Interreg South Baltic

Co-funded by the European Union

BePacMan
BETTER PAPER PACKAGING MANAGEMENT

2026

PROJECT DELIVERABLE

2.2 Report on lifecycle and potential of the paper packaging



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Preface

The project receives funding by the Interreg South Baltic Programme 2021-2027 under the project BePacMan - Better Paper Packaging Management, STHB.02.03-IP.01-0014/23.

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List of Abbreviations

B2B	Business-to-Business
B2C	Business-to-Consumer
CEPI	Confederation of European Paper Industries
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
EPR	Extended Producer Responsibility
EU	European Union
EUR	Euro (Currency)
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FEFCO	European Federation of Corrugated Board Manufacturers
GHG	Greenhouse Gas
LCA	Lifecycle Analysis
NGO	Non-Governmental Organization
PPWR	Packaging and Packaging Waste Regulation
SBS	South Baltic Sea (Region)
SEK	Swedish Krona (Currency)
SME	Small and Medium-sized Enterprises
SPP	Association of Polish Papermakers (*Stowarzyszenie Papierników Polskich*)
WP	Work Package

Executive Summary

This report presents the findings of Deliverable 2.2 of the BePacMan project, an Interreg South Baltic Programme initiative developing a reusable paper packaging system for business-to-consumer e-commerce logistics across five partner countries: Germany, Sweden, Denmark, Lithuania, and Poland. Building on the regulatory analysis of Deliverable 2.1, this report combines three activities: mapping packaging flows across the five countries, surveying stakeholder needs and challenges among 151 participants, and assessing the lifecycle and economic potential of reusable paper packaging.

Market Context

Paper packaging represents the largest single category of European paper and board production, accounting for 62.4 per cent of the 73.9 million tonnes produced across CEPI member countries in 2023. Corrugated case materials dominate this category in every BePacMan partner country, confirming corrugated packaging as the natural priority for reuse interventions. The five partner countries occupy distinct trade positions: Germany, Sweden, and Poland form a tightly integrated producer-exporter core, while Denmark and Lithuania are structurally import-dependent markets. This existing trade infrastructure, particularly the Sweden-Germany-Poland trade triangle, provides a ready-made logistics backbone for a regional reuse system.

Stakeholder Readiness

The survey indicates consumer readiness to participate in reuse systems. Among the 126 consumers surveyed, 75% stated that they would return packaging if a convenient system existed, and 93% would accept receiving an order in a reused box. Lithuania records the highest consumer motivation in the region, with 85.2 per cent willingness to return packaging. The significant barrier identified is not consumer reluctance but a systematic perception gap: all seven e-commerce respondents believed that customers were unlikely to return packaging, contrasting with the consumer data. Producers and logistics providers cite cost and the absence of return infrastructure as their primary concerns, with 72.8 per cent and 85.7 per cent respectively identifying these as major obstacles.

Environmental Performance

The lifecycle assessment indicates that a reusable corrugated box (0.90 kg, five-trip design lifetime) reaches carbon break-even after three to five trips, depending on the vehicle used for return logistics, and saves 59.8 per cent of water consumption in every scenario. Vehicle choice is the most decisive operational variable: a heavy tractor-

semitrailer is approximately 15 times more carbon-efficient per tonne-kilometre than a delivery van, meaning vans should be reserved for routes under 90 km, medium trucks for 90-480 km, and heavy consolidated freight for all cross-border redistribution beyond that. Over a five-trip lifetime, carbon savings range from 6.0 per cent with van logistics to 56.4 per cent with heavy freight. When applied to the theoretical full apparent consumption of paper packaging in the five partner countries, the model estimates annual savings of 432,180 tonnes of CO_2e and 75,843 million litres of water, alongside a 60 per cent reduction in the total weight of paper packaging material manufactured.

Economic Potential

The 60 per cent reduction in packaging material manufactured translates directly into a proportional reduction in procurement expenditure and Extended Producer Responsibility compliance fees. A company spending EUR 500,000 per year on single-use packaging could expect to reduce this to approximately EUR 200,000 under full adoption of the reuse model. The economic case is strongest in high-EPR markets: Sweden's 2026 EPR rate of SEK 6.67 per kilogram (approximately EUR 587 per tonne) means that every tonne of packaging not placed on the market avoids a substantial compliance cost. EPR fees are expected to rise further across the region as the PPWR introduces reuse-based fee modulation from 2026.

Three trends create an opportunity for early action. First, the PPWR introduces reuse targets for certain transport-packaging formats by 2030, although cardboard transport boxes are exempt under Article 29. Second, EPR fees are increasing across the region. Third, continued e-commerce growth is increasing the volume of corrugated packaging in circulation. The BePacMan partnership, spanning all five countries and the full paper packaging value chain, is well positioned to explore and demonstrate a scalable, cross-border reusable packaging system ahead of these requirements becoming fully binding

1. Introduction

1.1 Purpose and scope

Deliverable 2.2 is the analytical output of Work Package 2 in the BePacMan project. The project is part of the Interreg South Baltic Programme and focuses on creating and testing a reusable paper packaging system for business-to-consumer, e-commerce and logistics in the South Baltic Sea Region. This deliverable combines three connected activities:

- The stakeholder needs and challenges mapping.
- The collection and analysis of packaging flow data.
- The assessment of the potential for paper packaging reuse.

These activities bring stakeholder perspectives, data, and lifecycle evaluation into one report. The report has three main purposes. It identifies and maps the key stakeholders in paper packaging across Germany, Sweden, Denmark, Lithuania, and Poland. It records their views on the barriers, needs, and opportunities for moving from single-use to reusable packaging. It also collects and analyses data on production, trade, consumption, and end-of-life management of paper packaging in each country. This data provides the baseline needed to assess reuse potential. It evaluates the environmental, logistical, and economic feasibility of reusable paper packaging in the region. This includes a lifecycle analysis of carbon and water footprints and an estimate of possible economic savings.

The scope of the report is limited to paper packaging categories defined by the Confederation of European Paper Industries. These categories include corrugated case materials, cartonboard, wrapping papers, and sack and kraft papers. The geographic scope covers the five BePacMan partner countries, with Germany used as the main case study for lifecycle analysis because it is Europe's largest paper and board producer and consumer. The timeframe focuses on the years 2022 to 2025, using the most recent data available from CEPI, FEFCO, FAOSTAT, and national industry sources.

1.2 Relationship to Deliverable 2.1 and the BePacMan framework

The BePacMan project follows a step-by-step framework where each deliverable build on the previous one. Deliverable 2.1 examined national and EU regulations for paper packaging, including market rules, recycling requirements, and the new EU Packaging and Packaging Waste Regulation (PPWR) 2025/40. Deliverable 2.2 builds on this by moving from policy to practice. It looks at the market, identifies key actors, gathers their

views, and measures the potential for reuse. These deliverables provide the evidence base for designing the pilot system in Work Package 3. Deliverable 2.2 covers three activities: stakeholder mapping and surveys (Activity 2.2), country-level packaging flow data (Activity 2.3), and lifecycle and economic assessment (Activity 2.4). These include carbon and water footprint analysis, break-even modelling, and scaling by country.

1.3 Structure of the report

The report is structured into six sections that follow the three activity areas and move logically from context to conclusions. Section 1 describes the introduction. Section 2 explains the methodology, including data collection, stakeholder engagement, and the analytical framework, as well as scope and limitations. Section 3 presents paper packaging flows in each partner country, covering production, trade, consumption, recycling, and end-of-life management, illustrated with material flow diagrams. Section 4 reports on stakeholder mapping and surveys, highlighting key groups, their needs, barriers to reuse, and readiness to join a reuse system. Section 5 integrates these findings into the reuse potential assessment, including lifecycle carbon and water footprint analysis, break-even modelling, country-level scaling, and estimates of economic savings. Section 6 presents the conclusions and recommendations.

2. Methodology

The methodology for Deliverable 2.2 utilises a multi-dimensional approach to assess the lifecycle and economic potential of paper packaging in the SBS Region (Germany, Sweden, Denmark, Lithuania, and Poland). The research design integrates quantitative material flow accounting with primary stakeholder insights and lifecycle modelling.

2.1 Report design and workstreams

The analysis is structured around three primary workstreams:

1. Material flow accounting: A quantitative mapping of paper packaging flows across six lifecycle stages: raw material inputs, production, trade (imports and exports), apparent consumption, collection for recycling, and end-of-life environmental impact.

2. Stakeholder needs mapping: A primary research strand involving 151 participants (producers, logistics providers, e-commerce, and consumers) to identify barriers and opportunities for packaging reuse.

3. Lifecycle and economic assessment: An integrated model quantifying the carbon and water break-even points for reusable packaging, using Germany as the primary benchmark case study.

2.2 Data sourcing and extraction

2.2.1 Secondary data and FAOSTAT extraction

Quantitative data were sourced from official European and national statistics (CEPI, Eurostat, DIE PAPIERINDUSTRIE e.V.). For Denmark and Lithuania, data were systematically extracted from the FAOSTAT Forestry Production and Trade database using the following parameters:

- Timeframe: 2024 reporting year.
- Metrics: Production, Import Quantity, and Export Quantity (Unit: Tonnes).
- Categories: A comprehensive set of 11 items including wood pulp (mechanical/chemical), recovered paper, and all major paper/board grades (case materials, cartonboard, wrapping, and newsprint).

2.2.2 Primary research tools

Stakeholder data were collected through four targeted, structured questionnaires administered via online forms, paper responses, and direct interviews. Data were analyzed using descriptive statistics to identify regional trends and cross-sectoral challenges.

2.3 Analytical framework

The report utilizes the industry standard formula to determine national demand:

$$Apparent\ Consumption = Production + Imports - Exports$$

Environmental impacts were modelled using a system-boundary LCA approach, focusing exclusively on the lifecycle phases that differ between single-use and reusable systems (e.g., reverse logistics and reprocessing cycles).

2.4 Scope and strategic limitations

- Geographic Focus: Five BePacMan partner countries; Germany serves as the primary LCA case study due to data completeness.
- Material Scope: Limited to paper-based packaging grades (containerboard, cartonboard, and wrappings).
- Data Variability: Reference years vary by country based on the most recent available national data at the time of writing: Germany and Poland draw on 2023 data; Denmark and Lithuania draw on 2024 data; and Sweden draws on 2025 data from the Skogsindustrierna statistical database. This variation reflects different national reporting cycles rather than an analytical choice. It should be noted that 2023 was an exceptional trough year for the European paper industry, with production down 12.8% from 2022, while 2024 saw a partial recovery of 5.9% (CEPI). The resulting uncertainty between country figures is estimated at approximately 5-6%, which is considered a minor concern that does not materially affect the conclusions of the report. Cross-country comparisons of absolute volumes particularly in Table 26 and Table 34 should therefore be read as directional rather than precisely comparable.
- Sample Constraints: Stakeholder results for producers, logistics, and e-commerce are indicative of perspectives rather than statistically representative population estimates.
- Economic Modelling: Savings are presented in proportional terms using market price indices and EPR fee schedules where per-unit proprietary costs were unavailable.

3. Paper packaging flows in the SBS region

This section defines the main paper and cardboard packaging grades and presents their market shares, clarifying the terminology used in subsequent flow mapping and trade analysis.

3.1 Overview of paper and cardboard types and market proportions

3.1.1 Definitions and classification of packaging grades

The European pulp and paper industry is represented by the Confederation of European Paper Industries (CEPI). This organization divides paper and board into different grades. Most of the paper produced belongs to packaging grades, which make up the largest share of total production. For this study, the main categories of interest are case materials, cartonboard, and wrapping papers. In this report, "paper and board" refers to all paper and paperboard types listed by CEPI. Paper packaging represents the largest category within this group, which is the main focus of the BePacMan project. Paper packaging makes up about 62.4% of all paper produced in Europe.

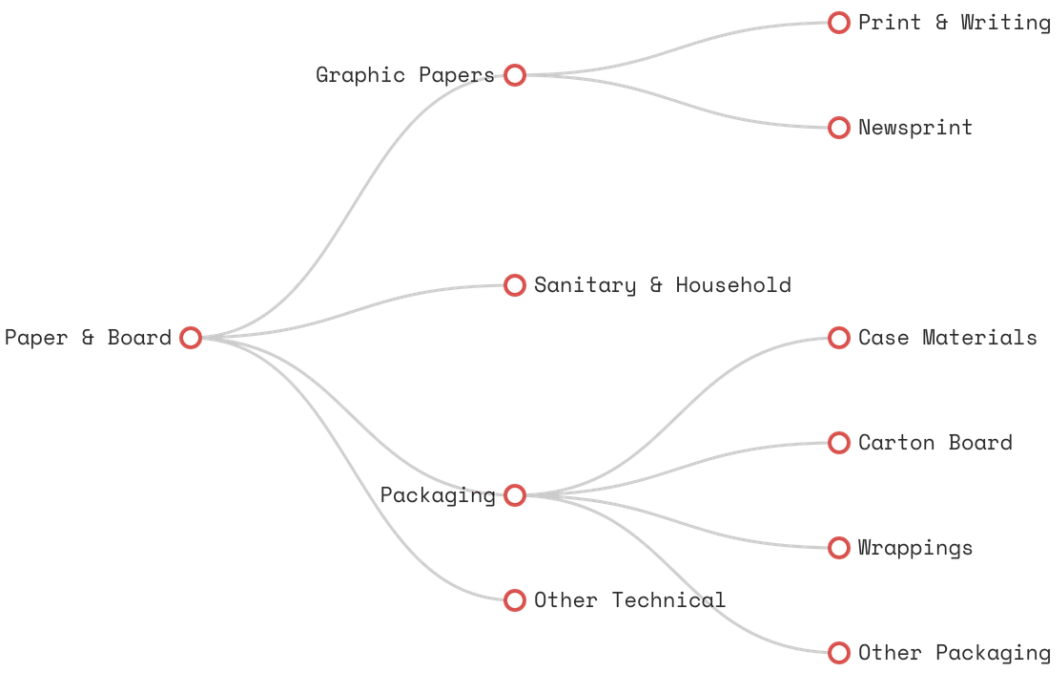


Figure 1 Type of paper and board (modified from [1])

Case materials, or containerboard, are used to produce corrugated board. They include kraftliner, which is made from virgin fibre; testliner, which is made from recycled fibre; semi-chemical fluting; and recycled fluting. They represent the largest share of packaging paper production in Europe and serve as the main packaging type for e-commerce and logistics.

Cartonboard (Folding Boxboard) includes solid bleached sulphate, solid unbleached sulphate, folding boxboard, and white-lined chipboard. It is mainly used for consumer packaging, such as food cartons and cosmetics boxes. Cartonboard plays an important role in business-to-consumer (B2C) reuse models [1]. The most common type is corrugated fiberboard, which has a fluted layer between two flat sheets and is strong yet lightweight, making it ideal for shipping. Single-face board is similar but has only one flat layer, often used inside boxes to separate items during transit. The single-wall board has paperboard on both sides of the fluting, offering moderate protection and serving as the standard for many packaging boxes. Double-wall board adds another fluted layer for extra strength and resistance to bending, while triple-wall board contains three fluted layers, making it extremely strong and suitable for heavy items like automotive parts or appliances. Less common is honeycomb cardboard, which uses multiple corrugated layers along its length and is useful for filling empty spaces in packaging. Paperboard, also called chipboard or carton, is thinner and less durable, used for lighter items or non-load-bearing applications. Grey paperboard and grey cardboard are made from recycled paper, differing in thickness, with the former used mainly for packaging and the latter in industries such as bookbinding. In terms of applications, cartonboard is widely used in food and confectionery for dry and chilled foods, chocolates, and baked goods, with barrier or wax-coated boards chosen for frozen meals, pet food, and fast-food takeaway. For liquids and beverages, liquid packaging board (LPB) laminated with foils or plastics safely holds milk, juice, soups, and water, while cupstock is used for hot and cold beverage cups. In health and personal care, cartonboard is essential for pharmaceuticals, supporting braille embossing and security tracking, and in cosmetics, brilliant white boards are preferred for a premium look.

Wrapping and other packaging papers include sack kraft, machine-glazed kraft, greaseproof paper, and liquid packaging board. Although these grades are less significant in e-commerce logistics, they play an important role in food service and industrial packaging within the European Union [1]. Wrappings

come in many different applications and are used for everything from food preparation to heavy-duty industrial shipping. Applications span from industrial wrappings with heavy-duty kraft paper and pallet-wrapping paper to waxed and grease-proof paper wrapping for various food products, for example, in bakeries and food-service applications such as sandwich wrapping.

The EN 643 standard further classifies recovered paper grades that feed back into packaging production, ensuring a standardised approach to secondary raw materials across Europe. This is particularly relevant to the BePacMan project, which aims to keep paper packaging in productive use through reuse rather than immediate recycling [2].

3.1.2 Market proportions and production volumes

In 2023, total paper and board production within CEPI member countries reached approximately 74 million tonnes, of which packaging grades accounted for 46.2 million tonnes, representing around 62% of total output. This underscores the dominant role of packaging within the broader paper industry and confirms the strategic significance of the sector for circular economy policy [3]. The production breakdown and market shares are presented in Figures 2 and 3.

Table 1 Total paper and board production and market share in 2023 [3]

Category	2023 Production ('000 Tonnes)	2023 Market Share (%)
Newsprint	2,778	3.76%
Uncoated Mechanical	2,983	4.03%
Coated Mechanical	2,718	3.68%
Uncoated Woodfree	5,581	7.55%
Coated Woodfree	2,668	3.61%
Printing and Writing Papers	13,950	18.87%
Total Graphic Papers	16,727	22.62%
Sanitary and Household	7,647	10.34%
Containerboard	30,852	41.73%
Carton Board	7,769	10.51%
Wrappings	3,628	4.91%

Other Paper and Board for Packaging	3,914	5.29%
Total Packaging Paper and Board	46,163	62.44%
Other Paper and Board	3,394	4.59%
Total Paper and Board	73,933	100.00%

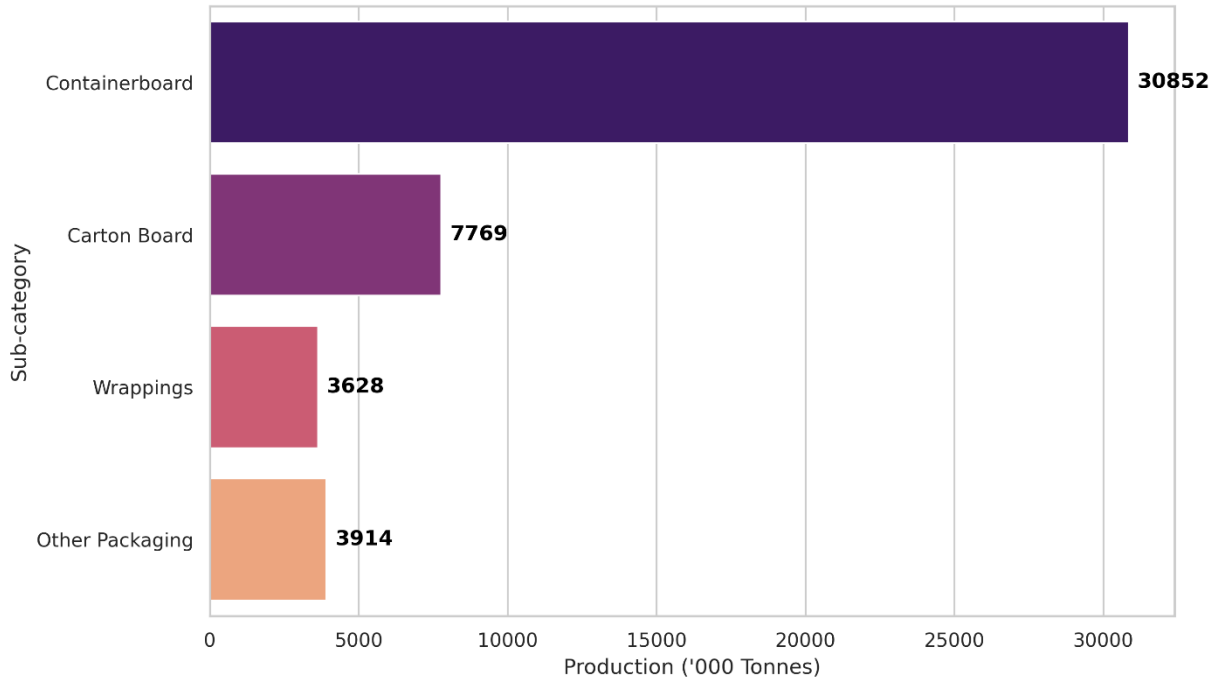


Figure 2 Paper packaging production breakdown [3]

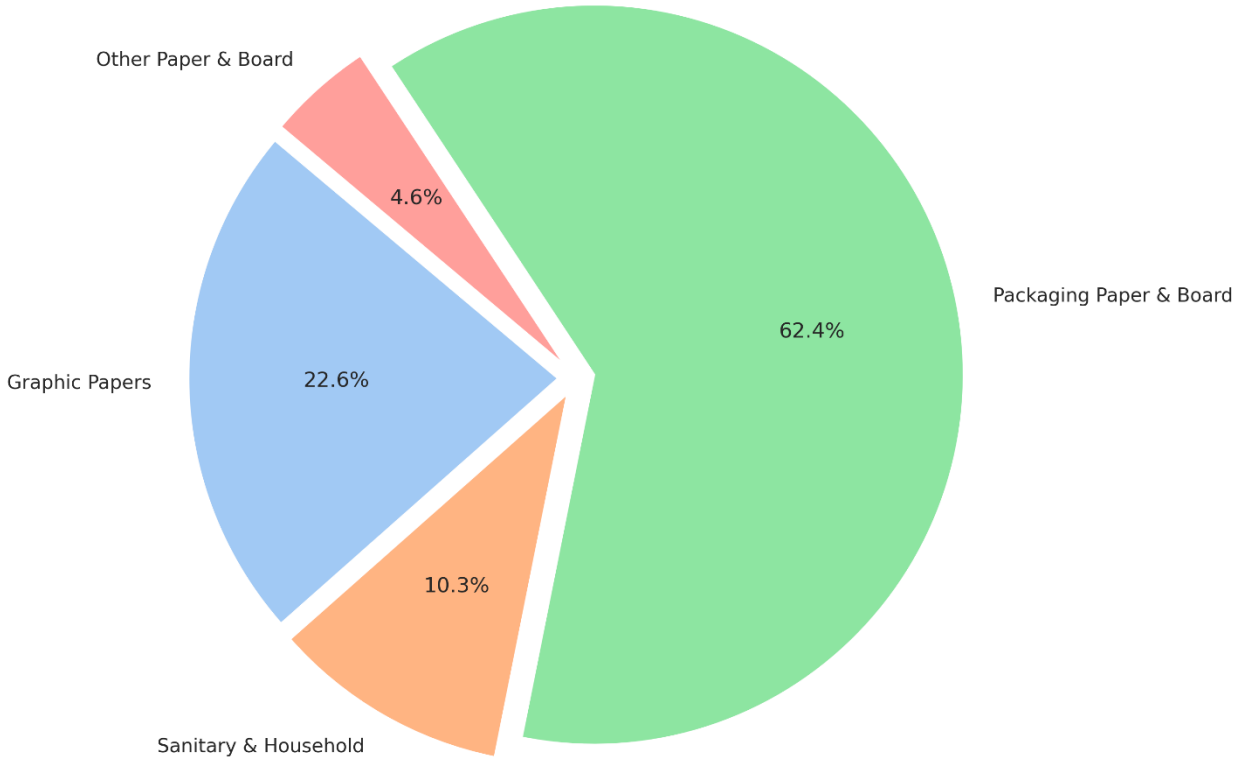


Figure 3 Market share by category [3]

Corrugated board is the most prominent packaging format in Europe. According to the European Federation of Corrugated Board Manufacturers (FEFCO), European corrugated board production stands at approximately 43.4 billion square metres per year, an area equivalent to the size of Switzerland or Denmark [4]. Furthermore, corrugated packaging is derived on average from 88% recycled content, and the material achieves a recycling rate exceeding 90% [5]. These figures highlight the strong recycling base on which the BePacMan reuse system can build.

3.1.3 The role of paper in the EU packaging waste stream

Paper and cardboard constitute the largest fraction of packaging waste generated in the European Union. In 2023, the EU generated 79.7 million tonnes of total packaging waste, with paper and cardboard accounting for 32.3 million tonnes equivalent to 40.4% of the total. This volume significantly outpaces plastic (19.8%), glass (18.8%), and wood (15.8%) [6].

The high volume of paper packaging waste underscores the critical importance of efficient

collection and recycling systems, and more importantly for BePacMan, the development of robust reuse systems within the SBS Region. Even a modest shift from single-use to reusable paper packaging formats could yield significant environmental and economic benefits at the regional level.

3.2 Packaging flow mapping by country

The level of detail in the country-level analyses varies according to the availability and format of the underlying data. Where detailed written information was available, separate subsections were provided. Where the available information was more appropriately presented visually, the relevant material flows are shown in the corresponding country-level flow chart.

3.2.1 Paper packaging flow in Germany: a lifecycle analysis

This section provides a comprehensive analysis of the paper packaging lifecycle in Germany, tracing the flow of materials from raw material input through production, trade, consumption, and collection, to final recycling or disposal. All data in this section were drawn from the PAPIER 2024 - Ein Leistungsbericht published annually by DIE PAPIERINDUSTRIE e.V. [7].

3.2.1.1 Raw material inputs

Germany's paper industry processes two categories of raw material: fibrous materials (recovered paper, chemical pulp, mechanical pulp, and other fibres) and non-fibrous materials (fillers, coatings, and starch). In 2023, the industry consumed a total of 21,846,883 tonnes of raw materials. Recovered paper was by far the dominant input at 70.9%, reflecting the industry's deep commitment to circular resource use. The utilisation rate of 83% and recycling rate of 85% achieved in 2023 are both the highest ever recorded in Germany. The utilisation rate measures the share of recycled fibre used as a raw material input in new paper production, while the recycling rate measures the share of paper consumed in Germany that is collected and sent for recycling. Both indicators reflect different stages of the material lifecycle and should not be used interchangeably. Despite these exceptional performance figures, recycling remains an energy-intensive process: each tonne of paper that enters the recycling stream requires significant thermal and mechanical energy to be reprocessed into new fibre. Reuse, by contrast, extends the functional life of paper packaging without requiring full remanufacture at each cycle, reducing the per-delivery energy burden and directly supporting the core objective of the

BePacMan project. High recycling rates and reuse systems are therefore complementary rather than competing strategies. Table 2 summarizes these figures.

Table 2 Total raw material input in Germany

Raw Material Type	Volume (tonnes, 2023)	Share (%)
Recovered paper	15,481,343	70.9%
Chemical pulp	3,262,407	14.9%
Mechanical pulp	526,929	2.4%
Other fibres	51,408	0.2%
Total fibres	**19,322,087**	**88.4%**
Non-fibrous materials (fillers, coatings, starch)	2,524,796	11.6%
TOTAL RAW MATERIALS	**21,846,883**	**100%**

Germany is a net importer of recovered paper. In 2023, it collected 12,662,000 tonnes domestically, imported 4,542,000 tonnes, and exported 1,716,000 tonnes, resulting in a net import surplus of 2,826,000 tonnes. The total consumed in paper production was 15,488,000 tonnes. In parallel, Germany consumed 8,271,052 m^3 of pulpwood (of which 4,789,290 m^3 roundwood and 3,481,762 m^3 sawmill byproducts), imported 2,529,872 tonnes of chemical pulp, and exported 728,259 tonnes. Domestic pulp production was 1,930,000 tonnes. Table 3 summarizes these figures.

Table 3 Recovered paper and virgin fibre flows in Germany

Recovered Paper Metric	Volume (tonnes)	Chemical Pulp Metric	Volume (tonnes)
Collected domestically	12,662,000	Domestic production	1,930,000
Imported	4,542,000	Imported	2,529,872

Exported	1,716,000	Exported	728,259
Net import surplus	**2,826,000**	Pulpwood consumed (m^3)	8,271,052
Consumed in production	**15,488,000**	of which: roundwood (m^3)	4,789,290
Recycling rate	**85% (record)**	of which: sawmill byproducts (m^3)	3,481,762
Utilisation rate	**83% (record)**	-	-

Note on units: pulpwood volumes in Table 3 are expressed in cubic metres (m^3) because roundwood is traded and measured by volume in the forestry industry; all other quantities in this table are expressed in tonnes.

3.2.1.2 Paper and board types production

In 2023, German paper mills produced 18,646,595 tonnes of paper, board, and paperboard, a decline of 13.7% compared to 2022 and the lowest level in 20 years. The industry operated 142 mills, employed 38,400 people (approximately 46,000 including all subsidiaries), and generated a turnover of €15,486 million down 27% from 2022. Despite the downturn, paper and board for packaging remained the dominant product category at 62.9% of total output (11,733,413 tonnes). Energy input was 2,798 kWh per tonne produced, and CO_2 emissions stood at 0.526 tonnes of CO_2 per tonne of paper produced. These figures are illustrated into Table 4.

Table 4 Paper and board production by grade in Germany

Grade	Volume (tonnes)	Share of total
Paper and Board for Packaging	**11,733,413**	**62.9%**
Graphic Papers	4,135,141	22.2%
Sanitary and Household Papers	1,378,606	7.4%
Other Paper and Board	1,399,435	7.5%
TOTAL	**18,646,595**	100%

The Other Paper and Board category (7.5% of total production) encompasses specialty grades not classified within the four main groups, including technical papers, security papers, filter papers, and other niche industrial applications that fall outside the packaging, graphic, and tissue classifications. Within the 11,733,413 tonnes of packaging production, case materials (containerboard for corrugated boxes) account for 79.7% (9,346,566 tonnes) and are the dominant packaging type used in logistics, e-commerce, and food retail. Carton board (used in food cartons, pharmaceutical boxes, and retail packaging) accounts for 15.8% (1,858,304 tonnes). Wrapping and label papers represent 4.3% (499,131 tonnes), while millboard for industrial and technical uses accounts for 0.3% (29,412 tonnes). Table 5 summarises these figures.

Table 5 Paper and board for packaging by sub-type in Germany

Packaging Sub-Type	Volume (tonnes)	Share of packaging
Case Materials / Containerboard	9,346,566	79.7%
Carton Board	1,858,304	15.8%
Wrappings & Label Paper	499,131	4.3%
Millboard	29,412	0.3%
TOTAL PACKAGING	**11,733,413**	100%

3.2.1.3 Trade flow: exports and imports

Germany is Europe's largest paper and board exporter. In 2023, it exported 12,118,000 tonnes equivalent to 65.0% of its total production while importing 8,343,000 tonnes, giving a net export balance of +3,775,000 tonnes. Paper and board for packaging dominated exports at 8,231,000 tonnes (67.9% of all exports). Table 6 summarises these figures.

Table 6 Paper and board exports by grade in Germany

Export by Grade	Volume (tonnes)	Share of exports
Paper & Board for Packaging	**8,231,000**	67.9%
Graphic Papers	3,139,000	25.9%

Sanitary and Household	131,000	1.1%
Other Paper and Board	617,000	5.1%
TOTAL EXPORTS	**12,118,000**	100%

Poland is Germany's largest export customer, receiving 2,449,543 tonnes in 2023 (20.2% of all exports), a significant cross-border flow directly relevant to BePacMan's reuse system design. The EU27 collectively received 9,233,489 tonnes (76.2%), while total exports to Europe reached 10,655,143 tonnes (87.9%). This volume of cross-border packaging flow represents a direct opportunity for the BePacMan project: a bi-national return logistics system along the Rostock-Gdańsk corridor could form the operational backbone of a regional reusable paper packaging network within the South Baltic Sea (SBS) Region.

On the import side, Sweden is Germany's largest supplier, providing 1,840,674 tonnes (22.1% of all imports). Finland contributed 1,077,705 tonnes (12.9%), Austria 976,059 tonnes (11.7%), France 768,325 tonnes (9.2%), the Netherlands 668,205 tonnes (8.0%), and Poland 553,034 tonnes (6.6%). The EU27 collectively supplied 7,330,098 tonnes (87.9% of all imports). Table 7 summarises some of these figures.

Table 7 Paper and board imports by grade in Germany

Import by Grade	Volume (tonnes)	Share of imports
Paper & Board for Packaging	**4,903,000**	58.8%
Graphic Papers	3,098,000	37.1%
Sanitary and Household	192,000	2.3%
Other Paper and Board	150,000	1.8%
TOTAL IMPORTS	**8,343,000**	100%

3.2.1.4 Domestic consumption

The apparent consumption of paper and board in Germany is calculated as production plus imports minus exports. In 2023, apparent consumption totalled 14,872,000 tonnes down 15.1% from 17,522,000 tonnes in 2022. Paper and board for packaging was the largest category at 8,405,000 tonnes (56.5%) as shown in Table 8.

Table 8 Apparent consumption by grade in Germany

Grade	Apparent consumption (t)	Share (%)
Paper and Board for Packaging	**8,405,000**	56.5%
Graphic Papers	4,094,000	27.5%
Sanitary and Household	1,440,000	9.7%
Other Paper and Board	932,000	6.3%
TOTAL	**14,872,000**	100%

3.2.1.5 Collection: paper for recycling

Germany's paper collection system achieved its highest ever recycling rate of 85% in 2023, rising sharply from 75% in 2022 and from 72% in 2000. The recycling rate is defined as the quantity of paper for recycling collected as a proportion of total apparent paper and board consumption (12,662,000 / 14,872,000 = 85.1%). In parallel, the utilisation rate is the share of recovered paper in total production of raw material input and reached its own record of 83%, up from 79% in 2022 and from 60% in 2000.

Germany consumed 15,488,000 tonnes of recovered paper in production in 2023. Since domestic collection (12,662,000 tonnes) was insufficient to meet this demand, Germany imported a net surplus of 2,826,000 tonnes of recovered paper (4,542,000 tonnes imported minus 1,716,000 tonnes exported). Within packaging, recovered-fibre utilisation varies by subtype: case materials use 108% recovered fibre, cartonboard uses 89%, and wrapping papers use 65%. The lower rate for wrapping papers reflects contamination associated with food-contact and laminated formats. Note: the 108% denominator is total packaging-grade production; imported recovered fibre supplementing domestic collection allows recycled-content share to exceed production volume for this sub-type.

Logistics: The German paper industry transported 5.6 million tonnes of paper and board products in 2023. The dominant mode was road transport at 85%, followed by rail at 10% and inland waterway at 5%. Total transport performance was 9.0 billion tonne-kilometres, generating 0.49 million tonnes of CO_2 from logistics. The dominance of road transport is directly relevant to BePacMan's focus on land-based cross-border packaging flows.

3.2.1.6 End of life: energy and environment

The energy consumption of German paper production in 2023 totalled 52,168,859 MWh (combining fossil fuels, alternative fuels, external heat, and power). Total CO_2 emissions from energy amounted to 9,802,071 tonnes. The CO_2 intensity per tonne of paper produced was 0.526 t CO_2/t a 3.7% improvement on 2022 and a 45% reduction since 1995 (from 0.977 t CO_2/t). Alternative and renewable fuels accounted for 15,941,583 MWh, an increase of 9.5% on 2022 and a 163% increase versus 2000, reflecting the industry's long-term transition away from fossil energy as shown in Table 9.

Table 9 Paper industry energy input and CO_2 emissions in 2023

Energy Category	Volume (MWh)	CO_2 (tonnes)
Fossil fuels (total)	**23,026,730**	**4,929,191**
of which: Natural gas	20,741,627	4,169,067
of which: Coal (hard + brown)	1,974,694	673,141
of which: Fuel oil	310,408	85,983
Alternative fuels (renewable/biomass)	**15,941,583**	0 (carbon neutral)
External heat supply	5,286,954	1,501,495
Power input	7,913,591	3,371,385
TOTAL ENERGY INPUT	**52,168,859**	**9,802,071 t CO_2**

Specific water use stood at 8.7 litres per kilogram of paper produced (2022 data; 2023 not yet published), with approximately 90% of water cleaned and returned to surface water after use. The paper industry's CO_2 per tonne of production has fallen by 45% since 1995, driven by fuel switching and efficiency improvements.

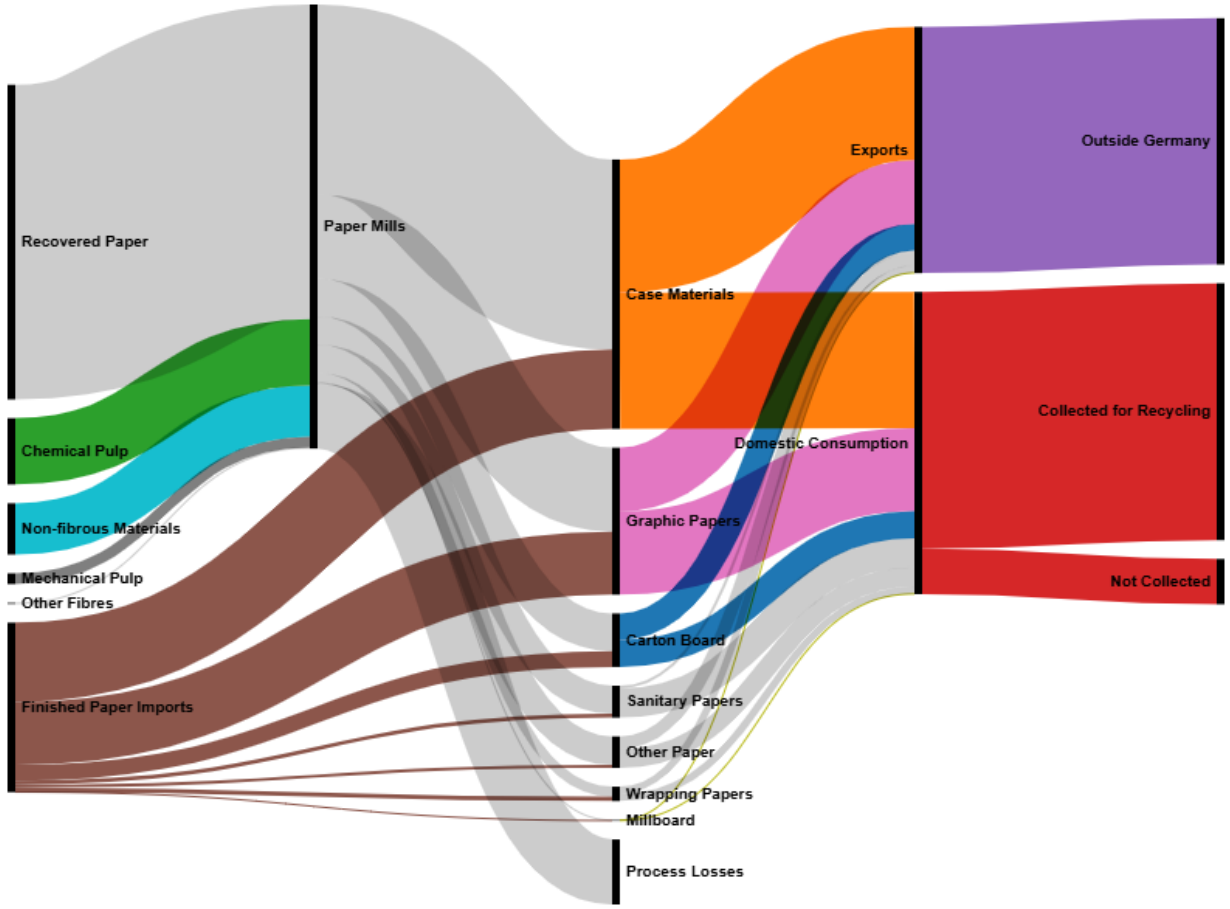


Figure 4: Material flow of paper and board in Germany by grade, trade and end-of-life destination in Germany (adapted from [7])

3.2.2 Paper packaging flow in Sweden: a lifecycle analysis

This section maps the paper and board packaging lifecycle in Sweden using data from the Snapshot of the Swedish Forest Industry 2025 [8], the Skogsindustrierna statistical and environmental database [9], and the CEPI Key Statistics 2024 [10]. Sweden is primarily an export-oriented producer of paper and board, supplying large volumes to other European markets while domestic apparent consumption represents a comparatively small share of production.

3.2.2.1 Raw material inputs

Sweden's paper and board production relies predominantly on fresh virgin fibres from its extensive domestic forests. According to Skogsindustrierna (2025) [8], raw material inputs in 2024 were composed of 81.5% fresh fibres (integrated and market pulp), 9.5% recycled fibres (paper for recycling), and 9.0% non-fibrous materials (fillers, coatings and starch). This contrasts with Germany, where recovered paper accounts for 70.9% of raw materials (Section 3.2.1.1), and reflects Sweden's forest-rich resource endowment.

Sweden is a major pulp producer: Swedish pulp mills produced 11,2 million tonnes of pulp [9] 32.9% of total CEPI pulp production, the highest share among all CEPI member countries [10]. Approximately 60% is consumed at integrated mills in Sweden, with the remainder (market pulp) primarily exported to mills across Europe [8].

Regarding recovered paper flows, Sweden collected 1,021,896 tonnes domestically [9], imported 348,915 tonnes, and exported 405,035 tonnes . Total paper for recycling consumed in Swedish production was 1,218,000 tonnes [9]. Sweden combines high collection and recycling of paper with a comparatively low use of recycled fibre in domestic paper production. In 2024, recycled fibres accounted for only 9.5% of raw material input, reflecting the Swedish industry's strong access to fresh forest fibres. Swedish fresh fibres subsequently enter recycling systems elsewhere in Europe through exported paper and board.

3.2.2.2 Paper and board production

In 2024, Swedish paper mills produced approximately 8,000,000 tonnes of paper and board [8], operating 66 mills, employing 30,000 people, and encompassing 26 companies [9] .

Table 10 : Paper and board production by grade in 2025 [9]

Grade	Volume (tonnes)	Share (%)
Paper and Board for Packaging	5,714,942	73.1%
Graphic Papers	1,711,987	21.9%
Sanitary and Household Papers	-	-
Other Paper and Board	388,809	5.0%
TOTAL	7,815,738	100%

3.2.2.3 Trade flow: exports and imports

Sweden is one of Europe's largest paper exporters. In 2024, approximately 90% of production was exported [8], with total reported exports reaching 7,177,539 tonnes and paper packaging accounting for 5,359,217 tonnes (74.7% of reported exports) [9] as illustrated in Table 11. Germany is the largest export destination (15%), followed by the United Kingdom (8%) and Italy (7%), while France and Poland each account for around 4%. The EU internal market receives 63% of Swedish paper and board exports [8]. These flows are directly relevant to BePacMan: Sweden is confirmed as Germany's single largest paper and board supplier (Section 3.2.1.3).

Table 11 : Paper and board exports by grade in 2025 [9]

Export by Grade	Volume (tonnes)	Share
Paper and Board for Packaging	5,359,217	74.7%
Graphic Papers	1,590,946	22.2%
Sanitary and Household	-	-
Other Paper and Board	227,376	3.2%
TOTAL EXPORTS	7,177,539	100%

Sweden is a modest importer of finished paper and board. Total reported imports were **519,655 tonnes** as shown in Table 12.

Table 12 Paper and board import by grade in 2025 [9]

Import by Grade	Volume (tonnes)	Share
Paper and Board for Packaging	395,755	76.2%
Graphic Papers	94,117	18.1%
Sanitary and Household	-	-
Other Paper and Board	29,783	5.7%
TOTAL IMPORTS	519,655	100%

3.2.2.4 Domestic consumption

Apparent consumption (production plus imports minus exports) for reported grades totalled 1,157,854 tonnes, approximately 7.8% of Germany's 14,872,000 tonnes. This underscores Sweden's export-oriented model: the country retains only a small fraction of its production for domestic use. Paper packaging accounted for 751,480 tonnes (64.9%) of domestic consumption [9] as shown in Table 13.

Table 13 Apparent domestic consumption by grade in 2025 [9]

Grade	Apparent consumption (tonnes)	Share (%)
Paper and Board for Packaging	751,480	64.9%
Graphic Papers	215,158	18.6%
Sanitary and Household Papers	-	-
Other Paper and Board	191,216	16.5%
TOTAL	1,157,854	100%

3.2.2.5 Collection: paper for recycling

Sweden collected 1,021,896 tonnes of paper for recycling , achieving a recycling rate of 78.6% above the CEPI European average of 75.1% [10]. The utilisation rate of 12.4% reflects structural reliance on virgin fibre: Swedish paper exported to Germany and other countries is subsequently recycled by continental European mills, making fresh Swedish fibres an essential input to Europe's recycling cycle [8].

3.2.2.6 End of life: energy and environment

Swedish pulp and paper production has a very low dependence on fossil fuels. Around 96% of the fuels used by the Swedish forest industry are biofuels, largely derived from process residues, while the sector is also a major producer and user of renewable electricity. [8].

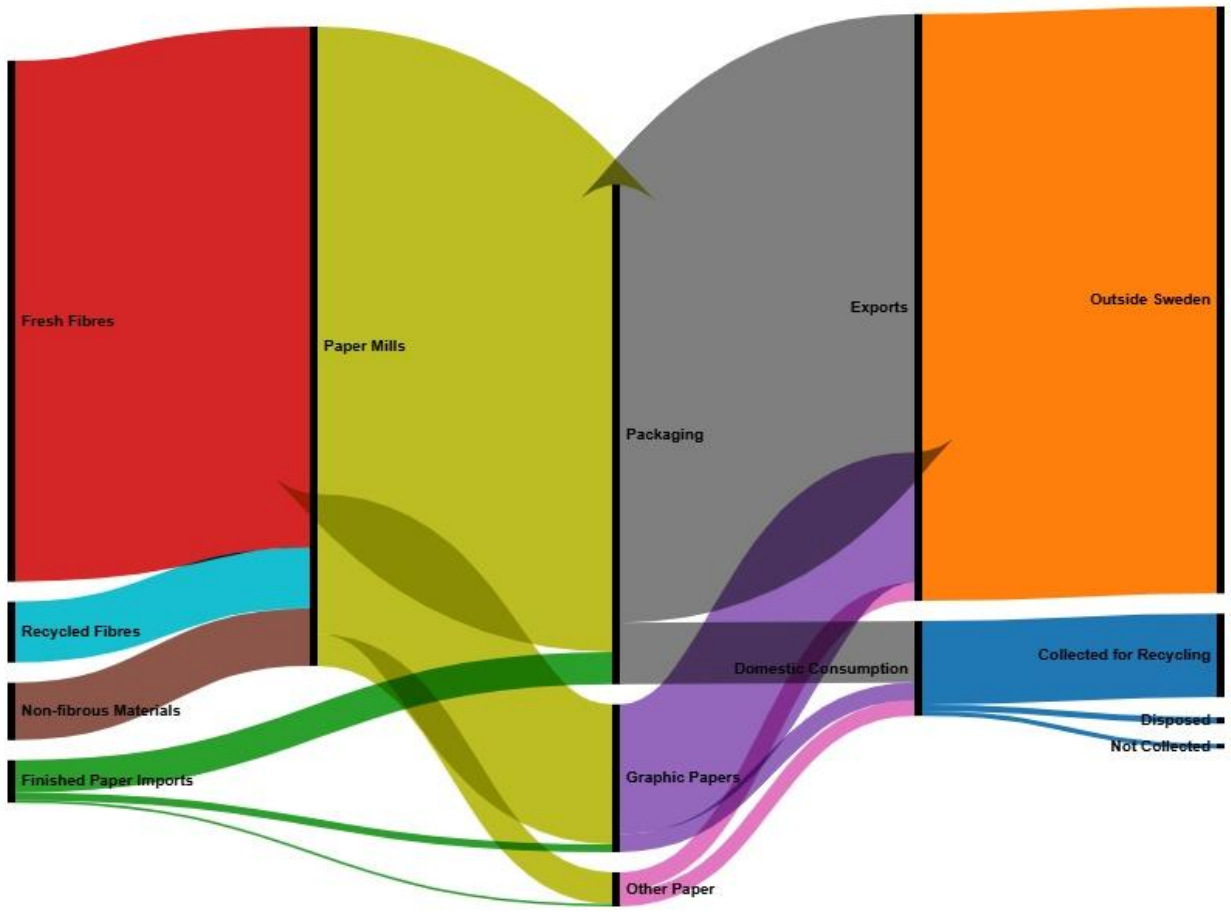


Figure 5 Material flow of paper and board in Sweden by grade, trade and end-of-life destination in Sweden adapted from [8] and [9]

3.2.3 Paper packaging flow in Denmark: a lifecycle analysis

This section maps the paper and board packaging lifecycle in Denmark, tracing material flows from raw material inputs through production, trade, domestic consumption, collection, and end-of-life management. Denmark has no significant domestic pulp or paper mill base and functions primarily as a converter, packaging consumer, and recycling participant rather than a major producer within the European paper supply chain.

3.2.3.1 Raw material inputs

According to FAOSTAT Forestry Production and Trade data [11], mechanical and semi-chemical wood pulp production in Denmark reached 4,830 tonnes in 2024, with chemical wood pulp production at zero, confirming negligible domestic pulp capacity. Denmark imported 54,429 tonnes of wood pulp in total

in 2024 (47,496 tonnes chemical pulp and 6,933 tonnes mechanical pulp) to supply its converting sector. According to FAOSTAT [11], recovered paper collection in Denmark reached 509,000 tonnes in 2024, with exports of 498,925 tonnes and imports of 27,886 tonnes. The actual recycling for cardboard and paper packaging is 360,840 tonnes (69.3%), and as much as 65.3% of this is recycled outside Denmark in 2020 [12], confirming the country's heavy reliance on cross-border recycling markets due to limited domestic reprocessing capacity as shown in Table 14. The recycling rate for packaging waste in Denmark stood at 70% in 2022, according to Miljotilstand.dk [13].

Table 14 Raw material inputs: Denmark

Indicator	Value	Source
Pulp production (mechanical and semi-chemical)	4,830 tonnes (2024)	[11]
Pulp production (chemical)	0 tonnes (2024)	
Total pulp imports	54,429 tonnes (2024)	
Paper for recycling (collected)	509,000 tonnes (2024)	
Paper for recycling (exported)	498,925 tonnes (2024)	
Paper for recycling (imported)	27,886 tonnes (2024)	

3.2.3.2 Paper and board production

According to FAOSTAT Forestry Production and Trade [11], total paper and board production in Denmark across all grades amounted to 152,000 tonnes in 2024. This confirms Denmark's position as a very small producer compared with major European paper nations. The dominant production category is other papers mainly for packaging (57,000 tonnes), followed by cartonboard (30,000 tonnes), printing and writing papers (28,000 tonnes), case materials (21,000 tonnes), wrapping papers (12,000 tonnes), and other paper and paperboard not elsewhere specified (4,000 tonnes) as illustrated in Table 15. Newsprint and household and sanitary paper production are negligible or zero. These figures are consistent with Denmark's role as a packaging converter and consumer rather than a primary paper producer.

Table 15 Paper and board production by grade in Denmark (2024, tonnes)

Grade	Production (t)

Case materials	21,000
Cartonboard	30,000
Wrapping papers	12,000
Other papers mainly for packaging	57,000
Paper packaging subtotal	**120,000**
Newsprint	0
Printing and writing papers	28,000
Graphic papers subtotal	**28,000**
Household and sanitary papers	0
Other paper and paperboard	4,000
TOTAL	**152,000**

3.2.3.3 Trade flow: exports and imports

Denmark is heavily dependent on imports of paper and board across all grades. According to FAOSTAT, total paper and board imports in 2024 amounted to 592,487 tonnes, against total exports of 158,184 tonnes, confirming Denmark as a significant net importer. Case materials represented the dominant import category at 240,565 tonnes, reflecting the country's reliance on corrugated packaging for logistics, retail, and e-commerce. Printing and writing papers imports totalled 138,035 tonnes, while cartonboard imports reached 94,245 tonnes. Total exports were driven primarily by cartonboard (79,860 tonnes) and wrapping papers (46,765 tonnes), reflecting re-export and converting activities as shown in Table 16.

Table 16 Paper and board trade flows by grade in Denmark (2024, tonnes)[11]

Grade	Imports (t)	Exports (t)
Case materials	240,565	9,096
Cartonboard	94,245	79,860
Wrapping papers	53,168	46,765
Other papers mainly for packaging	31,671	16,448
Paper packaging subtotal	**419,649**	**152,169**
Newsprint	28,488	14
Printing and writing papers	138,035	4,371

Graphic papers subtotal	**166,523**	**4,385**
Household and sanitary papers	1,585	374
Other paper and paperboard	4,730	1,256
TOTAL	**592,487**	**158,184**

3.2.3.4 Domestic consumption

Apparent consumption of paper and board in Denmark calculated as Production plus Imports minus Exports, totalled 586,303 tonnes in 2024 [11]. Paper packaging was the dominant consumption category at 387,480 tonnes (66.1% of total), driven primarily by case materials consumption of 252,469 tonnes, reflecting the central role of corrugated packaging in Danish logistics and e-commerce. Graphic paper consumption reached 190,138 tonnes, while household and sanitary papers and other grades contributed modest volumes as shown in Table 17.

Table 17 Apparent domestic consumption by grade in Denmark (2024, tonnes) [11]

Grade	Apparent consumption (t)
Case materials	252,469
Cartonboard	44,385
Wrapping papers	18,403
Other papers mainly for packaging	72,223
Paper packaging subtotal	**387,480**
Newsprint	28,474
Printing and writing papers	161,664
Graphic papers subtotal	**190,138**
Household and sanitary papers	1,211
Other paper and paperboard	7,474
TOTAL	**586,303**

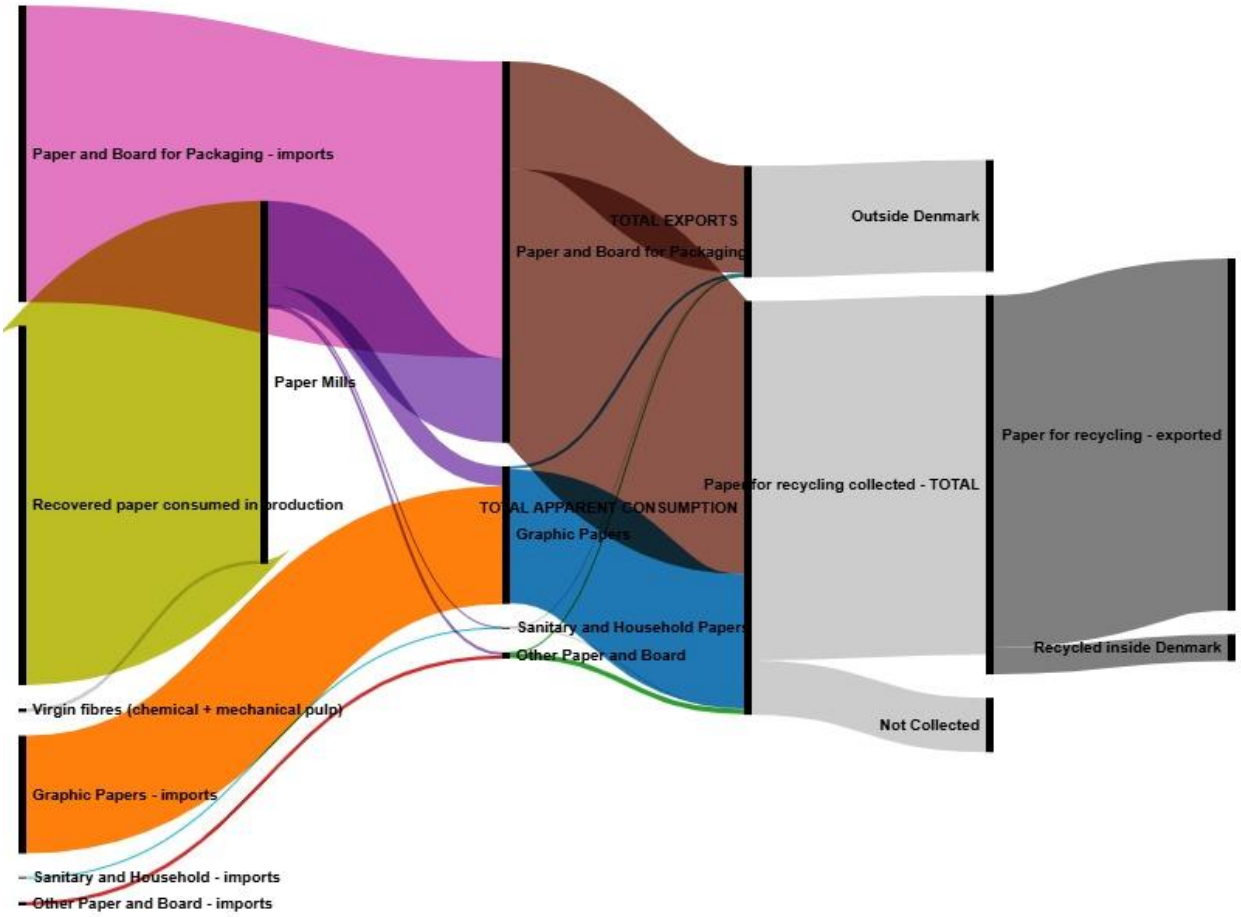


Figure 6 Material flow of paper and board in Denmark by grade, trade and end-of-life destination in Denmark adapted from [11]

3.2.4 Paper packaging flow in Lithuania: a lifecycle analysis

This section maps the paper and board packaging lifecycle in Lithuania, tracing material flows from raw material inputs through production, trade, domestic consumption, collection, and end-of-life management. All data presented in this section are drawn directly from the 2024 FAOSTAT Forestry Production and Trade database. Lithuania has no significant domestic pulp production capacity and functions primarily as a packaging producer (particularly corrugated case materials), converter, and consumer within the European paper supply chain.

3.2.4.1 Raw material inputs

According to FAOSTAT Forestry Production and Trade data [11], both chemical and mechanical wood pulp production in Lithuania amounted to zero in 2024, confirming that the country has no domestic pulp production capacity. Lithuania therefore depends entirely on imported pulp and

recovered paper to supply its paper and board sector. Total pulp imports reached 34,593 tonnes in 2024, comprising 34,580 tonnes of chemical wood pulp and 13 tonnes of mechanical and semi-chemical wood pulp [11]. Recovered paper collection in Lithuania reached 163,700 tonnes in 2024 according to FAOSTAT [11]. Of this, 83,562 tonnes were exported for processing abroad and 63,516 tonnes were imported, giving a net volume processed domestically of approximately 143,654 tonnes (163,700 − 83,562 + 63,516) as shown in Table 18.

Table 18 Raw material inputs in Lithuania

Indicator	Value	Source
Pulp production (chemical)	0 tonnes	[11]
Pulp production (mechanical and semi-chemical)	0 tonnes	
Total pulp imports (chemical)	34,580 tonnes	
Total pulp imports (mechanical)	13 tonnes	
Total pulp imports	34,593 tonnes	
Paper for recycling - collected	163,700 tonnes	
Paper for recycling - exported	83,562 tonnes	
Paper for recycling - imported	63,516 tonnes	
Recycled inside Lithuania (calculated)	143,654 tonnes	

3.2.4.2 Paper and board production

According to FAOSTAT [11], total paper and board production in Lithuania amounted to 141,300 tonnes in 2024. The dominant production category is case materials at 132,000 tonnes, reflecting Lithuania's significant corrugated packaging manufacturing capacity. Cartonboard production reached 6,100 tonnes and wrapping papers 2,200 tonnes as shown in Table 19. Sanitary and household papers production was 1,000 tonnes. Graphic papers, other papers mainly for packaging, and other paper and paperboard production were zero, confirming that Lithuania's paper sector is almost entirely focused on corrugated and packaging board.

Table 19 Paper and board production by grade in Lithuania [11]

Grade	Production (t)

Case materials	132,000
Cartonboard	6,100
Wrapping papers	2,200
Other papers mainly for packaging	0
Paper packaging subtotal	**140,300**
Newsprint	0
Printing and writing papers	0
Graphic papers subtotal	**0**
Household and sanitary papers	1,000
Other paper and paperboard	0
TOTAL	**141,300**

3.2.4.3 Trade flow: exports and imports

Lithuania is heavily dependent on imports of paper and board across all grades. According to FAOSTAT [11], total paper and board imports in 2024 amounted to 306,019 tonnes, against total exports of 99,598 tonnes. Case materials represented the dominant import category at 124,119 tonnes, while printing and writing papers imports reached 68,941 tonnes and cartonboard imports 56,209 tonnes as illustrated in Table 20. On the export side, case materials dominated at 56,281 tonnes, followed by wrapping papers at 19,973 tonnes, reflecting Lithuania's role as a corrugated packaging producer and re-exporter within the Baltic and European supply chain.

Table 20 Paper and board trade flows by grade in Lithuania [11]

Grade	Imports (t)	Exports (t)
Case materials	124,119	56,281
Cartonboard	56,209	6,160
Wrapping papers	34,921	19,973
Other papers mainly for packaging	5,786	238
Paper packaging subtotal	**221,035**	**82,652**
Newsprint	5,077	1,010
Printing and writing papers	68,941	12,443
Graphic papers subtotal	**74,018**	**13,453**

Household and sanitary papers	3,893	3,099
Other paper and paperboard	7,073	394
TOTAL	**306,019**	**99,598**

3.2.4.4 Domestic consumption

Apparent consumption of paper and board in Lithuania calculated as production plus imports minus exports totalled 347,721 tonnes in 2024 [11]. Paper packaging was the dominant consumption category at 278,683 tonnes (80% of total), driven primarily by case materials consumption of 199,838 tonnes. Graphic paper consumption reached 60,565 tonnes, while household and sanitary papers and other grades contributed modest volumes as shown in Table 21.

Table 21 Apparent domestic consumption by grade in Lithuania[11]

Grade	Apparent consumption (t)
Case materials	199,838
Cartonboard	56,149
Wrapping papers	17,148
Other papers mainly for packaging	5,548
Paper packaging subtotal	**278,683**
Newsprint	4,067
Printing and writing papers	56,498
Graphic papers subtotal	**60,565**
Household and sanitary papers	1,794
Other paper and paperboard	6,679
TOTAL	**347,721**

3.2.4.5 Collection: paper for recycling

According to FAOSTAT [11], recovered paper collection in Lithuania reached 163,700 tonnes in 2024. Of this, 83,562 tonnes were exported for processing outside Lithuania and 63,516 tonnes were imported, giving a net volume processed domestically of 143,654 tonnes. The overall recycling rate calculated as collected divided by total apparent consumption stood at 47.1% (163,700 ÷ 347,721 × 100). The volume not collected for recycling calculated as total consumption

minus collected amounted to 184,021 tonnes (347,721 - 163,700).

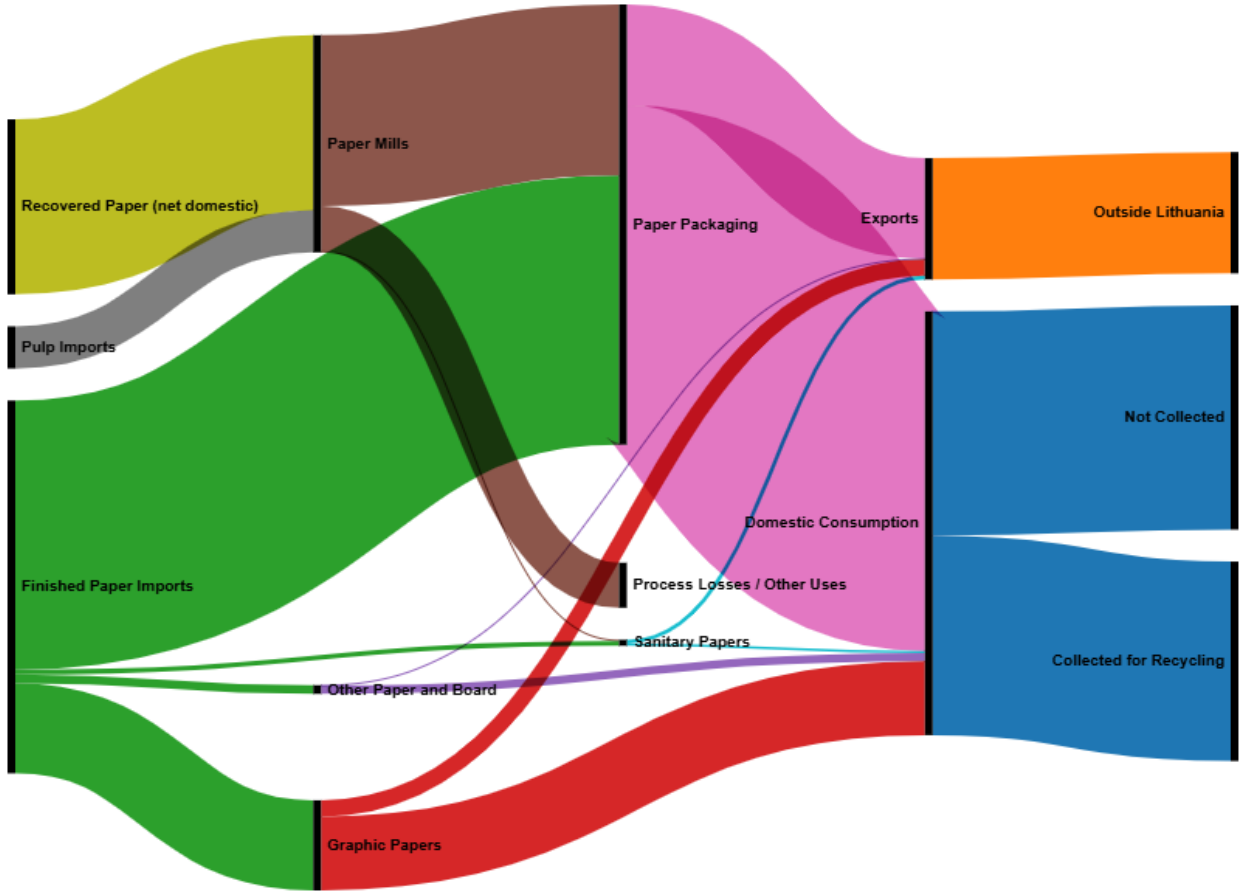


Figure 7 Material flow of paper and board in Lithuania by grade, trade and end-of-life destination in Lithuania adapted from [11]

3.2.5 Paper packaging flow in Poland: a lifecycle analysis

This section maps the paper and board packaging lifecycle in Poland for the reference year 2023. Data are drawn from CEPI Key Statistics 2023 [3], the Polish Central Statistical Office [14], Eurostat trade statistics [15], and the European Declaration on Paper Recycling [16]. Poland is a CEPI member through the Association of Polish Papermakers (SPP).

3.2.5.1 Raw material inputs

In 2023, Poland's paper mills consumed 4,100,000 tonnes of recovered paper, comprising 3,500,000 tonnes collected domestically, 900,000 tonnes imported, and

300,000 tonnes exported to mills in other countries [15] as shown in Table 22. Virgin fibres contributed a further 2,500,000 tonnes [3], giving a total known raw material input of 6,600,000 tonnes, excluding non-fibrous materials due to lack of publicly available data. The utilisation rate of recovered paper stands at 62%.

Table 22 Raw material input in Poland

Metric	Volume (tonnes)
Recovered paper consumed	4,100,000
collected domestically	3,500,000
imported	900,000
exported	300,000
Virgin fibres (chemical + mechanical pulp)	2,500,000
Non-fibrous materials	-
TOTAL RAW MATERIALS	6,600,000
Utilisation rate	62%
Recycling rate	50.7%

3.2.5.2 Paper and board production

In 2023, Poland's paper and board sector produced 7,600,000 tonnes across 45 mills, with 120 companies and 45,000 direct employees as shown in Table 23. Total industry turnover was estimated at €11,000 million [14]. Paper and board for packaging dominated at 5,200,000 tonnes (68.4%), with case materials and containerboard representing the largest sub-category at 3,400,000 tonnes (44.7%), reflecting Poland's significant corrugated packaging sector [3].

Table 23 Paper and board production by grade in Poland

Grade	Volume (tonnes)	Share (%)
Paper and Board for Packaging (TOTAL)	5,200,000	68.4%
Case Materials / Containerboard	3,400,000	44.7%
Carton Board	1,100,000	14.5%

Wrappings and Label Paper	600,000	7.9%
Millboard	100,000	1.3%
Graphic Papers	1,400,000	18.4%
Sanitary and Household Papers	700,000	9.2%
Other Paper and Board	300,000	3.9%
TOTAL PRODUCTION	7,600,000	100%

3.2.5.3 Trade flow: exports and imports

Poland exported 3,500,000 tonnes and imported 2,800,000 tonnes of paper and board in 2023. Germany was both poland's the largest export destination and the largest import supplier [15] as illustrated in Table 24, consistent with Germany's own trade data identifying Poland as its largest export destination at 2,449,543 tonnes in 2023 (Section 3.2.1.3).

Table 24 Paper and board trade flows by grade in Poland

Grade	Exports (tonnes)	Imports (tonnes)
Paper and Board for Packaging	2,200,000	1,800,000
Graphic Papers	800,000	600,000
Sanitary and Household Papers	300,000	250,000
Other Paper and Board	200,000	150,000
TOTAL	3,500,000	2,800,000

3.2.5.4 Domestic consumption

Apparent consumption (production plus imports minus exports) totalled 6,900,000 tonnes in 2023 as shown in Table 25. Paper and board for packaging dominated at 4,800,000 tonnes (69.6%), followed by graphic papers at 1,200,000 tonnes (17.4%), sanitary and household papers at 650,000 tonnes (9.4%), and other paper and board at 250,000 tonnes (3.6%) [3], [15].

Table 25 Apparent domestic consumption by grade in Poland

Grade	Apparent consumption (tonnes)	Share (%)
Paper and Board for Packaging	4,800,000	69.6%

Graphic Papers	1,200,000	17.4%
Sanitary and Household Papers	650,000	9.4%
Other Paper and Board	250,000	3.6%
TOTAL APPARENT CONSUMPTION	6,900,000	100%

3.2.5.5 Collection: paper for recycling

Poland collected 3,500,000 tonnes of paper for recycling in 2023, achieving a recycling rate of 50.7%. It imported 900,000 tonnes and exported 300,000 tonnes of recovered paper [15] reflecting the country's high demand for secondary fibre .

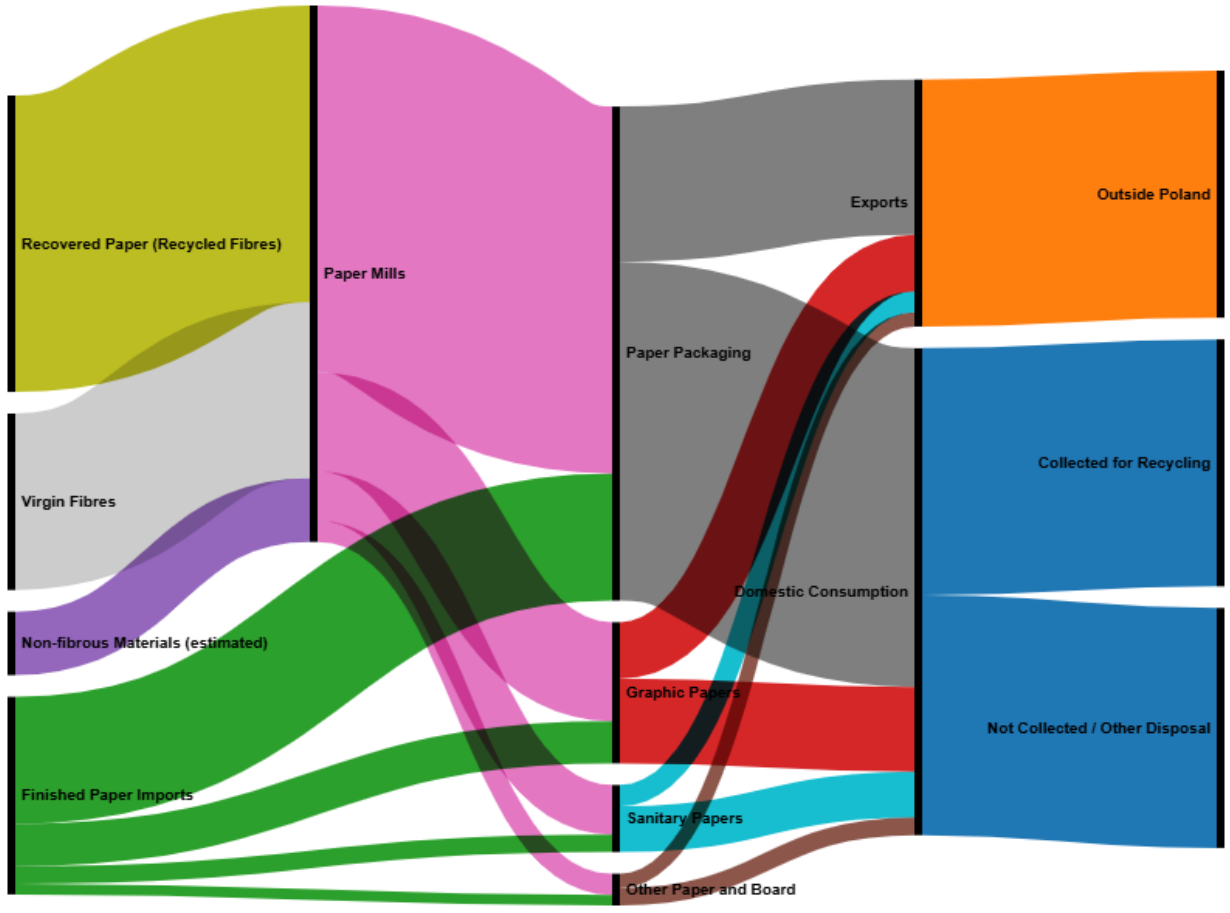


Figure 8 Material flow of paper and board in Poland by grade, trade and end-of-life destination in Poland

3.3 Cross-border packaging dynamics and trade flows

The five BePacMan partner countries analysed in Section 3.2 occupy markedly different positions within the regional paper and board trade network. Germany, Sweden and Poland are major producers and net exporters, while Denmark and Lithuania are structurally net importers at a much smaller scale. Table 26 summarises the net trade position of each country, drawing together the export and import totals already presented in Sections 3.2.1 to 3.2.5.

Table 26 Net trade position in paper and board by country

Note on reference years: Germany and Poland figures refer to 2023; Denmark and Lithuania figures refer to 2024; Sweden figures refer to 2025. Direct cross-country volume comparisons should be interpreted with this variation.

Country	Exports (t)	Imports (t)	Net position (t)	Reference year
Germany	12,118,000	8,343,000	+3,775,000	2023
Sweden	7,177,539	519,655	+6,657,884	2025
Poland	3,500,000	2,800,000	+700,000	2023
Denmark	158,184	592,487	-434,303	2024
Lithuania	99,598	306,019	-206,421	2024

3.3.1 The Sweden-Germany-Poland trade triangle

Germany occupies a central position in this network. As Europe's largest paper and board exporter, Germany exported 12,118,000 tonnes in 2023, of which Poland was the single largest destination, receiving 2,449,543 tonnes 20.2% of all German exports. On the import side, Sweden was Germany's largest supplier, providing 1,840,674 tonnes (22.1% of German imports), while Poland also supplied Germany with 553,034 tonnes (6.6% of German imports).

This bilateral relationship is corroborated from both the Swedish and Polish perspectives. Sweden's own trade data identify Germany as Sweden's largest export destination, receiving 15% of Sweden's 7,177,539 tonnes of total exports in 2025 directionally consistent with Germany's import figures, though the reported volumes differ (approximately 1.08 million tonnes by Sweden's reported share versus 1,840,674 tonnes reported in Germany's import data), reflecting different reference years (2025 for Sweden, 2023 for Germany) and possibly

different product scope. Similarly, Poland's trade data identify Germany as both Poland's largest export destination and largest import supplier, consistent with the two-way German-Polish flows already noted.

Taken together, these three countries form the structural core of regional paper and board trade. Sweden, exporting approximately 90% of its production, directs its largest single export share toward Germany. Germany, as Europe's largest producer (18,646,595 tonnes in 2023) and exporter, both supplies and absorbs large volumes to and from Poland. Poland itself is a substantial producer (7,600,000 tonnes in 2023) and an active two-way trading partner with Germany, exporting 3,500,000 tonnes and importing 2,800,000 tonnes in total.

3.3.2 Import-dependent markets: Denmark and Lithuania

Denmark and Lithuania present a markedly different trade profile from the Sweden-Germany-Poland core. Both countries are net importers of paper and board at a much smaller absolute scale. In 2024, Denmark imported 592,487 tonnes against exports of 158,184 tonnes, a net import position of 434,303 tonnes. Lithuania imported 306,019 tonnes against exports of 99,598 tonnes, a net import position of 206,421 tonnes.

In both countries, case materials (containerboard for corrugated packaging) represent the largest single import category: 240,565 tonnes for Denmark and 124,119 tonnes for Lithuania. For Denmark, this category shows the largest net trade deficit of any grade 240,565 tonnes imported against only 9,096 tonnes exported indicating that Denmark relies almost entirely on imported corrugated packaging material. Lithuania shows a somewhat different pattern: while it also imports substantially more case materials than it exports (124,119 tonnes versus 56,281 tonnes), its export figure is considerably larger relative to its imports than Denmark's, suggesting a more active role as a converter and re-exporter of corrugated packaging within the regional supply chain.

3.3.3 Implications for BePacMan

The most significant cross-cutting finding from this section is the consistent dominance of case materials and containerboard across the entire region, regardless of whether a country is a net producer or a net importer. In Germany, case materials account for 79.7% of packaging production (9,346,566 tonnes). In Poland, case materials and containerboard represent 44.7% of total production (3,400,000 tonnes). In Denmark and Lithuania, case materials are the single largest import category. This convergence indicates

that corrugated packaging used predominantly for logistics, e-commerce and retail transport is the dominant paper packaging format throughout the BePacMan region, making it a natural priority focus area for reuse interventions.

The triangular core of Sweden, Germany and Poland represents where the largest volumes of material are produced and circulated, and where existing industrial infrastructure and high-volume logistics networks already exist. Reuse systems piloted within this core could leverage these established flows and the close bilateral integration already documented between Germany and its two largest trading partners.

For Denmark and Lithuania, the structurally import-dependent position means that any reuse or refill system must be designed to integrate with inbound logistics rather than relying on domestic production capacity, which in both countries remains comparatively small. Lithuania's relatively stronger export and converting activity for case materials suggests it may be better positioned than Denmark to act as a regional hub for re-circulating packaging within the Baltic area, whereas Denmark's near-total reliance on imports across most grades' points to a need for closer coordination with supplying countries particularly Sweden and Germany, the two largest net exporters identified in Table 26**.**

Overall, the data presented in this section indicate a region structured around a small number of high-volume producer-exporters (Sweden, Germany, Poland) supplying a wider set of consuming markets (Denmark, Lithuania), with corrugated case materials forming the common thread across both production and consumption patterns. This structure should inform where BePacMan prioritises reuse interventions and how reverse logistics for reusable packaging are designed across the South Baltic Area as shown in Figure 9.

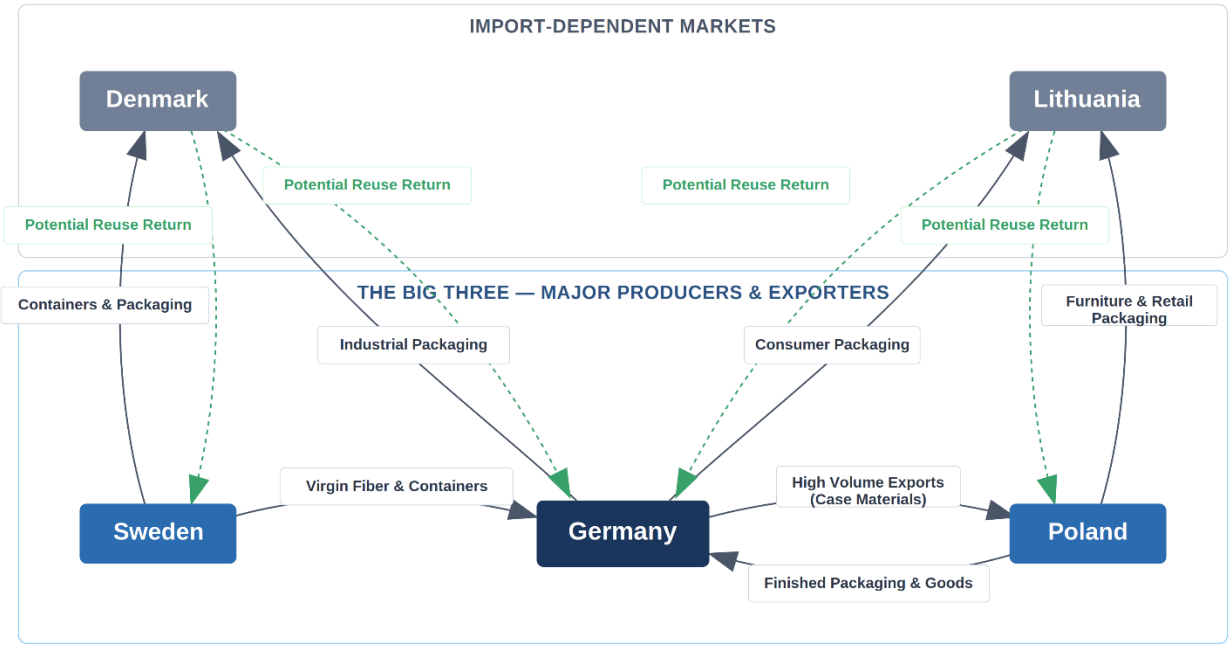


Figure 9 shows how packaging materials typically move from the main producer-exporter countries Sweden, Germany, and Poland to markets that rely heavily on imports, such as Denmark and Lithuania. In addition, the diagram outlines possible reverse-logistics routes for returning and reusing packaging. These reuse-return routes, marked with dashed lines, are not actual trade flows but rather conceptual pathways proposed to encourage more sustainable packaging practices.

Note: Solid lines represent reported or documented material flows. The dashed lines represent conceptual reverse-logistics routes proposed for future reuse-system development and are not actual trade flows.

4. Stakeholder needs and challenge mapping

This section reports on the stakeholder mapping conducted within WP2 under Activity 2.2 of the BePacMan project. This mapping highlights the main stakeholder groups engaged in the paper packaging lifecycle across the SBS Region, outlining their stated needs and priorities, the barriers they encounter in adopting circular packaging practices, and a comparative synthesis across countries. In total, 151 stakeholders contributed to the study, representing four groups: producers (n=11), logistics providers (n=7), e-commerce businesses (n=7), and consumers (n=126). The results were analyzed using descriptive statistics to reveal key patterns, challenges, and opportunities for advancing circular paper packaging systems.

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4.1 Stakeholder groups mapped

To assess the potential for reusable paper packaging systems within the SBS Region, stakeholders were identified and categorised based on their position in the packaging value chain, their functional role, and their potential impact on circular economy outcomes. The stakeholder categories and subcategories shown in Figure 10 were identified across the partner countries

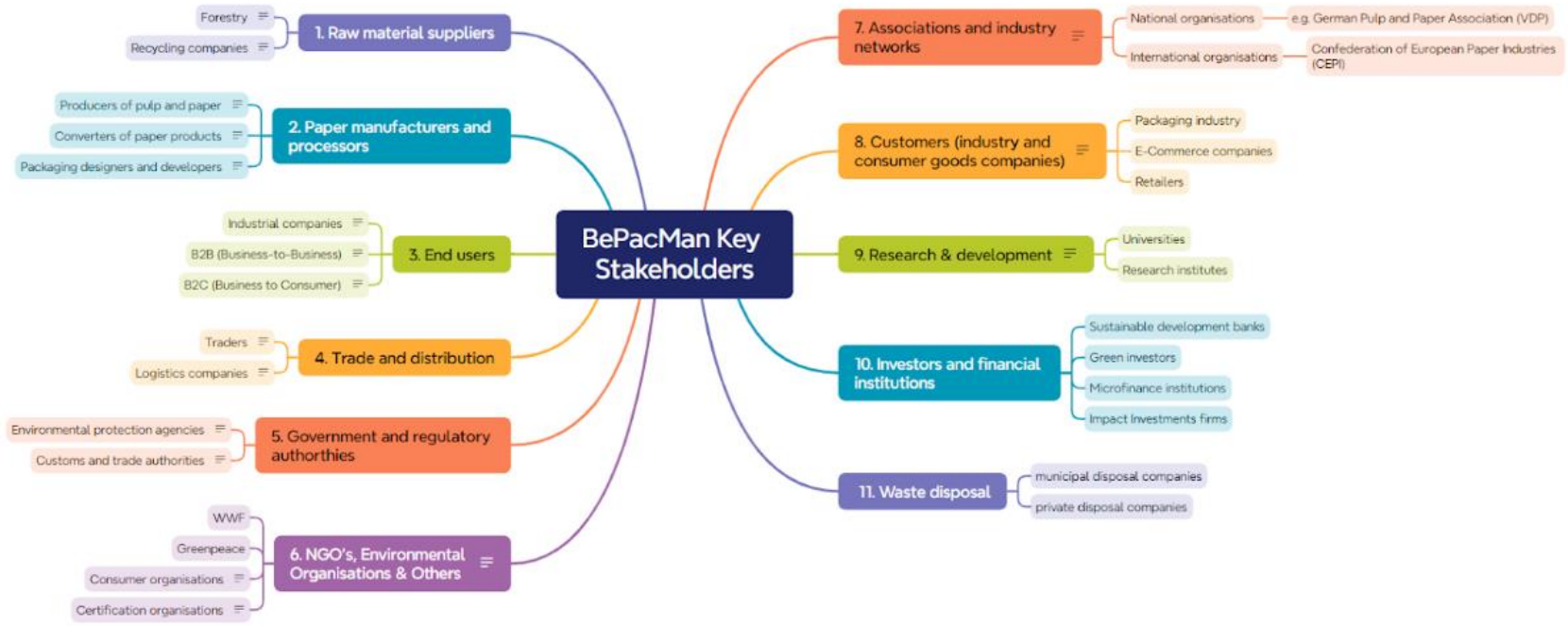


Figure 10 Overview of stakeholder categories across the packaging value chain

a. Raw material suppliers: This group includes forestry operations and recycling companies that provide virgin or recovered materials used in paper packaging production. They influence material availability, quality, and environmental footprint at the very beginning of the value chain.

b. Paper manufacturers and processors: Comprising pulp and paper producers, paper product converters, and packaging designers and developers, this group determines the physical characteristics of packaging, including its durability, reusability, and recyclability.

c. End users: Industrial companies, business-to-business (B2B), and business-to-consumer (B2C) actors represent the end users of paper packaging. Their purchasing preferences, operational models, and waste management behaviour shape demand for viable circular-packaging solutions.

d. Trade and distributions of actors: This group includes traders and logistics companies responsible for transporting packaged goods. Their systems and infrastructure play a key role in the feasibility of reverse logistics required for reusable packaging.

e. Government and regulatory authorities: These stakeholders, such as environmental protection agencies and customs or trade authorities, are responsible for setting, enforcing, and harmonizing legal frameworks. They influence incentives, obligations, and market access for circular packaging models.

f. Non-governmental and environmental organisations: NGOs, consumer advocacy groups, and certification bodies raise awareness, promote sustainability standards, and provide oversight or independent validation of packaging claims.

g. Associations and industry networks: National and international organisations in the paper, packaging, and waste management sectors serve as platforms for knowledge sharing, lobbying, and coordination. They are instrumental in aligning cross-sector efforts.

h. Customers (industry and consumer goods companies): This group includes packaging-intensive sectors like the e-commerce industry, retailers, and consumer goods companies. Their demand for sustainable packaging and willingness to invest in reuse models are critical to mainstream adoption.

i. Research and development institutions: Universities and research institutes provide

data, pilot testing, and innovation support. Their role is essential in evaluating the environmental and economic impacts of reuse models and designing scalable solutions.

j. Financial institutions and impact investors: Banks, green investment funds, microfinance institutions, and impact-oriented investors influence the financial viability of circular packaging systems through capital allocation, grants, and risk-sharing mechanisms.

k. Waste disposal and management companies: Including both municipal and private actors, these stakeholders handle the end-of-life stage of packaging. Their ability to separate, collect, and manage reusable items versus waste is a key factor in the effectiveness of reuse systems.

Following the stakeholder mapping, data collection was conducted through four structured questionnaires, each tailored to a specific group within the paper packaging value chain as shown in Figure 11. The producer questionnaire targeted a range of actors including raw material suppliers, pulp and paper manufacturers, converters, and packaging designers. The logistics questionnaire addressed stakeholders involved in transportation, distribution, collection, and recycling, capturing insights from companies managing both forward and reverse logistics as well as waste handling and material recovery. The e-commerce questionnaire focused on retailers, online sellers, and packaging-intensive SMEs, exploring their operational needs, customer interaction points, and potential roles in reuse systems. The consumer questionnaire gathered information on end-user behaviour, awareness, and preferences related to reusable paper packaging. These four questionnaires provided a comprehensive foundation for identifying stakeholder specific needs, barriers, and opportunities in the transition toward reusable packaging models across the SBS Region.

The survey was conducted to better understand the needs, motivations, and barriers faced by producers, logistics operators, e-commerce stakeholders, and consumers in the SBS Region when considering or adopting reusable paper packaging. In total, interviews were carried out with two producers from Germany, two from Poland, two from Lithuania, one from Denmark and four from Sweden. Among logistics stakeholders, two were interviewed in Germany, four in Poland, one in Lithuania, and no information was obtained in Denmark

and Sweden. For e-commerce stakeholders, no data were obtained in Germany, while two were completed in Poland, three in Lithuania, one in Denmark and one in Sweden. Regarding consumers, twenty-seven were interviewed in Germany, thirty in Poland, twenty-seven in Lithuania, twenty-two in Denmark and twenty in Sweden.

The questionnaires were completed through online forms, paper-based responses and direct phone interviews. This process provided valuable insights into the factors influencing stakeholder decisions, the main challenges encountered, and the specific needs identified. The following section presents an in-depth analysis of the survey results gathered from producers, logistics stakeholders, e-commerce stakeholders, and consumers across the SBS Region, with particular attention to Poland, Lithuania, Denmark, Germany, and Sweden.

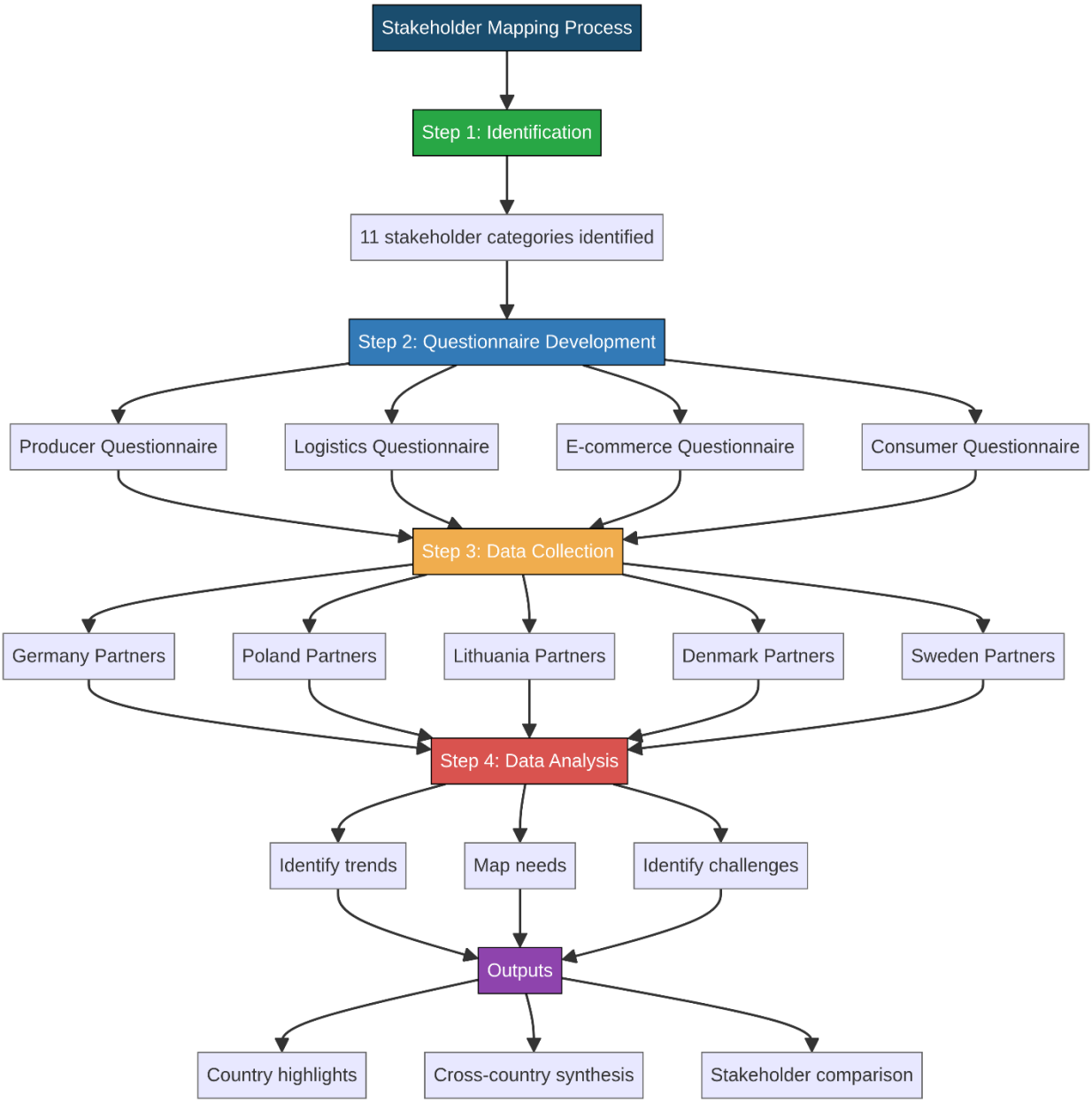


Figure 11 Stakeholder needs and challenge mapping process

4.2 Stakeholder needs and priorities

This section outlines the specific needs and priorities of the four key stakeholder groups as identified through the survey analysis. The results reveal both shared requirements and group-specific priorities that are essential for designing effective and acceptable reuse systems. Figure 12 provides a comparative overview of the business stakeholders' readiness and willingness to engage in reuse systems.

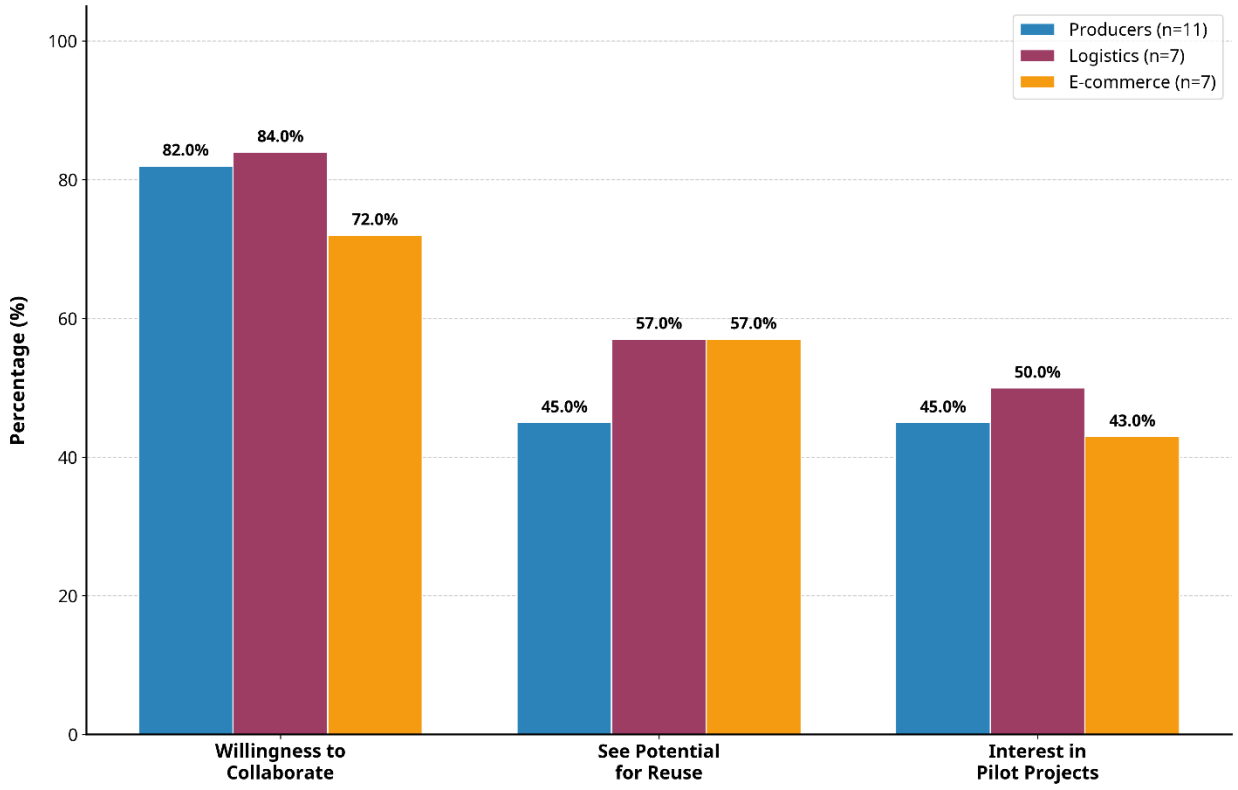


Figure 12 A comparison of the willingness to collaborate, perceived potential for reuse, and interest in pilot projects among producers, logistics providers, and e-commerce businesses.

4.2.1 Producers

Producers of paper packaging are cautiously optimistic about reuse systems but require practical and economically solutions to transition from a linear to a circular model. Their needs are primarily focused on de-risking the investment and operational shifts required. The foremost need is for business models that are cost-effective, as a significant majority (82%) of producers are open to collaboration on a return system, but this willingness is contingent on economic viability. This is underscored by the fact that 72.8% agree or strongly agree that taking back products involves high logistical costs. Consequently, producers need efficient and low-cost reverse logistics, as 72.8% view return transport as uneconomical or harmful to the environment. Furthermore, there is a clear demand for well-defined collaboration models that outline roles, responsibilities, and cost-sharing mechanisms to reduce uncertainty. While immediate interest is moderate, 45% of producers expressed some level of interest in participating in pilot projects, indicating a need for platforms and funding opportunities to test and validate new reuse concepts before large-scale implementation.

4.2.2 Logistics

Logistics providers are central to any reuse system, with needs focused on efficiency, standardisation, and the integration of new services. Like producers, they prioritize cost-effectiveness, as 85.7% of survey respondents identified high costs or effort as a major obstacle. Their main requirement is return systems that fit seamlessly into existing delivery networks while remaining economically viable. To support collection, sorting, and redistribution, they also call for standardized, durable packaging formats, with 43% highlighting durability as a key concern. Since 71% lack systems to collect used packaging, there is a clear demand for guidance on how to establish and operate such mechanisms, including technical support and best practices. Practical solutions such as stronger boxes, simplified cartons, and designs that are easy to transfer and redeploy are seen as essential. Some stakeholders already reuse cartons as shipping containers or filler material and recognize opportunities to expand these practices through collaboration with waste and recycling service providers. A deposit-and-return mechanism is also mentioned to improve return rates. Overall, many stakeholders are open, sometimes conditionally, to collaboration, provided the concept is clearly defined and adequately supported.

4.2.3 E-commerce

The e-commerce sector, as a major user of paper packaging, plays a critical role in the success of B2C reuse models. Its needs are driven by customer experience, cost pressures, and the unique challenges of last-mile delivery. The most pressing requirement is a functional return system, since currently none of the surveyed e-commerce businesses (100%) have a mechanism for collecting used packaging from customers. This issue is compounded by the unanimous belief that customers are unlikely to return packaging, a perception that sharply contrasts with consumer-reported willingness (75%). High costs also pose a significant barrier, with 85.4% of businesses identifying this as an obstacle. To make reuse economically viable, reduced shipping rates for returned packaging are essential. Equally important is bridging the gap between the sector's perception of consumer behaviour and actual consumer willingness by providing data that demonstrates strong consumer interest in reuse.

4.2.4 Consumers

Consumers are the ultimate drivers of B2C reuse systems, with their priorities centred on

convenience, simplicity, and tangible benefits. Convenience stands out as the most important factor: the preferred return options are collection stations near supermarkets or shopping centres (37%) and reverse vending machines (28%) as shown in Figure 13. Financial incentives are also a strong motivator, with 65.9% of consumers supporting deposit-style systems. Participation in such schemes scored an impressive average of 7.82 out of 10. While 85% of consumers believe reuse is important, 10% identify a lack of information as a barrier, underscoring the need for stronger awareness campaigns. The most frequently cited obstacle, however, is limited storage space (40%), highlighting the importance of return systems that minimise the need to keep bulky packaging at home for extended periods.

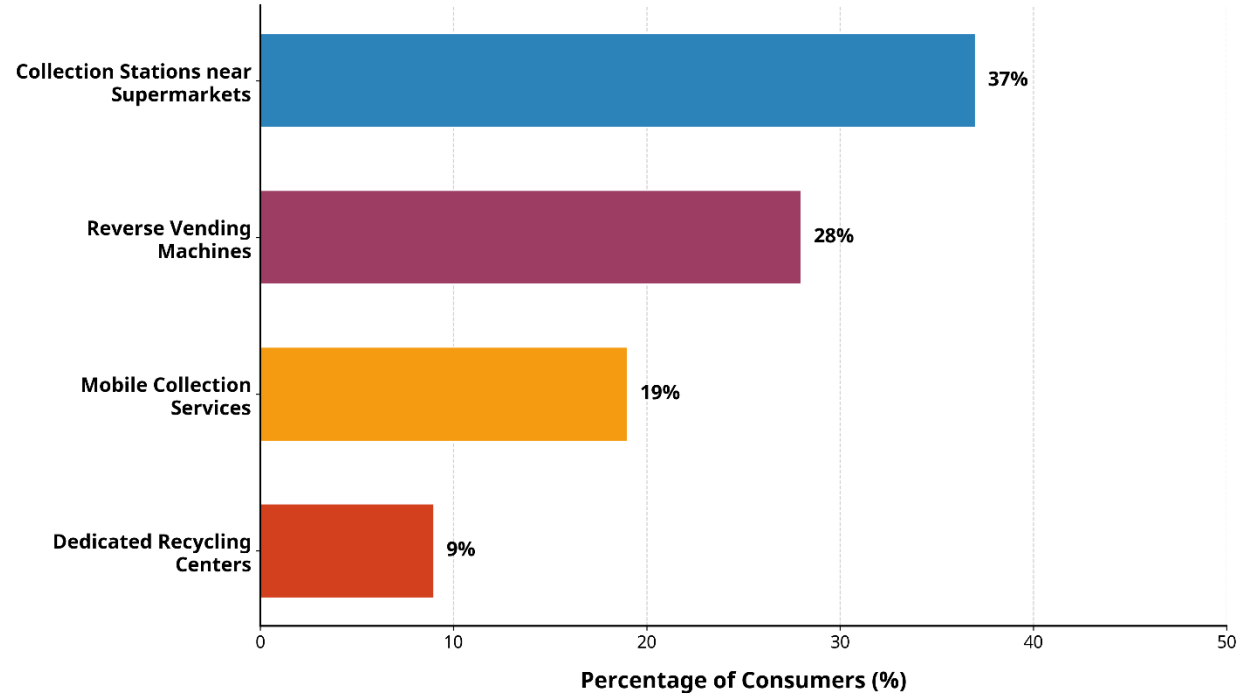


Figure 13 A bar chart showing the percentage of consumers who prefer different types of collection systems for returning paper packaging.

4.3 Main challenges and barriers reported

The transition to a circular economy for paper packaging is constrained by a range of challenges that differ across stakeholder groups. This section highlights the main obstacles reported by producers, logistics providers, e-commerce businesses, and consumers, drawing on quantitative survey data. Figure 14 offers a comparative overview

of the barriers identified by business stakeholders.

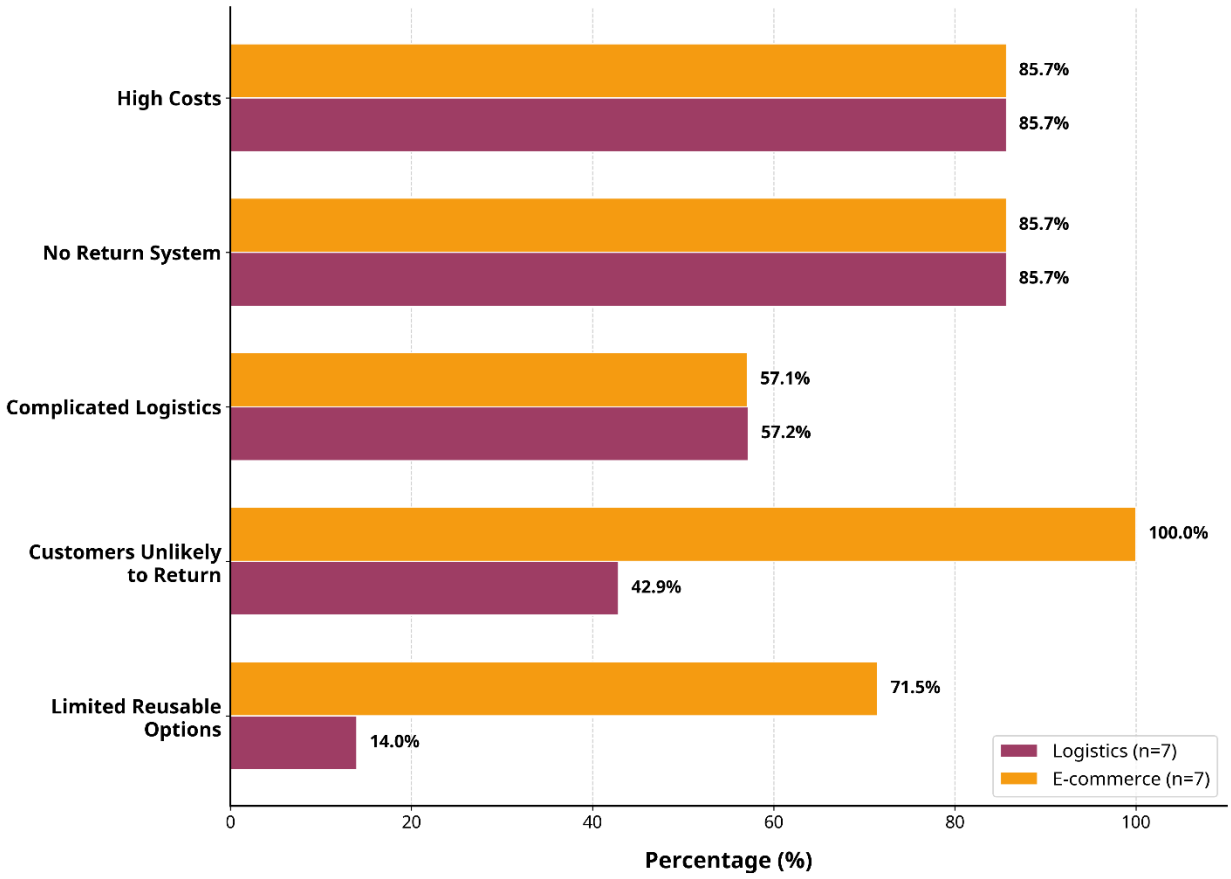


Figure 14 A horizontal bar chart comparing the main barriers to paper packaging reuse as reported by Logistics providers, and e-commerce businesses

- Producers face primarily economic and logistical barriers. A significant majority (72.8%) agree that taking back products involves high logistical costs, while the same proportion believe that return transport is uneconomical or environmentally harmful. The convenience of existing practices also plays a role, with 54.6% stating that recycling is easier than reuse.
- Logistics providers encounter substantial infrastructural hurdles. Most respondents (85.7%) point to the absence of return systems or infrastructure, as well as the high costs and effort involved, as major obstacles. Beyond infrastructure, 57.1%

also identify complicated logistics as a barrier.

- E-commerce businesses report some of the strongest barriers, rooted in cost, infrastructure, and perceptions of consumer behaviour. Within the e-commerce sample, all respondents expressed doubts that customers would return packaging. This indicative finding should be interpreted cautiously because the sample was small (n=7). In addition, 85.7% agree that the lack of return systems or infrastructure, along with high costs and effort, are critical hurdles.
- Consumers, by contrast, face barriers that are more practical than attitudinal. The most significant issue is a lack of space to store packaging (40%), as shown in Figure 15. The second largest barrier is the condition of the packaging itself, with 32% noting that it is often unsuitable for reuse (e.g., damaged or poor quality). Other notable challenges include lack of time or convenience (12%) and insufficient information (10%).

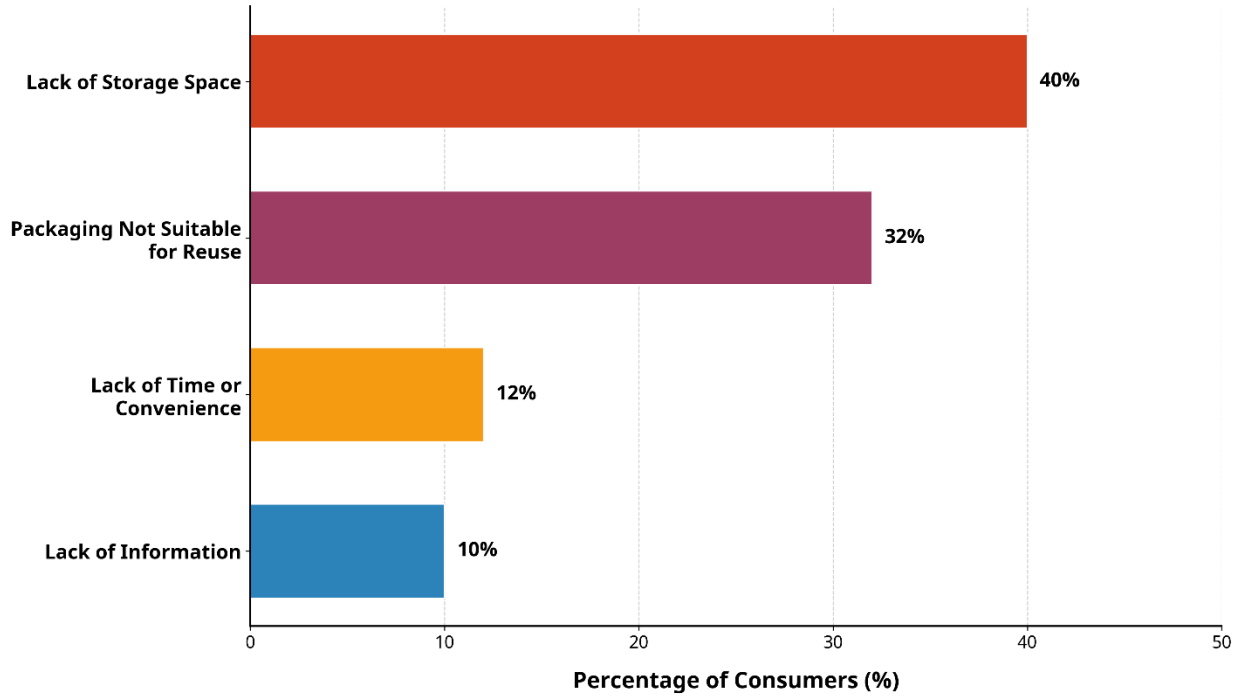


Figure 15 A horizontal bar chart illustrating the main practical barriers that prevent consumers from reusing paper packaging more often

4.4 Country-specific highlights

While many needs and challenges are shared across the SBS Region, the survey data reveals distinct country-specific priorities and states of readiness. This section provides highlights from Germany, Poland, Lithuania, Denmark and Sweden, drawing on responses from consumers. Figure 16 compares consumer readiness across the five countries.

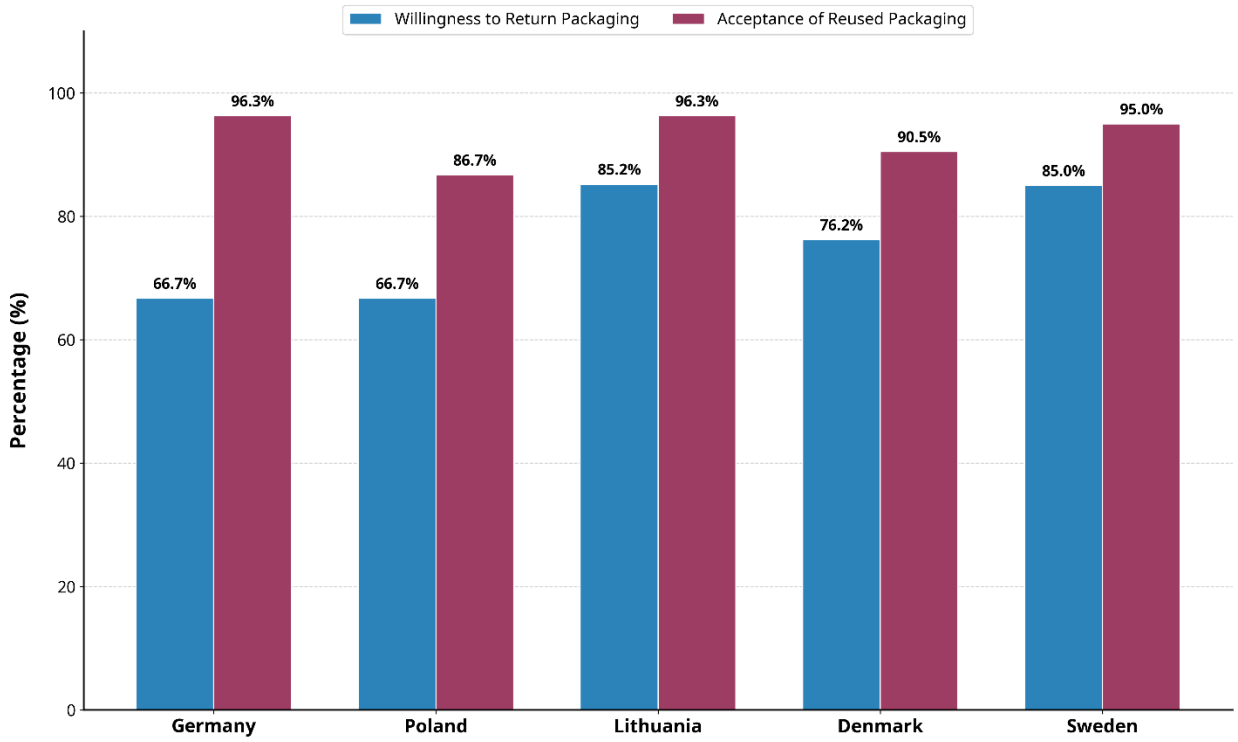


Figure 16 A bar chart comparing consumer willingness to return packaging and their acceptance of reused packaging across the five partner countries.

Germany emerges as a frontrunner in readiness, characterised by high consumer awareness. German consumers demonstrate strong engagement, with 96.3% willing to accept reused packaging. However, their willingness to return packaging is more moderate at 66.7%. There is a strong sentiment for shared responsibility, with German consumers rating the responsibility of businesses at an average of 8.6 out of 10.

Poland shows high consumer motivation, presenting a key opportunity for incentive-based systems. Willingness to return packaging is 66.7%, while acceptance of reused packaging is 86.7%. The concept of a deposit-return system is popular, receiving an average participation score of 7.2 out of 10.

Lithuania demonstrates the highest consumer readiness in the survey. Lithuanian consumers

are exceptionally open to reuse, with 96.3% willing to accept reused packaging and a remarkable 85.2% willing to return it. This indicates a high level of stated support for testing circular models within the survey sample. Lithuania also shows the highest enthusiasm for deposit systems, with an average score of 8.9 out of 10, and the highest business responsibility rating at 9.4 out of 10.

Denmark, with its strong focus on sustainability, shows a high degree of consumer awareness. Danish consumers report a satisfaction rate of 71.4% with current recycling options (combining Satisfied and Very satisfied responses). They are highly willing to accept reused packaging (90.5%) and return it (76.2%). They also hold businesses to a high standard, giving an average score of 8.9 out of 10 for business responsibility.

Sweden shows strong consumer readiness, with 95.0% willing to accept reused packaging, the highest rate across the five countries and 85.0% willing to return it, on par with Lithuania. Satisfaction with existing recycling is high (80.0%), though packaging condition and lack of storage space remain the main practical barriers. Deposit system participation scored 7.5/10, and business responsibility 8.8/10 as shown in Figure 17. Preferred return options are supermarket collection stations and mobile services. Overall, Sweden is a promising market for cross-border reusable packaging pilots within the SBS Region.

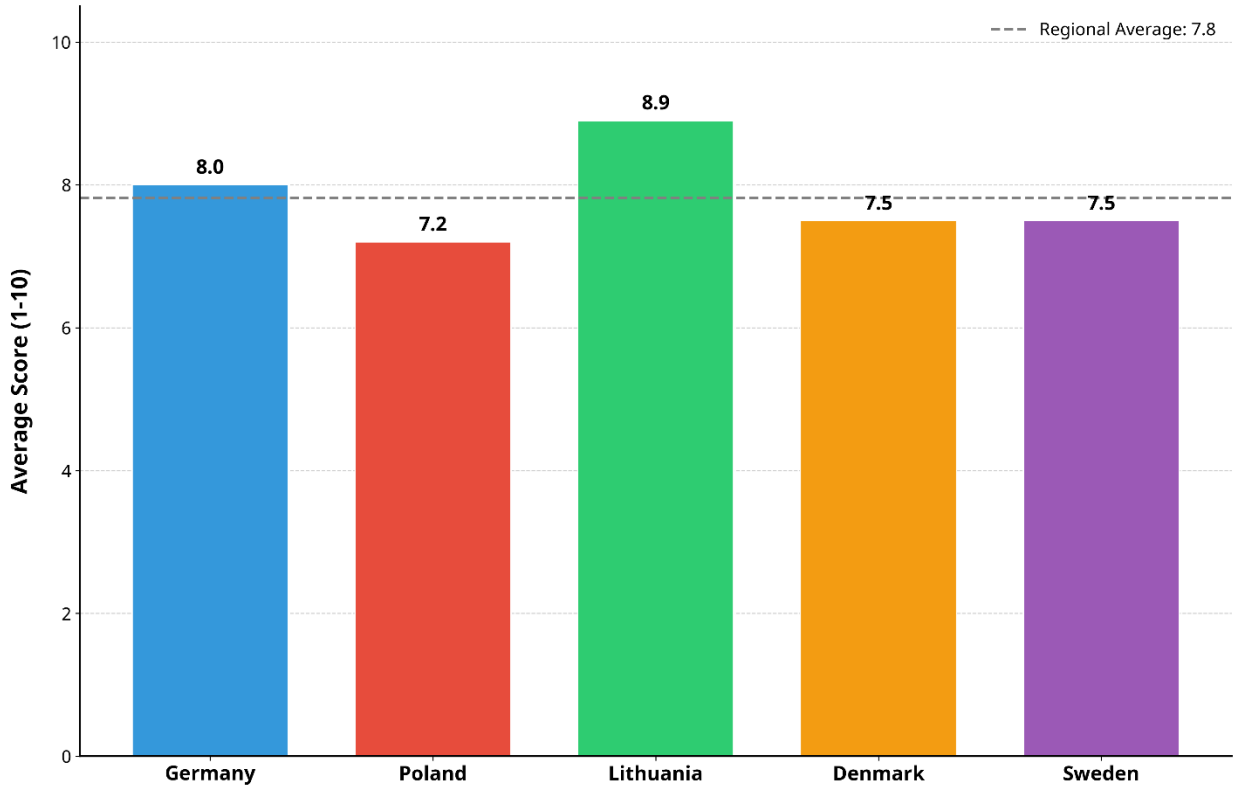


Figure 17 A bar chart comparing the average consumer willingness to participate in a deposit system (on a scale of 1-10) by country.

4.5 Cross-country synthesis and stakeholder group comparison

This section synthesises the findings to provide a comparative analysis across the five SBS partner countries and the key stakeholder groups. The analysis reveals both common patterns and significant variations, highlighting the complex interplay of factors that will shape the transition to a circular economy for paper packaging.

4.5.1 Cross-country synthesis

Across the region, a consistent narrative emerges: there is universal recognition of the need for circularity, but the path forward is fraught with shared challenges. At the same time, each country's unique context creates different levels of readiness. Table 27 summarises key consumer metrics by country, indicating that while Germany may be the most structurally ready, the highest levels of consumer motivation are currently found in Lithuania, presenting a unique opportunity to pilot reuse systems in that market.

Table 27 Summary of key consumer metrics by country

Country	Willingness to Return	Acceptance of Reused Packaging	Deposit System Score	Business Readiness
Germany	66.7%	96.3%	8.0/10	High, but cost-sensitive
Poland	66.7%	86.7%	7.2/10	Moderate, infrastructure-focused
Lithuania	85.2%	96.3%	8.9/10	Highest consumer motivation
Denmark	76.2%	90.5%	7.5/10	Seeking policy guidance
Sweden	85.0%	95.0%	7.5/10	High awareness, convenience-driven

4.5.2 Stakeholder group comparison

A comparison of the four stakeholder groups reveals critical differences in perspective, priorities, and perceived barriers. The most significant result is the dramatic gap between business perception and consumer reality, as illustrated in Figure 18.

The survey suggests a potential perception gap within the small e-commerce sample: while e-commerce respondents expressed doubts about customer return behaviour, consumer responses indicate a higher willingness to participate in convenient return systems. Furthermore, 93% of consumers would accept receiving their orders in a reused box. This perception gap is a critical barrier, as it discourages e-commerce businesses from investing in or piloting return models. Bridging this gap by disseminating accurate consumer data is a primary strategic priority.

Across all business groups, cost remains the dominant concern. In contrast, consumers are driven by practicalities. Their willingness is high, but it is conditional on systems being easy to use and, ideally, rewarding. They emerge from this analysis not as a barrier, but as a key, untapped enabler for the transition to a circular economy. The challenge is to design systems that are convenient for consumers and cost-effective for businesses. This task is made more difficult by the perception gap among customer-facing companies.

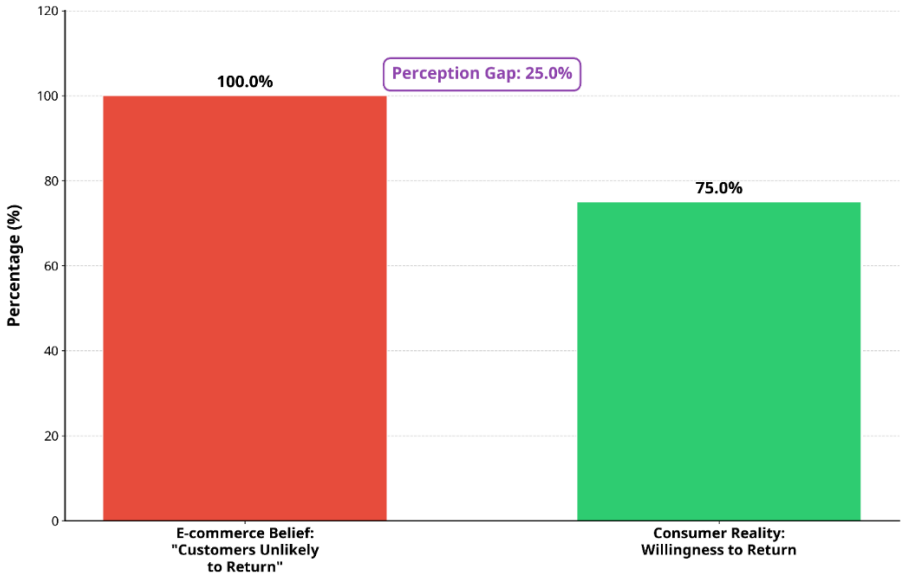


Figure 18 A bar chart illustrating the critical perception gap between e-commerce businesses' belief that customers are unlikely to return packaging and the reality of consumer willingness

5. Assessment of paper packaging reuse potential

5.1 Current reuse rates and benchmarks per country

No standardised paper packaging reuse rate is published in national statistics for any SBS partner country. Reuse of paper packaging is currently negligible or limited to early-stage pilots and mandatory foodservice obligations. This section therefore establishes the current circularity baseline through three measurable indicators: (i) the paper packaging recycling rate, (ii) packaging waste generated per capita, and (iii) the binding reuse and waste reduction obligations of Regulation (EU) 2025/40 (PPWR) [17] entered into force on 11 February 2025 and applied from 12 August 2026. It provides the forward-looking regulatory benchmark for the current position of the SBS region.

The PPWR sets the following binding targets directly relevant to paper packaging in the SBS region. Under Article 29, from 1 January 2030, at least 40% of transport packaging (material pallets, rigid plastic containers, and metal canisters but explicitly excluding transport packaging in the form of cardboard boxes, which are exempt from these reuse targets under Article 29) must be reusable within a reuse system, rising to 70% by 2040. For grouped packaging in the form of boxes (excluding cardboard boxes), 10% must be reusable by 2030 and 25% by 2040. Cardboard boxes are explicitly exempt from all reuse targets under Article 29. Under Article 11, all Member States must reduce packaging waste per capita by 5% by 2030, 10% by 2035, and 15% by 2040 compared to 2018 levels. The EU paper and cardboard packaging recycling target stands at 85% by 2030.

5.2 Market size, growth trends and demand projections

5.2.1 European production context

Within CEPI member countries, total paper and board production reached 73.9 million tonnes in 2023, of which packaging grades accounted for 46.2 million tonnes (62.4%) [3]. This represents a historically anomalous low point: Production contracted by 12.8% in 2023, the steepest decline since at least 2000. The decline was driven by destocking, high energy costs, and subdued macroeconomic demand. In 2024, production partially recovered, rising by 5.9% to approximately 77.8 million tonnes, with packaging paper and board leading the rebound at +6.7% [10]. Preliminary CEPI data for 2025 indicate a renewed contraction of approximately 1.5%, attributable to persistent energy cost pressures, sluggish demand, and rising global

trade tensions, with corrugated board holding broadly stable (-0.2%) while folding carton declined (-3.5%) [18]. The 2023 baseline figures used throughout Section 3 therefore reflect a trough condition rather than a structural equilibrium, and medium-term projections must be interpreted accordingly.

5.2.2 Corrugated packaging: volume and growth

Corrugated board (case materials) is the dominant packaging format in Europe and across all five BePacMan partner countries. As documented by FEFCO, European corrugated board production stands at approximately 43.4 to 49 billion m² per year, representing one of the largest material flows in the European packaging economy [4]. At the national level, Germany's case materials production alone reached 9.35 million tonnes in 2023 (79.7% of its total packaging output), and Poland's containerboard production reached 3.40 million tonnes (44.7% of its total packaging output). Case materials are also the dominant import category for Denmark (240,565 tonnes) and Lithuania (124,119 tonnes), confirming corrugated packaging as the structurally central format across the entire region.

5.2.3 Demand drivers

Four structural factors are expected to sustain demand growth for paper packaging and corrugated formats in particular through 2030 in the SBS Region:

E-commerce expansion: Online retail is the primary driver of corrugated box demand across Europe. E-commerce has been a sustained demand driver for corrugated case materials since 2020, with Northern and Eastern Europe with Germany and Poland recording particularly strong growth in corrugated box volumes in 2024. The European e-commerce industry's share of total retail was projected to reach 17.5% by 2025, directly amplifying corrugated packaging volumes [19].

Plastic substitution mandates: The PPWR (Regulation (EU) 2025/40), which enters into application on 12 August 2026, and national single-use plastic bans are systematically redirecting packaging demand from plastic to paper-based formats across food service, retail, and logistics. This substitution effect benefits paper packaging across all sub-grades but is most pronounced for wrappings and cartonboard in food contact applications.

PPWR reuse obligations: Under Article 29 of the PPWR, from 1 January 2030, at least 40% of certain transport packaging formats

including pallets, rigid plastic containers, and metal canisters must circulate within a reuse system, rising to 70% by 2040. Cardboard transport boxes are explicitly exempt from these reuse targets under Article 29 of Regulation (EU) 2025/40. The BePacMan reuse model for corrugated packaging therefore goes beyond current regulatory requirements, representing a voluntary and forward-looking initiative that anticipates future market and regulatory developments rather than responding to an existing legal obligation for this packaging format.

Recovered fibre demand: Sustained corrugated production depends on recovered paper as a primary input. In Germany, corrugated case materials already utilise 108% recovered fibre content (drawing on both domestic collection and imports), while Poland consumed 4.2 million tonnes of recovered paper in production in 2023, representing a utilisation rate of 62%. Europe-wide, the recycling rate for paper and board recovered fibres averaged 75.1% in 2024 [10]. Any expansion of reuse systems that delays packaging entry into the recycling stream must account for the capacity constraints and cross-border dependencies of recovered fibre supply chains, particularly in import-dependent markets such as Denmark and Lithuania.

5.2.4 Waste stream baseline and reduction obligations

Paper and cardboard constitute the single largest fraction of EU packaging waste. In 2023, the EU generated 79.7 million tonnes of total packaging waste, of which 32.3 million tonnes (40.4%) was paper and cardboard, more than double the share of plastic (19.8%) [6]. This figure is directly relevant to quantifying the scale of intervention required: even a modest shift of 5 to 10% of this volume from single-use to reusable formats would represent 1.6 to 3.2 million tonnes annually. The PPWR further requires all Member States to reduce per capita packaging waste by 5% by 2030, 10% by 2035, and 15% by 2040 relative to 2018 levels, creating an obligation for waste reduction that complements the reuse targets.

5.3 Lifecycle tracking: carbon and water footprint analysis

5.3.1 Case study: Germany

The transition from single-use corrugated cardboard to reusable packaging systems introduces a fundamental shift in environmental impact profiles. Though single-use systems generate emissions linearly with every trip due to continuous manufacturing, reusable systems require a

higher initial material investment and incur ongoing reverse-logistics emissions, but amortise the manufacturing footprint over multiple cycles. To evaluate the environmental viability of the BePacMan reuse model, this section establishes a lifecycle assessment (LCA) footprint model using Germany as the primary case study, calculating the critical break-even point at which reuse becomes environmentally preferable.

5.3.2 Baseline footprint of single-use corrugated packaging

Germany, as Europe's largest producer and consumer of paper and board, provides an appropriate baseline for assessing environmental impacts. As outlined in Section 3.2.1, the German paper industry has achieved substantial progress in decarbonisation, reducing CO_2 intensity by 45% since 1995 to 0.526 t CO_2 per tonne of paper produced in 2023. Specific water consumption is currently 8.7 litres per kilogram of paper produced, supported by high recovery rates. When this raw paper is converted into corrugated board packaging (case materials), FEFCO reports a cradle-to-grave carbon footprint of 491 kg CO_2e per tonne of corrugated board [20]. This figure reflects the combined impact of fossil fuel use, biogenic emissions from fiber materials, carbon removals through forest absorption, and direct land-use change. The breakdown is shown in Table 28, which presents the contribution of each emission category to the total carbon footprint.

Table 28 Breakdown of carbon footprint for corrugated board production per tonne (kg CO_2e), by emission category

Category	Fossil GHG Emissions	Biogenic GHG Emissions	GHG Removals	Direct Land-Use Change	Total
Value (kg CO_2e)	669	442	-624	4	491

For modelling purposes, a medium-sized, single-use, single-wall corrugated B2C transport box is assumed to weigh 0.45 kg. This value is slightly above the typical weight range for standard e-commerce corrugated shipping boxes reported in the literature [21], which cited a range of 50 to 430 g. The sensitivity of this assumption is further examined in the corridor sensitivity analysis below. For a typical single-use e-commerce

transport box weighing 0.45 kg, this equates to a lifecycle carbon footprint of approximately 0.221 kg CO_2e and a water footprint of 3.9 litres per box. Because each shipment requires a newly manufactured box, these impacts accumulate linearly: for example, 10 shipments generate 2.21 kg CO_2e as illustrated in Figure 19.

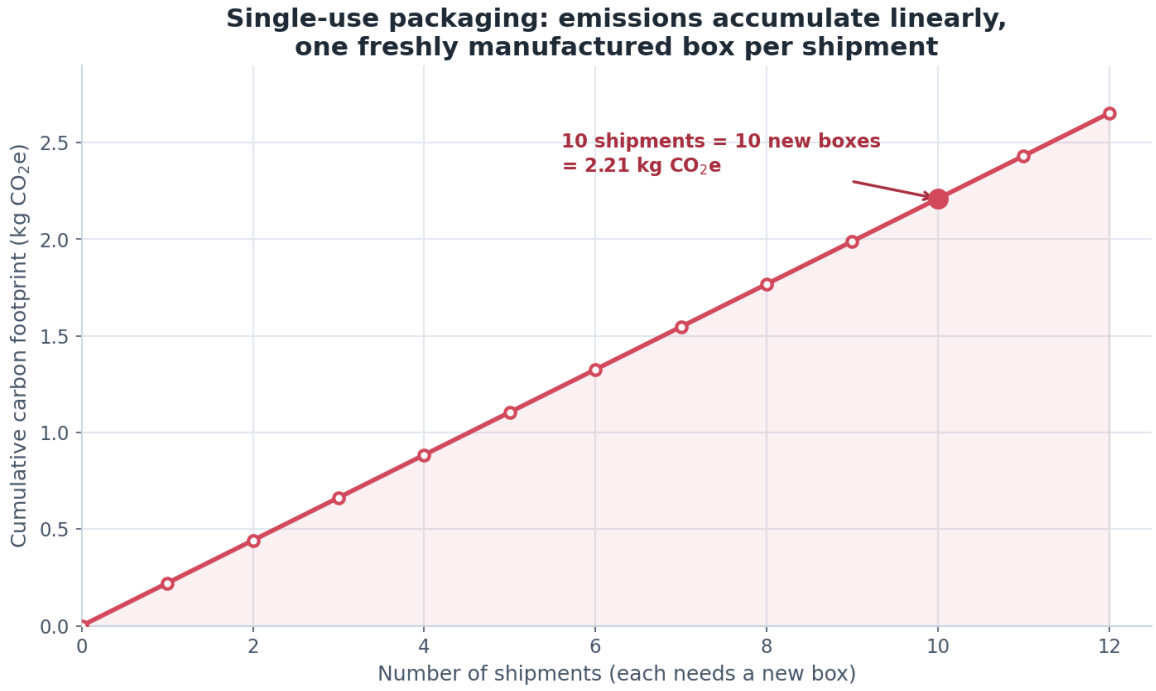


Figure 19 Single-use packaging emissions accumulate linearly, requiring one freshly manufactured box per shipment.

5.3.3 Modelling the reusable packaging lifecycle

Reusable paper packaging needs to be much stronger than single-use boxes so it can survive multiple transport cycles. In this model, it was assumed that a reusable corrugated box weighs about 0.9 kg, which is roughly 2 times heavier than a standard single-use box. This extra weight comes from using double-wall or reinforced construction to make the box more durable. Because of the additional material required, the production footprint of a reusable box is higher, at 0.442 kg CO_2e. Using the same 8.7 litres per kilogram water intensity [7], the reusable box also carries a one-time production water footprint of $0.90 \times 8.7 = 7.83$ litres.

Beyond production, the reusable system introduces two lifecycle phases that are not present in the single-use system:

a. **Reverse logistics**: In 2023, the German paper industry transported 5.6 million tonnes of paper and board products, covering a total of 9.0 billion tonne-kilometres. These logistics operations produced 0.49 million tonnes of CO_2, which corresponds to an average emission intensity of 0.054 kg CO_2e per tonne-kilometre across all transport modes. Empty boxes must be transported back to distribution centres. This 0.054 kg CO_2e/tonne-km figure is an all-mode average and is not used directly in the model; the reverse logistics calculation instead uses the vehicle-specific road freight factors in Table 29, applied in the break-even analysis.

b. **Reprocessing**: Returned boxes undergo visual inspection and relabelling only. Unlike plastic or metal reusable containers that require hot-water washing and detergent processes that generate measurable CO_2 and water consumption per cycle, corrugated board cannot be wet-washed as water degrades its structural integrity. Reprocessing therefore involves a dry-cleaning stage, no water consumption, and negligible energy use. CO_2 emissions from this stage are considered negligible for the purposes of this model.

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The full reuse loop, including how the one-time production footprint is amortised across cycles, is shown in Figure 20



Figure 20 The reuse loops. A single production footprint is amortized over multiple use cycles, with reverse logistics forming the primary ongoing environmental burden

For the BePacMan reverse logistics model, road freight is the relevant mode, and the specific vehicle used materially affects the result. CE Delft's STREAM Freight Transport 2020 report [22] provides vehicle-specific emission factors for road freight, reproduced in Table 29 and Figure 21.

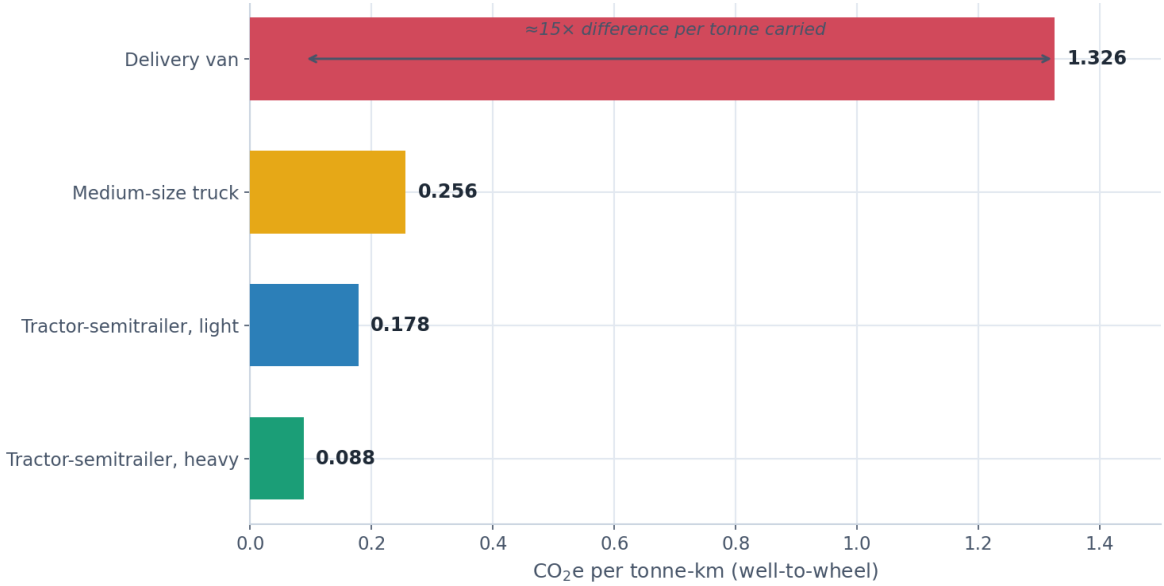


Figure 21 Vehicle choice dominates reverse-logistics emissions. A delivery van emits about 15 times more carbon per tonne-km than a fully-loaded heavy truck

Table 29 Road freight emission factors by vehicle type

Vehicle	CO_2e per tonne-km (WTW)	Realistic use in BePacMan
Delivery van (2,000-2,500 kg empty)	1.326 kg	Local/last-mile collection
Medium-size truck	0.256 kg	Regional consolidation
Tractor-semitrailer, light load	0.178 kg	Cross-border, smaller volumes
Tractor-semitrailer, heavy/full load	0.088 kg	Cross-border, consolidated freight

These figures are independently confirmed by ICCT's (2023) analysis of European heavy-duty vehicle reporting, which finds the most common European heavy truck group averages 0.052 kg CO_2e per tonne-km [23] ,

which is consistent with the 0.088 kg figure for heavy, fully-loaded tractor-semitrailers.

Best-case vehicle: the heavy tractor-semitrailer (0.088 kg CO_2e/t-km) is approximately 15 times more carbon-efficient per tonne of cargo than a delivery van (1.326 kg CO_2e/t-km), because its much larger payload spreads the same fuel burn across far more cargo weight. This single factor, not distance, vehicle age, or fuel type, is the main driver of every break-even result in this section: matching vehicle to leg is more important than minimising distance.

5.3.4 Break-even analysis

The environmental break-even point is the minimum number of use cycles at which a reusable box's cumulative footprint falls below that of an equivalent number of single-use boxes. This is a standard methodology in reuse packaging literature, used by [21], [24], and formally named the environmental break-even point [25]. Each reuse cycle requires the box to travel twice: the reverse logistics leg (customer back to the cleaning hub) and the redelivery leg (hub back out to the next customer). The initial forward delivery to the first customer is excluded from this count, since it is identical in both the single-use and reusable systems and therefore cancels out of the comparison; only the legs unique to the reuse system are counted. Both legs are counted in full. Using a delivery van for a 50 km route, the realistic vehicle for last-mile collection, the combined per-cycle logistics Footprint is: 2 × (0.0009 t × 50 km × 1.326 kg CO_2e/tonne-km) = 0.1193 kg CO_2e per cycle. Solving $N \times 0.221 = 0.442 + N \times 0.1193$ gives $N = 4.35$, rounding up to a break-even of 5 trips. With heavier, more efficient vehicles the picture improves substantially, as shown in Table 30 below. Since reprocessing requires negligible water regardless of vehicle or distance, the water break-even ($N = 7.83 \div 3.9 = 2.01$) remains 3 trips in every scenario.

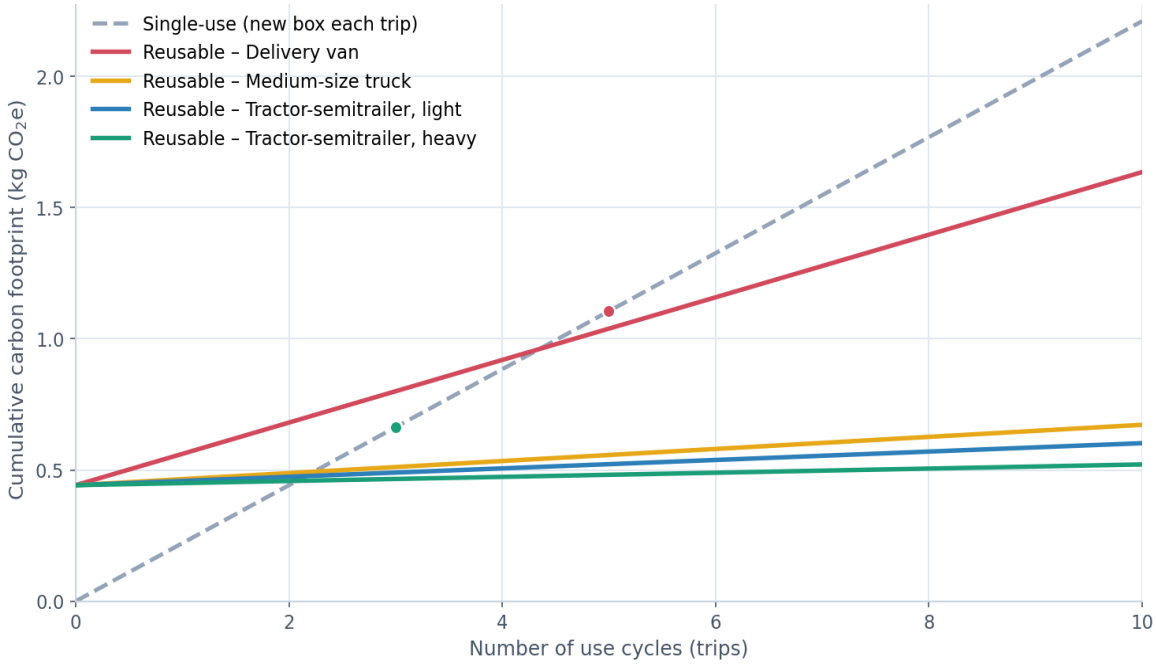


Figure 22 Cumulative carbon footprint at a 50 km return route. Efficient trucks recoup the reusable box in 3 trips, while vans need 5.

Table 30 Break-even point at 50 km baseline, by vehicle type

Vehicle	Logistics CO_2e per cycle	Carbon break-even
Delivery van	0.1193 kg	5 trips (N= 4.35)
Medium-size truck	0.0230 kg	3 trips (N= 2.23)
Tractor-semitrailer, light	0.0160 kg	3 trips (N= 2.16)
Tractor-semitrailer, heavy	0.0079 kg	3 trips (N= 2.07)

Best case: heavy tractor-semitrailer breaks even faster (3 trips), leaving a 2-trip safety margin within the project's 5-trip design lifetime.

In the worst-case scenario, a delivery van requires all five trips to reach break-even. If the box is lost, damaged, or retired one cycle early, it will not recover its higher production footprint. Van logistics should therefore be treated as a calculated-risk option rather than a default. As a practical rule of thumb: restrict van-based return collections to local urban loops under 90 km, and require consolidated freight for all longer distances.

5.3.5 Logistics architecture: decentralised versus centralised returns

The supply chain design is identified as a primary determinant of reuse carbon performance, distinguishing decentralised from centralised systems. In both architectures, the full cycle reverse logistics to the hub plus redelivery back out to the next customer is counted, consistent with the methodology established above. Figure 23 contrasts the two architectures.

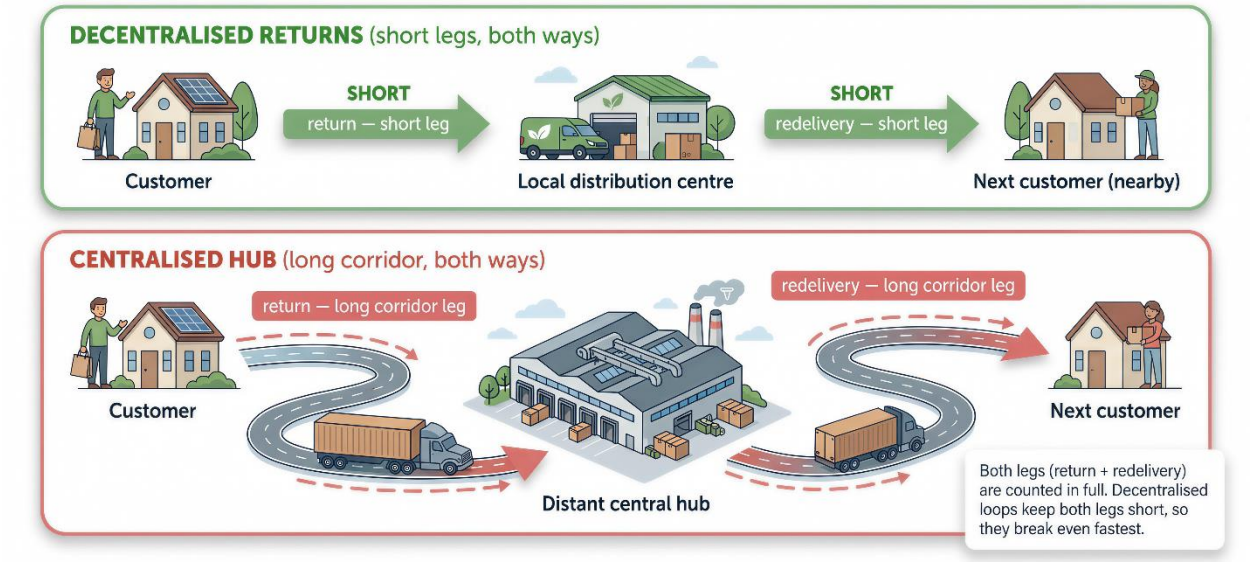


Figure 23 Logistics architecture comparison. Decentralised loops keep both legs short, outperforming centralised hubs at every distance

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In a decentralised model, the box returns to and is redelivered from the same local distribution centre, so both legs use the short local distance. In a centralised model, the box travels to a distant central hub and is redistributed back out over the same long distance, so both legs use the full corridor distance. Applying realistic vehicle assignment by corridor distance, Figure 24 and Table 31 show that BePacMan's local, regional and cross-border corridors remain viable within a break-even range of three to six trips, provided heavy consolidated freight is used for the longer cross-border legs rather than vans, and consistent with the conservative 5-trip design lifetime adopted in this model.

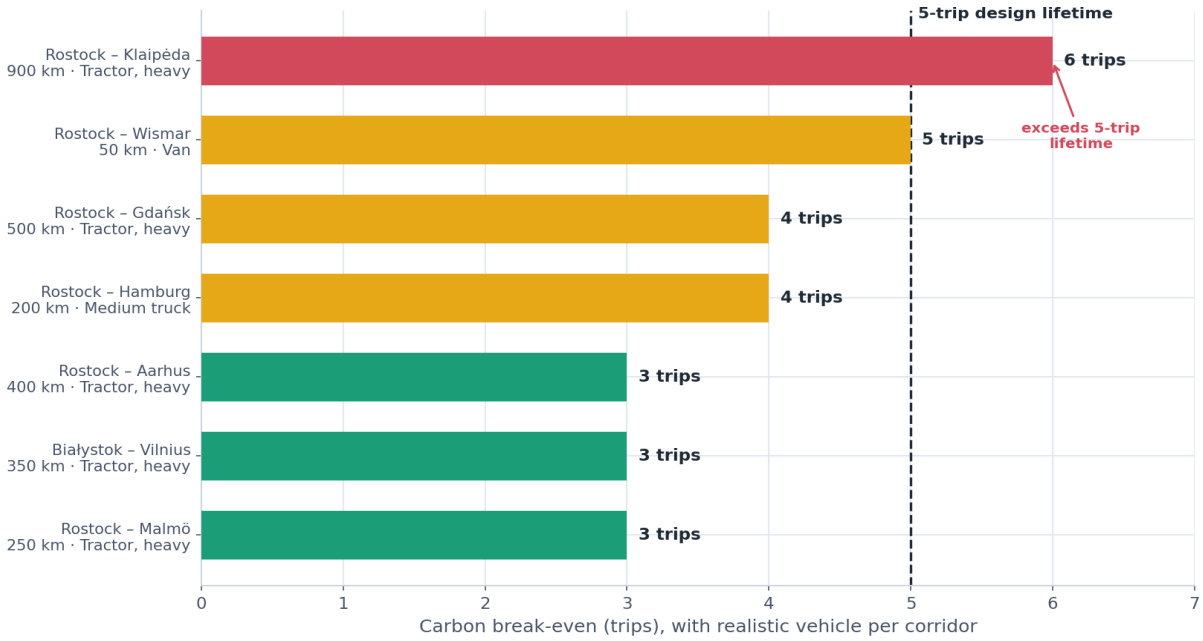


Figure 24 Carbon break-even across illustrative BePacMan corridors

Table 31 Break-even by BePacMan corridor, realistic vehicle assignment

Corridor	City Pair	Distance	Realistic vehicle	Break-even
Local urban loop	Rostock - Wismar	50 km	Van	5 trips
Regional	Rostock - Hamburg	200 km	Medium truck	4 trips
Germany - Sweden	Rostock - Malmö	250 km	Tractor, heavy	3 trips
Germany - Denmark	Rostock - Aarhus	400 km	Tractor, heavy	3 trips
Germany - Poland	Rostock - Gdańsk	500 km	Tractor, heavy	4 trips
Poland - Lithuania	Białystok - Vilnius	350 km	Tractor, heavy	3 trips

Germany - Lithuania	Rostock - Klaipėda	900 km	Tractor, heavy	6 trips

NB: The city pairs and distances in this table are illustrative examples, selected to demonstrate how transport distance and vehicle type affect the reusable packaging system's environmental break-even point. The city pairs and distances are illustrative. They demonstrate how transport distance and vehicle type affect break-even performance and should not be interpreted as confirmed operational routes for the BePacMan project.

The corridor analysis highlights both best and worst-case outcomes. The Germany to Denmark route (400 km, heavy tractor) represents the best-case, reaching carbon break-even in only three-trips, which is the fastest of any corridor tested and leaves a two-trip margin within the five-trip design lifetime. In contrast, the Germany to Lithuania (Klaipėda) corridor illustrates the worst-case, requiring six trips to reach break-even one more than the conservative five-trip design lifetime. At the fifth-trip, the reusable system has accumulated 1.1548 kg CO_2e compared to 1.1050 kg CO_2e for five singles-use boxes, leaving the reusable option 0.0498 kg CO_2e worse off at retirement. Even under optimal vehicle assignment, this corridor does not achieve a net carbon saving within the model's lifetime assumption and should therefore be paired with a higher-durability box design or excluded from claims of guaranteed carbon benefit.

To extend the corridor-specific results above into a general reference, Figure 25 and Table 32 present the full break-even point for each vehicle type across the entire 50-1000 km range, calculated using the same double-leg methodology (return plus redelivery, both counted).

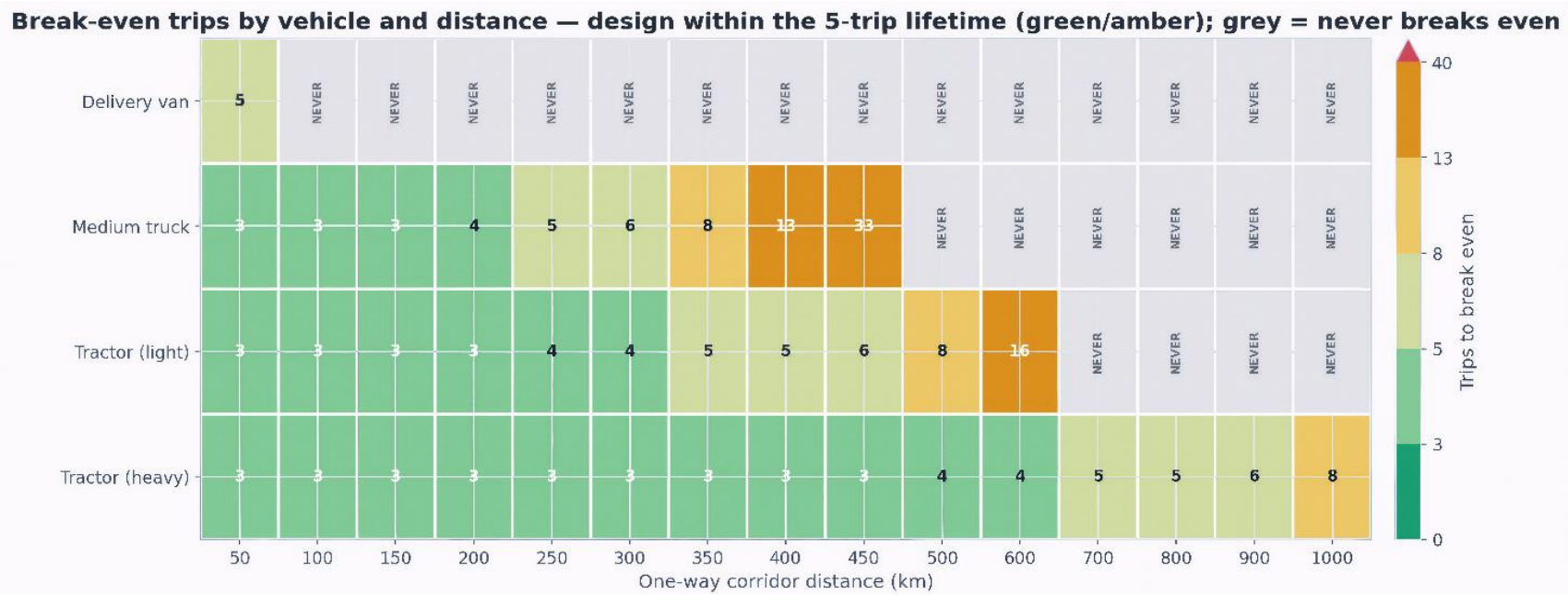


Figure 25 Break-even trips by vehicle and distance. The green and amber zones represent viable reuse within the 5-trip lifetime; grey indicates the reusable box never breaks even.

Table 32 Break-even point (trips) by vehicle type, 50-1000 km, full double-leg accounting

Distance	Van	Medium truck	Tractor, light	Tractor, heavy
50 km	5	3	3	3
100 km	NEVER	3	3	3
150 km	NEVER	3	3	3
200 km	NEVER	4	3	3
250 km	NEVER	5	4	3
300 km	NEVER	6	4	3
350 km	NEVER	8	5	3
400 km	NEVER	13	5	3
450 km	NEVER	33	6	3
500 km	NEVER	NEVER	8	4
600 km	NEVER	NEVER	16	4
700 km	NEVER	NEVER	NEVER	5
800 km	NEVER	NEVER	NEVER	5
900 km	NEVER	NEVER	NEVER	6
1000 km	NEVER	NEVER	NEVER	8

NEVER indicates the reusable system does not break even within its 5-trip design lifetime at that distance; the box would need to be retired and recycled while still carrying a higher footprint than single-use. Vans remain viable only up to 92.6 km one-way; medium trucks up to 479.6 km; light tractor-semitrailers up to 689.8 km; heavy tractor-semitrailers up to 1,395.2 km covering virtually every BePacMan cross-border corridor.

While industrial literature reports corrugated boxes can achieve 20-30 reuse cycles, BePacMan's reuse model uses a conservative, fixed lifetime assumption of 5 trips per reusable box, reflecting realistic wear, handling and loss in a consumer logistics system. This scenario also applies full logistics accounting: both the return trip (customer to hub) and the redelivery trip (hub to next customer) are counted for every cycle.

Both legs are counted because this is the more rigorous and conservative approach.

Over 5 uses, 5 single-use boxes generate 5 × 0.221 = 1.105 kg CO_2e and 5 × 3.9 = 19.5 litres of water. One reusable box used 5 times generates 0.442 kg CO_2e (production, once) plus 5 × (return + redelivery) logistics emission factor, plus 7.83 litres of water (production, once, since reprocessing requires no water). The resulting savings are summarised in Figure 26 and Table 33.

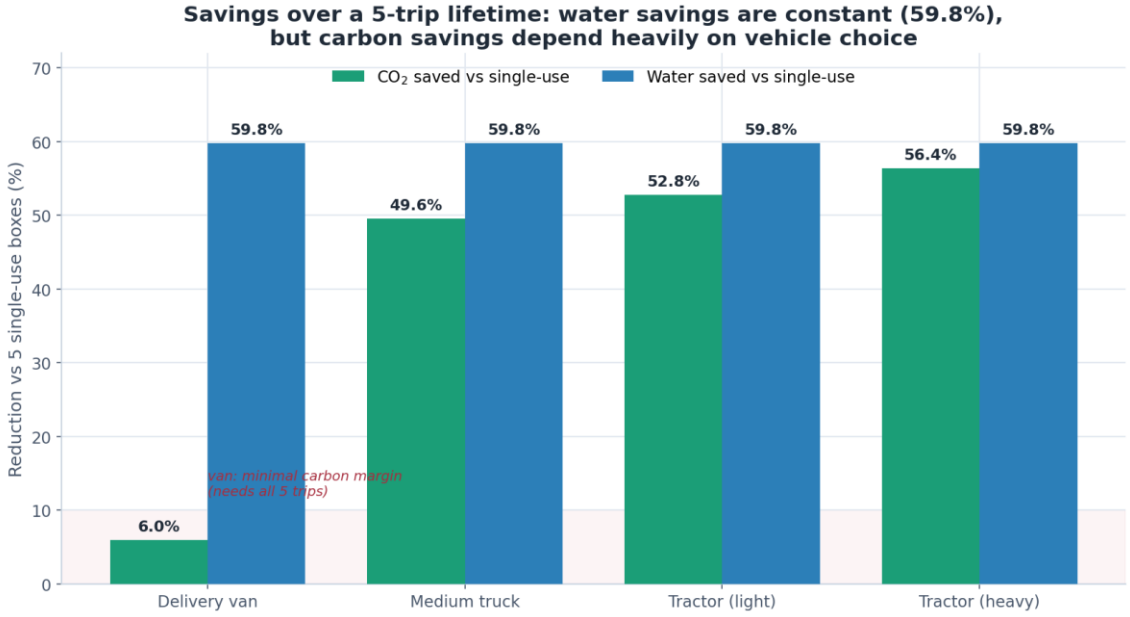


Figure 26 Savings over a 5-trip lifetime. Water savings are constant (59.8%), but carbon savings depend heavily on vehicle choice and distance

Table 33 Five-trip lifetime result, by vehicle, full double-leg logistics accounting at 50 km

Vehicle (both legs)	**Total reusable CO_2e (5 uses)**	**CO_2e saved compare to 5 single-use boxes**	**% CO_2 saved**	**% Water saved**
Delivery van	1.039 kg	0.066 kg	6.0%	59.8%
Medium-size truck	0.557 kg	0.548 kg	49.6%	59.8%
Tractor-semitrailer, light	0.522 kg	0.583 kg	52.8%	59.8%

Tractor-semitrailer, heavy	0.482 kg	0.623 kg	56.4%	59.8%

This finding is important for pilot design. When vans are used for both legs of the logistics cycle, the reusable system only surpasses single-use performance at the fifth trip at 50 km. If a box is lost or damaged before completing all five cycles, its impact could be higher than single-use. In contrast, under the model boundary, water savings remain 59.8% because reprocessing is assumed to require negligible water. For truck-based logistics, whether medium or heavy vehicles, the system consistently delivers a robust 50-56% reduction in carbon emissions, regardless of when within the five-trip cycle a box is retired. Vehicle-to-leg matching is the decisive operational variable. Heavy consolidated freight remains viable for cross-border redistribution; van logistics should be reserved for genuinely local, short-distance collection only. Decentralised return loops outperform centralised hubs at every distance tested.

5.3.6 Country-level scaling analysis

The unit-level analysis above establishes the environmental conditions under which a single reusable box outperforms a single-use box. To place this in a regional context, the model is extended to the full apparent consumption of paper packaging in each of the five BePacMan partner countries. Apparent consumption, defined as production plus imports minus exports, is the standard industry measure of domestic demand and is consistent with the methodology applied in Section 3.2 of this report. All figures are drawn directly from that section and represent the most recent available national data. This is an illustrative theoretical maximum scenario, not an operational forecast: it demonstrates the scale of potential impact if the reuse model were applied uniformly across all paper packaging consumption, using the most conservative logistics assumption throughout a delivery van operating a decentralised return loop of 50 km.

For each country with an apparent paper packaging consumption of T tonnes per year, the equivalent number of single-use boxes is $N = T \times 1{,}000 \div 0.45$, applying the baseline box weight of 0.45 kg. Under the reuse model with a five-trip design lifetime, only $N \div 5$ reusable boxes are required to serve the same delivery volume, an immediate reduction of 80% in the number of boxes that must be

manufactured, regardless of country size. This reduction is not an estimate but a mathematical consequence of the five-trip design lifetime. The annual carbon and water footprints follow directly from the formulas validated in Table 34: carbon footprint = 0.2077N kg CO_2e for the reusable system versus 0.221N kg CO_2e for single-use, yielding a saving of 0.0133 kg per delivery (6.0%); water footprint = 1.566N litres for the reusable system versus 3.9N litres for single-use, yielding a saving of 2.334 litres per delivery (59.8%). Table 34 presents these results for all five partner countries.

Table 34 Country-level impact under full apparent consumption of paper packaging, van 50 km decentralised baseline, 5-trip design lifetime

Country	Apparent paper packaging consumption (t/yr)	Equivalent single-use boxes (millions)	Reusable boxes needed 5-trip lifetime (millions)	Boxes no longer manufactured (millions)	CO_2e saved (t/yr)	Water saved (million litres/yr)
Germany	8,405,000	18,678	3,736	14,942	248,414	43,594
Poland	4,800,000	10,667	2,133	8,533	141,867	24,896
Sweden	751,480	1,670	334	1,336	22,210	3,898
Denmark	387,480	861	172	689	11,452	2,010
Lithuania	278,683	619	124	495	8,237	1,445
Total	14,622,643	32,495	6,499	25,995	432,180	75,843

Across all five countries, transitioning to the reuse model under this scenario would eliminate the need to manufacture approximately 26 billion single-use boxes per year, an 80% reduction that holds uniformly regardless of country size. Germany and Poland together account for over 90% of this regional impact, consistent with their dominant positions in European paper packaging production and consumption.

Beyond carbon and water, the country-level analysis reveals a third significant saving: a

reduction in the total weight of paper packaging material that must be manufactured. Although each reusable box is heavier than a single-use box (0.90 kg versus 0.45 kg), producing only one-fifth as many boxes results in a net material consumption of (N ÷ 5) × 0.90 kg = 0.40 × N × 0.45 kg that is, 40% of the original single-use tonnage. Across all five countries, total apparent paper packaging consumption of 14,622,643 tonnes per year falls to 5,849,057 tonnes of reusable box production required, a reduction of 8,773,586 tonnes per year, equivalent to a 60% decrease in raw paper packaging material consumed. This finding is directly relevant to the packaging waste reduction obligations imposed on all five countries by the EU Packaging and Packaging Waste Regulation, which requires a 5% reduction in per-capita packaging waste by 2030 relative to 2018 levels.

It is important to note that these figures represent a theoretical upper bound applicable to all paper packaging grades, case materials, cartonboard, wrapping papers, and other packaging paper across all sectors and end uses. The figures should therefore be interpreted as an illustration of potential scale rather than a forecast of achievable savings. Furthermore, the 6.0% carbon saving in Table 34 reflects the most conservative logistics assumption; applying medium trucks or heavy tractor-semitrailers, as recommended for regional and cross-border routes in Tables 31 and 32, would raise this figure to between 49.6% and 56.4% while leaving the 59.8% water saving and the 60% material reduction entirely unchanged.

The sensitivity of these results to two key input assumptions is worth noting.

Regarding design lifetime: the five-trip assumption used throughout this model is deliberately conservative. At eight trips, the material saving increases from 60% to 77.5%, and at ten trips to 82%, with carbon and water savings improving proportionally. Industrial literature confirms that 20-30 reuse cycles are achievable for corrugated boxes under optimal conditions, meaning the figures in Table 34 represent a lower-bound estimate of the regional potential.

Regarding box weight: the assumptions of 0.45 kg for single-use and 0.90 kg for reusable boxes represent mid-range estimates from available literature. Lighter single-use boxes would reduce the carbon savings marginally, while heavier reusable boxes would extend the break-even point.

5.4 Potential economic savings from reuse

The environmental savings established in Section 5.3 have direct economic implications. Because the reuse model replaces five single-use boxes with one reusable box over a five-trip design lifetime, it reduces the volume of paper packaging manufactured by 60%. Packaging procurement costs and EPR compliance fees would therefore decline proportionally. This estimate excludes the operational costs of collection, inspection, redistribution, and any deposit-return mechanism. A company currently spending EUR 500,000 per year on single-use paper packaging, for example, could expect to reduce that expenditure to approximately EUR 200,000 under full adoption of the reuse model, saving EUR 300,000 annually before accounting for the operational costs of the return system. EPR fees, which are charged per kilogram of packaging placed on the market, decrease by the same 60 per cent; in Sweden alone, where the 2026 EPR rate for paper packaging stands at SEK 6.67/kg [26] (equivalent to approximately EUR 587/tonne at the June 2026 exchange rate), this represents a substantial compliance saving. The 59.8 per cent reduction in production water use identified in Section 5.3 further reduces mill water costs in proportion. This illustrative gross saving excludes collection, inspection, redistribution, deposit management, and other operational costs associated with the reuse system.

5.5 Strategic collaboration opportunities

The findings of this report highlight four interconnected areas of strategic collaboration that would strengthen a reuse system in the SBS Region. The established trade flows between Sweden, Germany, and Poland provide a logistics backbone for reverse packaging, with the Rostock-Gdańsk corridor (500 km, carbon break-even in four trips with heavy freight) emerging as the most operationally mature starting point. Lithuania, with the highest consumer return willingness in the survey (85.2%) and its established role as a corrugated packaging converter and re-exporter, Lithuania may be suitable for evaluation as a regional collection and consolidation hub. A deposit-return mechanism offers the most practical way to translate consumer willingness into actual return behaviour, supported by 65.9% of consumers across all five countries and an average participation willingness of 7.82 out of 10; this directly addresses the perception gap where e-commerce businesses believe consumers will not return packaging, despite

75% of consumers stating they would if a convenient system existed. The design and operation of a reuse system require a multi-stakeholder governance model that distributes costs and responsibilities across producers, logistics providers, e-commerce businesses, and consumers, with the BePacMan partnership itself serving as the central driver for building such a collaborative structure.

6. Conclusions and recommendations

The analysis indicates that reusable corrugated packaging has environmental potential across the five BePacMan partner countries, but its performance depends strongly on the number of completed use cycles and the vehicle used for reverse logistics. Under the model assumptions, a reusable box reaches carbon break-even after three to five trips and reduces water consumption by 59.8%. Carbon savings over five trips range from 6.0% with van logistics to 56.4% with heavy consolidated freight. The pilot should therefore prioritise short-distance van collection and consolidated freight for regional and cross-border redistribution. The five-trip design lifetime should be treated as a minimum operational threshold, particularly for van-based routes, because early loss or damage may eliminate the carbon benefit. The model also indicates substantial theoretical material and water savings when reuse is applied at scale. These results represent an upper-bound scenario rather than an operational forecast because the calculation applies the model to all paper-packaging consumption. The stakeholder survey indicates a positive basis for further testing, although the business samples are small and should not be treated as statistically representative. The next phase should validate packaging durability, return rates, user incentives, reverse-logistics costs, and actual reprocessing requirements through a controlled pilot. The findings and break-even thresholds presented in this report can serve as baseline indicators for monitoring in Work Package 3.

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