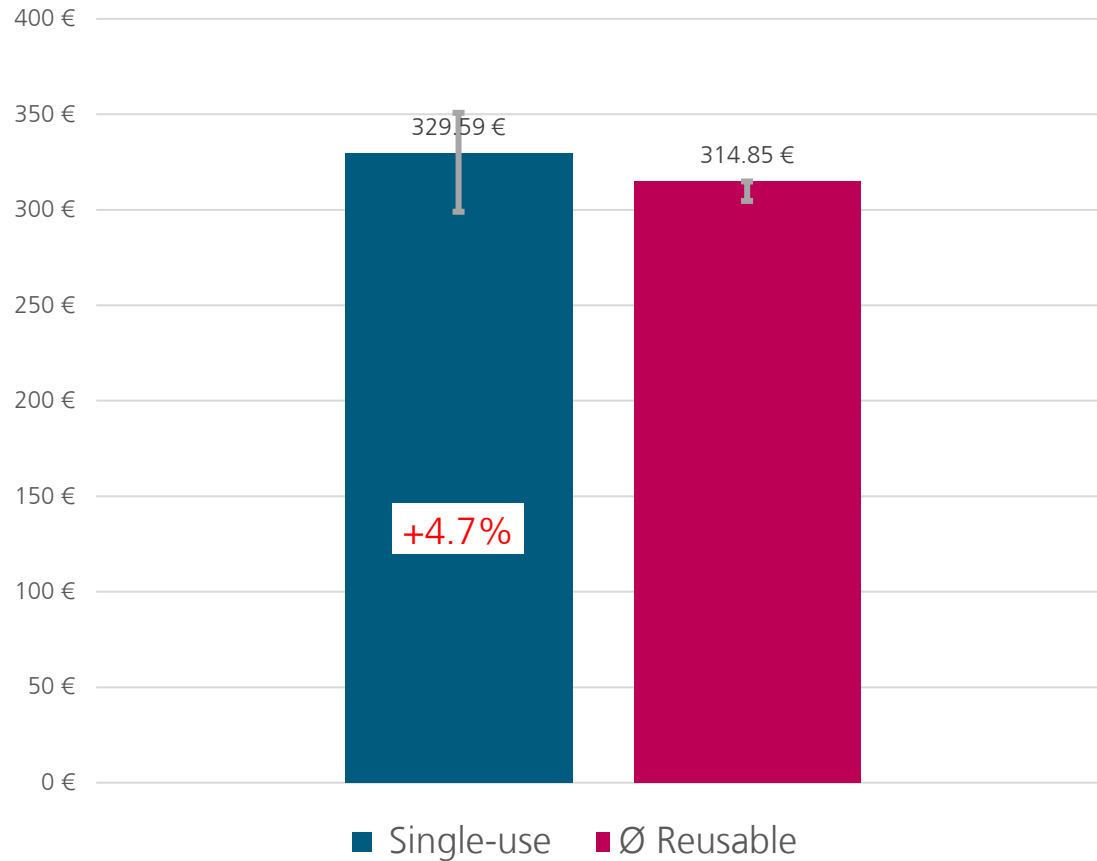
Process costs basic scenario apples from GER (€/1,000 kg)



*In the single-use system, waste paper revenues are generated during disposal

Calculation results

Total costs basic scenario oranges from ES (€/1,000 kg)



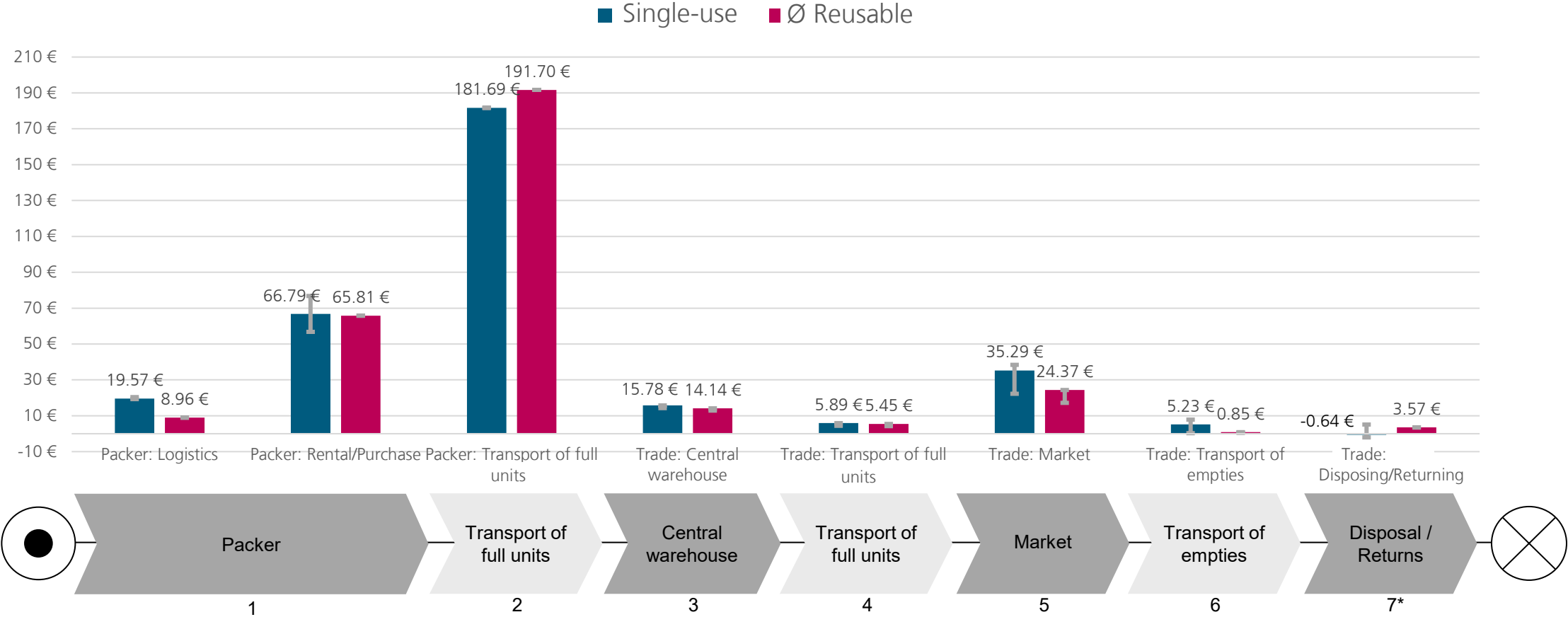
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 - at the packer
 - in the market
 - for the return transport of empties or crates for disposal
- The profitability is strongly determined by
 - the transport processes from the packer to the central warehouse
 - the costs of using or procuring the packaging
 - Overall, single-use costs are 4.7% higher

Calculation results

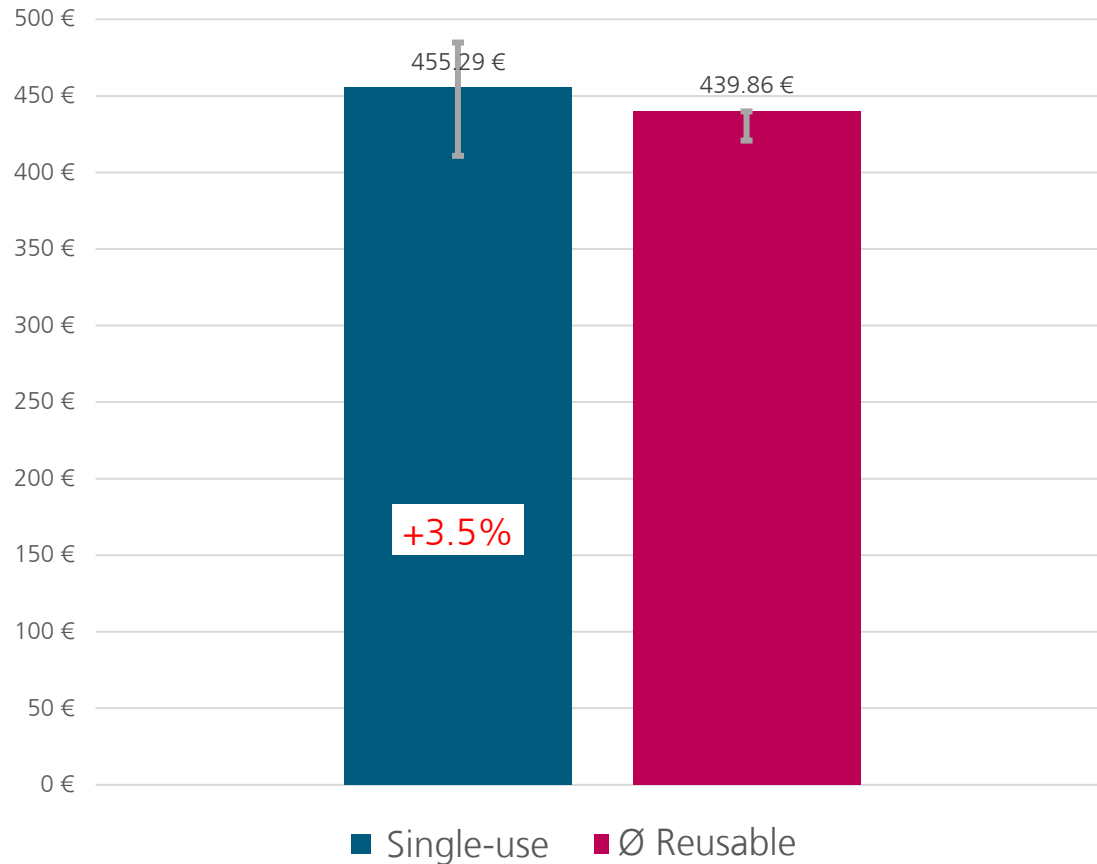
Process costs basic scenario oranges from ES (€/1,000 kg)



*In the single-use system, waste paper revenues are generated during disposal

Calculation results

Total costs basic scenario grapes from IT (€/1,000 kg)



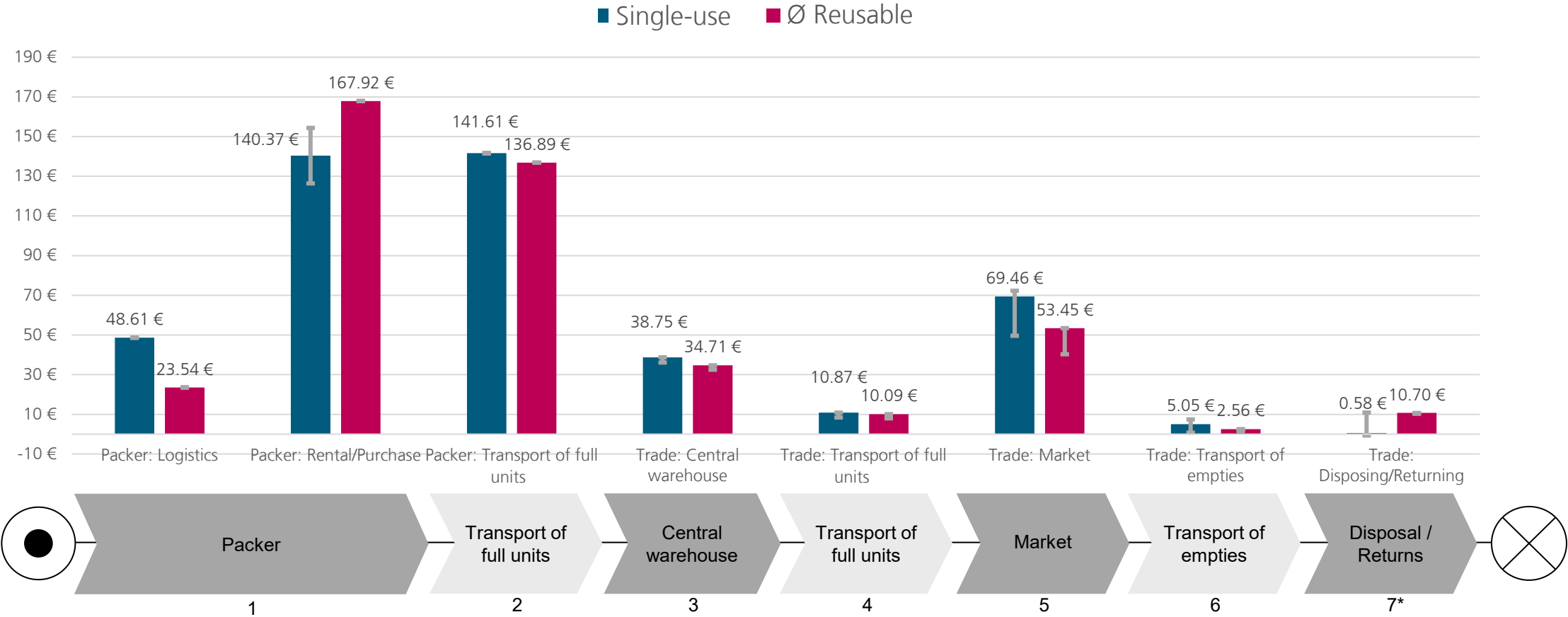
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In detail

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- The advantage is particularly evident in the processes
 - at the packer
 - in the market
- The profitability is strongly determined by
 - the transport processes from the packer to the central warehouse
 - the costs of using or procuring the packaging
- In this use case, the usage costs of the reusable crates are higher than the procurement costs for the single-use crates
- Overall, single-use costs are 3.5% higher

Calculation results

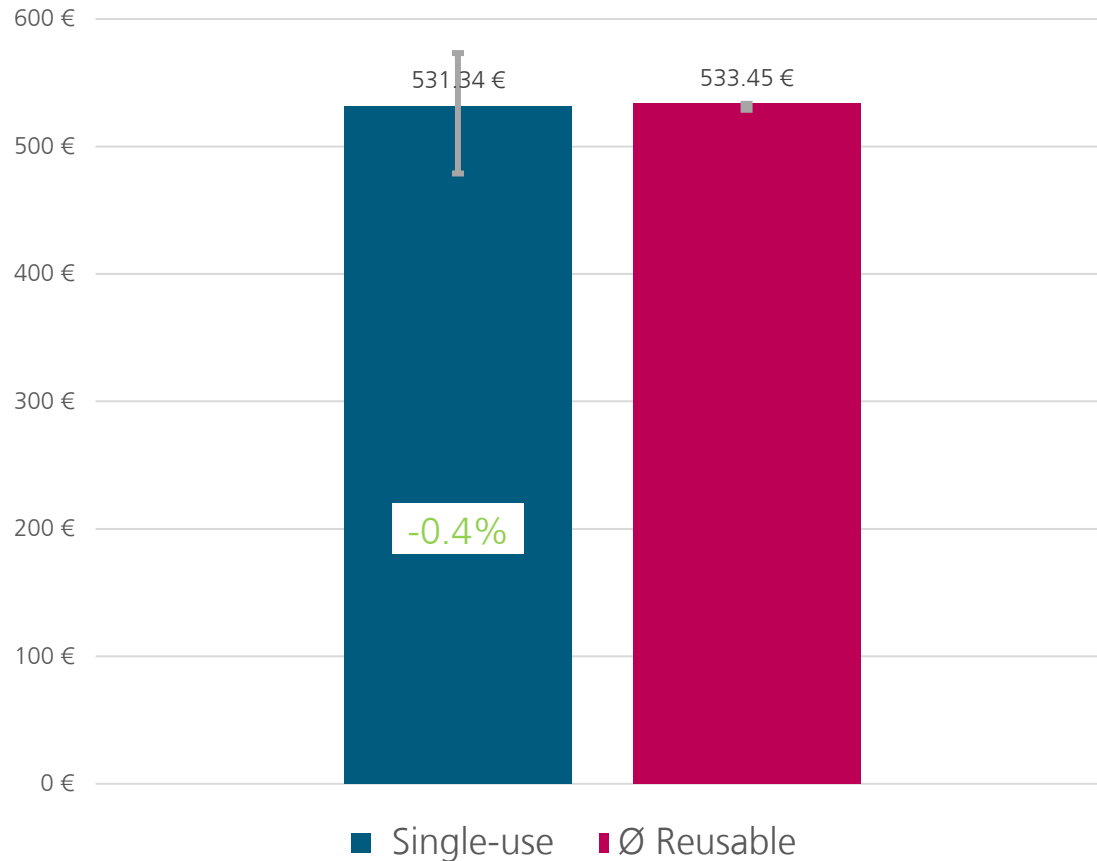
Process costs basic scenario grapes from IT (€/1,000 kg)



*In the single-use system, waste paper revenues are generated during disposal

Calculation results

Total costs basic scenario mushrooms from PL (€/1,000 kg)



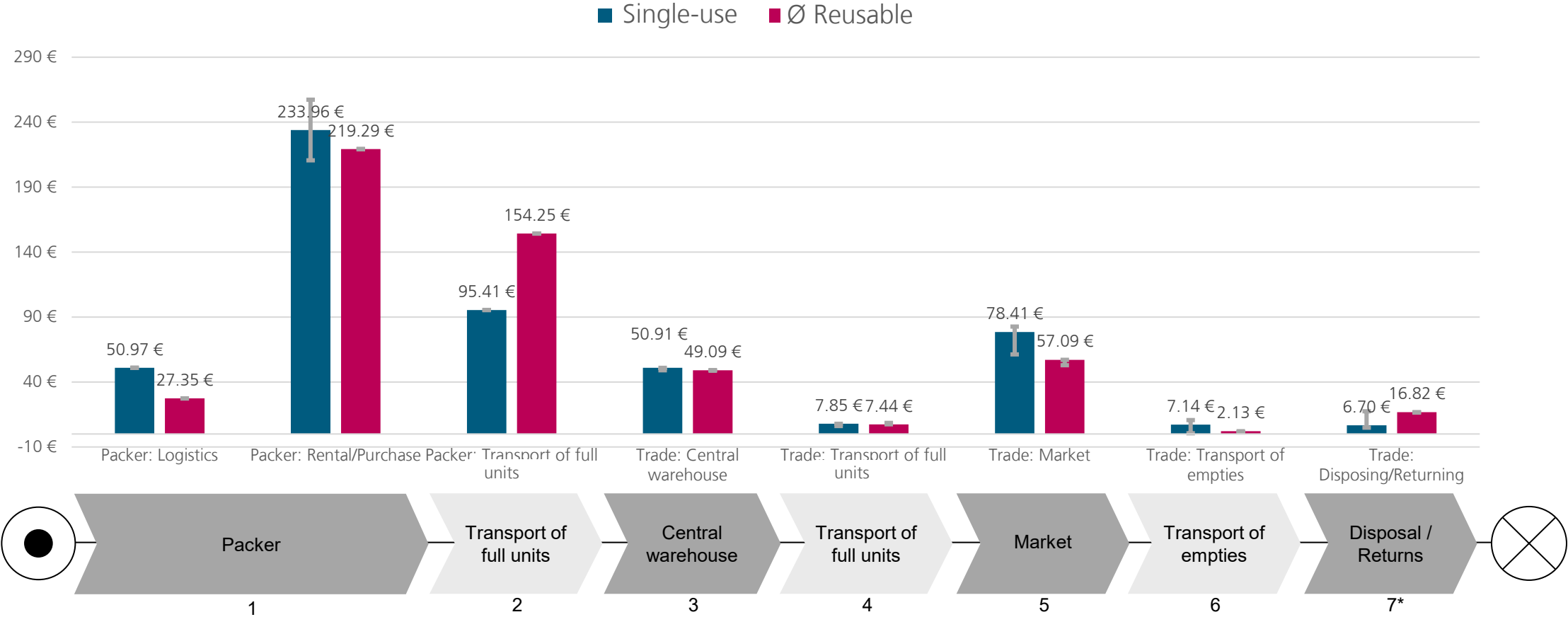
Single-use packaging is more cost-effective than reusable packaging. The advantage is primarily driven by greater savings in transport from the packer to the central warehouse.

In detail

- In the present use case, single-use and reusable are each more cost-effective in different process steps.
- The processes at the packer, the usage fee, the market processes and the transport of empties are cheaper with reusable packaging
- However, single-use packaging has the decisive advantage when it comes to transport from the packer to the central warehouse, which is due to the higher use of loading space due to a better adapted crate height
- The profitability is essentially determined by
 - the costs of using or procuring the packaging
 - the transport processes from the packer to the central warehouse
- Overall, reusable packaging causes 0.4% higher costs

Calculation results

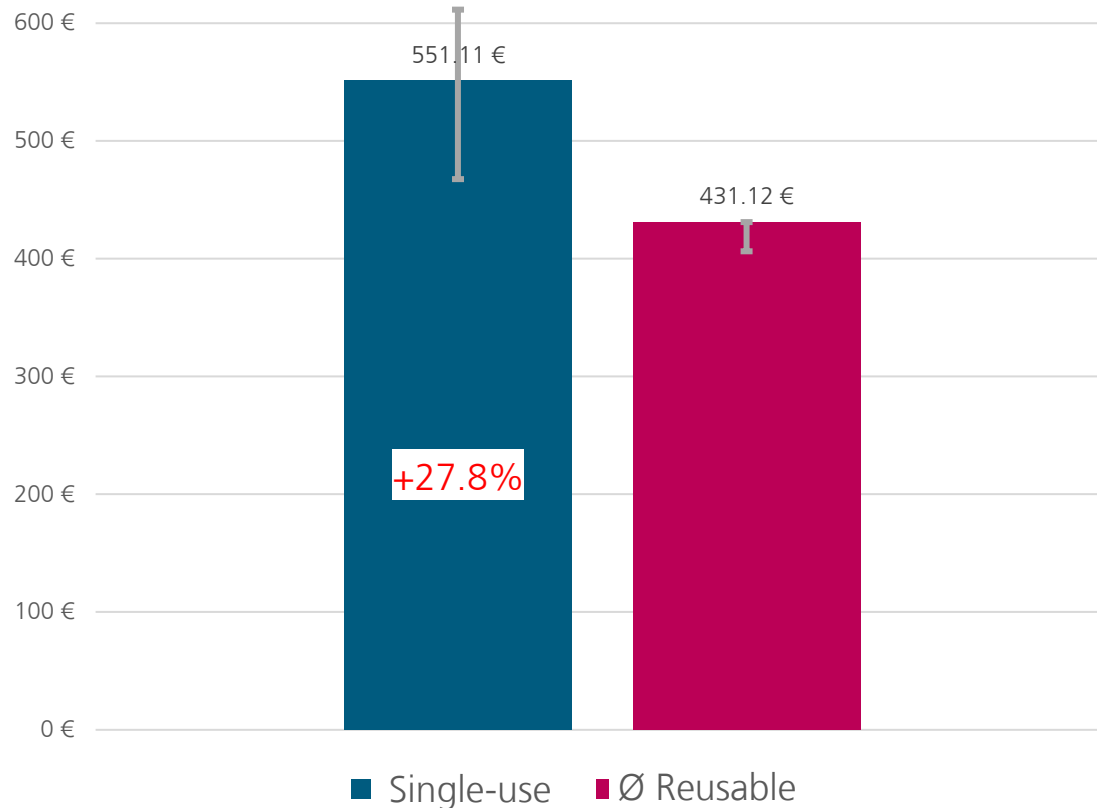
Process costs basic scenario mushrooms from PL (€/1,000 kg)



*In the single-use system, waste paper revenues are generated during disposal

Calculation results

Total costs basic scenario tomatoes from NL (€/1,000 kg)



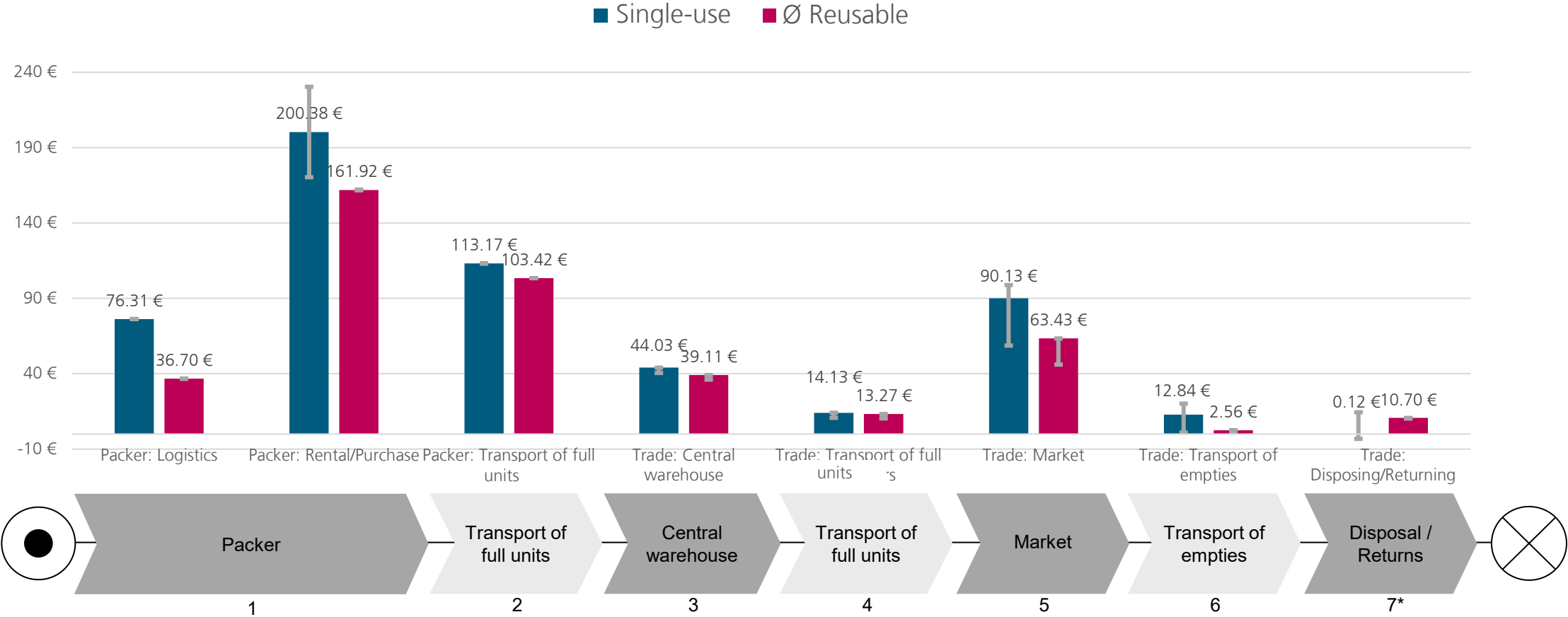
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 - at the packer
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 - for the return transport of empties or crates for disposal
- The profitability is strongly determined by
 - the costs of using or procuring the packaging
 - the transport processes from the packer to the central warehouse
 - the market-side processes
- Overall, single-use costs are 27.8% higher

Calculation results

Process costs basic scenario tomatoes from NL (€/1,000 kg)



*In the single-use system, waste paper revenues are generated during disposal

Calculation results

Conclusion

Results

- Reusable crates are more cost-effective than single-use crates **in 4 out of 5** use cases in the baseline scenario
- The **average cost savings are 11.6%** when using reusable crates
- The only exception is the "Mushrooms from PL" use case, where single-use crates incur **slightly lower costs (-0.4%) in the baseline scenario**
- In almost all use cases, **procurement costs/usage fees are the largest cost component**, followed by transport costs from the packer to the central warehouse
- Exception: **In the "Oranges from SP" use case, the transport costs clearly dominate** the costs due to the comparatively long distance
- The scenario analysis shows that the results of the use cases are largely **robust against changing framework parameters**

Limitations

- The results apply to the use cases considered, the **existing process chain** and its defined system boundaries
- Furthermore, they apply to the underlying detailed **data basis**
- The baseline scenarios reflect the **currently prevailing situation** with regard to external and internal influencing factors
- Parameters such as procurement costs, transport costs and recovered paper revenues can be **subject to significant fluctuations**. Therefore, the results should be considered in the temporal context in which this study was conducted

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