Technical Report

GAPL 2 Project

Green Air Pharma Logistics

with a focus on Tertiary Packaging

PHARMA.AERO

APRIL 2025

I. Introduction

The Life Science sector, while dedicated to saving lives, contributes significantly to the global carbon footprint[1]. At the global level, regulations on climate issues are increasing. The sector is also faced with a scarcity of certain resources, which can have an impact on their cost structure and finally their profitability.

In 2023, Pharma.Aero launched the Green Air Pharma Logistics (GAPL) project suite, focusing on sustainability in Life Science supply chain logistics. The first GAPL project (GAPL 1 – Focus on Green Lane) explored the concept of a sustainable air lane and developed a set of standards, indicators and measurements to qualify and quantify it. This second project, GAPL 2, addresses tertiary packaging, a crucial component for product protection with significant sustainability improvement potential. The project focused on a critical challenge: balancing packaging integrity and performance with measurable sustainability.

Only through cross-functional alignment and collaboration can the sector achieve a sustainable Life Science air transport system. Pharma.Aero engaged its Value Chain Stakeholders (later referred to as "VCS") – Life Science manufacturers, freight forwarders, airlines, airports, cargo handlers, solution providers, etc. – to actively participate in all project phases. This report presents the project's findings, including sustainability trends, key selection criteria, proposed integration with the Lane Sustainability Readiness Index (LSRI) (GAPL 1 findings), and pathways for collaborative action.

This technical report, designed exclusively for Pharma.Aero members, outlines the research and findings from the project's collaborative working groups, aiming to:

- Define assessment criteria for responsible selection and qualification of packaging and consumables.
- Foster innovation and reduce environmental impact while maintaining regulatory and quality compliance.

This document is intended for decision-makers and contributors across the entire Life Science air cargo value chain, including:

- Procurement and sourcing teams responsible for the selection and contracting of packaging solutions and consumables.
- Supply chain and logistics functions that define shipping lane readiness and operational feasibility.
- Sustainability and corporate responsibility leaders driving environmental performance and reporting.
- Packaging design and research & development teams involved in the innovation and qualification of new materials and technologies.
- Airlines, ground handling agents, and airport authorities tasked with operational implementation, waste management, and circular economy practices.

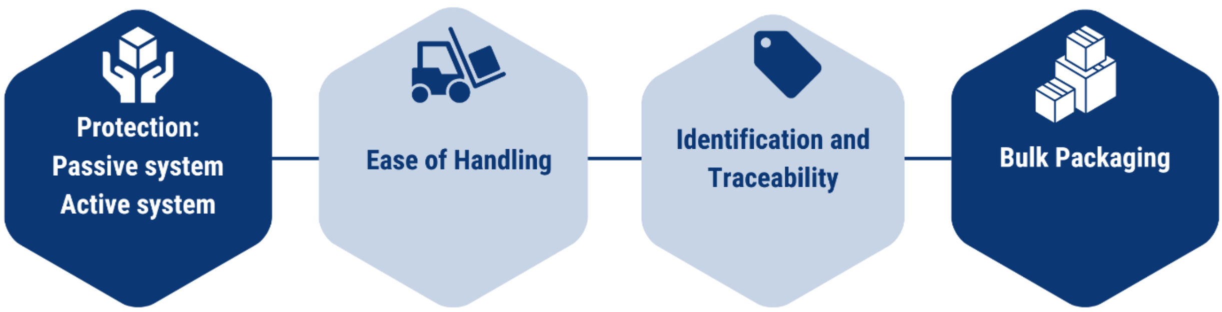
[1] A carbon footprint refers to the Greenhouse Gas (GHG) emissions including carbon dioxide (CO_2), methane (CH4) and nitrous oxide (N_2O) associated with an organisation, product, or service over a specific time.

II. Project Charter

1. Project Objectives

The role of Life Science manufacturers is crucial in selecting and qualifying tertiary packaging, the outermost protective layer for products during transportation and storage. This packaging safeguards secondary packaging from physical damage and environmental factors, while optimizing handling and logistics. Though typically removed before reaching the end consumer, it is imperative for ensuring product safety, integrity, and compliance with strict industry regulations.

The term Tertiary Packaging refers to different elements such as Active Containers, Passive Containers, Thermal Blankets & Covers, Pallets (Wooden / Plastic), Cargo Nets, Straps, Edge Protectors. For a detailed breakdown, click to access Chapter III.2 Research: Current Tertiary Packaging Types and Appendix A – Overview of tertiary packaging elements and stakeholder roles.



Key features of tertiary packaging

This project focused on protection, which is the main element on which the VCS involved can have an impact in terms of sustainability. The aim was to define sustainability criteria to integrate into tertiary packaging selection to reduce impact and improve industry practices.

Tertiary packaging decisions are traditionally driven by technical performance and cost considerations. However, sustainability is becoming an important consideration for shippers and logistics players due to heightening regulatory requirements and urgency to reduce Scope 3 emissions. But they are facing various challenges such as:

- Absence of standardized assessment tools and framework
- Limited application and interpretation of LCAs
- Insufficient data-sharing from packaging suppliers
- Challenges in reverse logistics
- Good practices and innovations have not been properly qualified and quantified and recognized by the industry
- Lack of concerted efforts by the industry in pursuit of sustainable packaging

While the Pharma.Aero GAPL 1 project focused on establishing a Lane Sustainability Readiness Index (LSRI) - a comprehensive framework for assessing sustainability readiness across airlines, airports, and ground handlers, the GAPL 2 initiative takes it a step further. It defines a process and a set of indicators and sub-indicators to evaluate the sustainability impact of tertiary packaging. As a result, the enhanced LSRI helps stakeholders to identify and adopt sustainable packaging solutions that align with both environmental goals and transport requirements.

2. Project Team

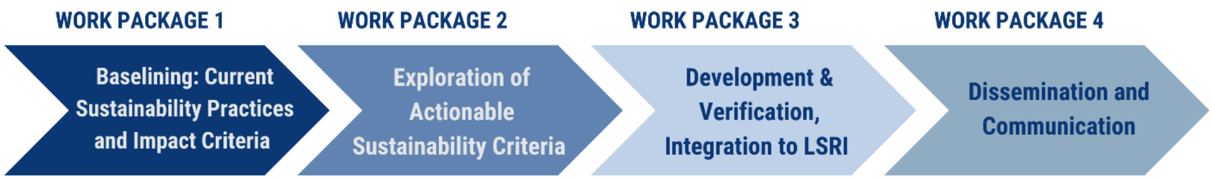
Project Role	Full Name	Organization
Board Liaison	Samuel Speltdoorn	Brussels Airport
Project Lead	Olav Glorvigen	Cargolux
Project Leads	Claire Jung Gergely Szorcsik	Zoetis
Content Review	Jaisey Yip Yue Ming	Changi Airport Group
Project Manager	Céline Crahay	3CeL
Project Experts	Anne-Catherine Trinon Fany Ramadier	Cap Conseil
Project Coordinator	Sara Van Lerberghe	Pharma.Aero
Secretary General	Frank Van Gelder	Pharma.Aero

3. Project Structure and Methodology

Using a three-phase methodology, the GAPL 2 project examined stakeholder perspectives and identified sustainable solutions for tertiary packaging in air transport. VCS were invited to participate and contribute to different phases of the project.

1. Baseline: An online qualitative study to assess VCS maturity levels and current sustainability practices, establishing baseline insights. A global value chain mapping then engaged stakeholders across the different stages of packaging—design, production, usage and end-of-life management—to build a holistic understanding of challenges, opportunities and key sustainability indicators.
2. Exploration: A large-scale workshop with 163 participants refined major sustainability challenges, generated solutions and provided diverse perspectives.
3. Deployment and verification: Insights from previous phases informed the development of a preliminary sustainability framework, further refined through qualitative interviews with packaging providers and validated in a concluding workshop. This systematic and iterative approach successfully integrated economic, ecological, and operational considerations, resulting in a practical and comprehensive sustainability framework for tertiary packaging—serving as a model for addressing sustainability challenges in complex logistics systems.

The GAPL 2 project was structured in four work packages.



WP 1 - Baselining: Current Sustainability Practices and Impact Criteria

- Desk Research

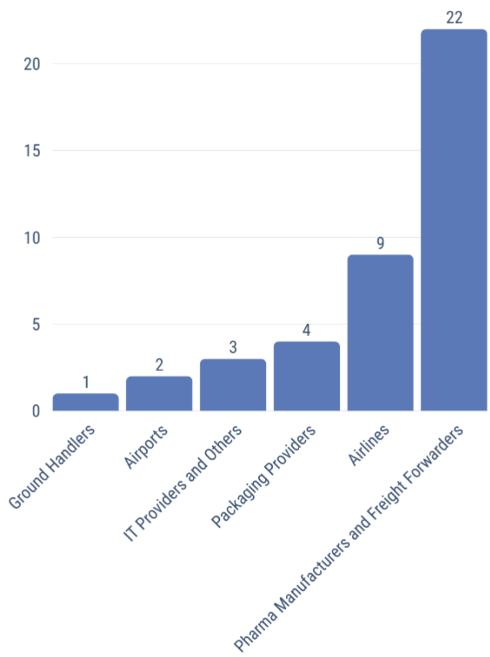
The project began with desk research to collect sustainable practices in tertiary packaging and industry challenges. This phase helped clarify expectations and define key areas of analysis for the GAPL 2 project. An in-depth documentary analysis compared findings with industry trends, regulations, and sustainability innovations. This phase incorporated multiple sources (Bibliography), establishing a solid analytical framework:

  - Reference materials from IATA, TIACA, Pharma.Aero, and studies by the United Nations Environment Programme (UNEP) provided insights into standards and recommendations for sustainable air cargo packaging.
  - Research from academic databases (e.g., ScienceDirect, Wiley Online Library) covering eco-friendly packaging materials, life cycle assessment (LCA), and reverse logistics models applied to Life Science packaging.
  - Market studies and industry benchmarks with reports from McKinsey, Deloitte, and BCG showcasing strategies adopted by leading companies to enhance supply chain sustainability.

- Survey Dissemination & Analysis

Sustainable practices in the air cargo industry were assessed through a category-specific survey (Shipper/FF, Airline, GHA, Airport, Packaging Providers, IT Providers/Others). During summer 2024, the questionnaire was sent online to 89 Pharma.Aero members, achieving a 57.3% response rate.

Each participant completed a list of category-specific questions (Appendix B – Survey Questions) covering tertiary packaging selection, including type, criteria, best practices, and expectations for the GAPL 2 project). The survey analysis is detailed in Chapter IV, GAPL 2 Industry Consultation - Key Findings and Takeaways.

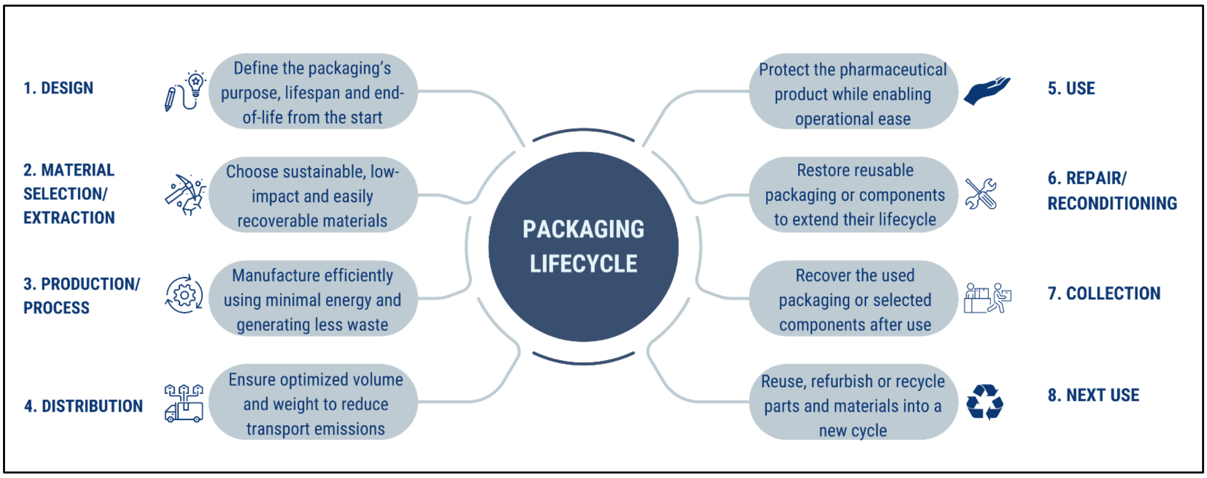


- Workshop 1: Value Chain Canvas

Following the survey, an online collaborative workshop brought together 50 participants from 25 companies representing the value chain, to define assessment criteria for tertiary packaging across the value chain in life-sciences air shipments. The objectives of the workshop were to:

- Share an understanding of the life cycle approach of tertiary packaging
- Identify ways to improve the sustainability of the value chain by applying the principles of the circular economy (Appendix C – Circular economy & sustainable procurement).

Two representatives of each VCS category were selected to share key figures and best practices enriching the global discussion. Participants used interactive tools allowing them to share, visualize and organize input. They identified the following touchpoints in the packaging lifecycle to improve sustainability practices: Design, Material Selection, Production, Distribution, Disposal. At each touchpoint, best practices as well as pain points were identified.



Considering the pain points, the participants brainstormed through specific, open-ended "How might we" (HMW) questions focusing on packaging sustainability. These challenges were then refined and prioritized through collaborative discussions on impact, feasibility and viability outcomes.

At the end, four major HMW challenges were identified:

- *How might we rethink single use packaging materials, to meet 100% recycling targets and to avoid landfill waste?*
- *How might we rethink repositioning strategies, to meet our goal of lowering CO_2 emissions and to avoid transporting empty containers by airfreight?*
- *How might we reduce the cost of reverse logistics for reusable pallet shippers, to meet our cost-saving targets and to avoid new production cycle?*
- *How might we reuse 100% of thermal blankets, to minimize waste and to avoid additional costs?*

The workshop enabled a shared understanding of the current value chain and challenges for implementing sustainable strategies which were key inputs to WP 2.

WP 2 - Exploration of Actionable Sustainability Criteria

Leveraging the insights from WP1, a large-scale workshop with 163 participants was organized during the Pharma Logistics Masterclass (PLMC 2024) in Dallas Fort Worth. Divided into small groups, participants engaged in discussing the specific pre-determined *HMW* questions over three sessions. At the end of each session, the paper boards with insights rotated to the next group to allow building on ideas collectively. A "board leader" summarized past discussions to ensure continuity. The process encouraged diverse perspectives to help identify sustainable criteria. The main ideas gathered during the consultation can be found in Appendix D – HOW MIGHT WE? Questions.

The workshop enabled a shared understanding of the current value chain opportunities and identified some actionable sustainable strategies to the identified challenges. The findings are developed in Chapter V, Defining the Criteria to Assess Sustainability of Tertiary Packaging.

WP 3 - Development & Verification, Integration to LSRI

Further building on the findings of WP 1 and WP 2, this work package focused on:

- Identifying solutions and best practices for reducing the environmental impact of tertiary packaging in other industries.
- Developing sustainability assessment indicators – measurable criteria to facilitate procurement decision when selecting packaging options.
- Exploring the application of these indicators on the Lane Sustainability Readiness Index (LSRI), a tool used to assess the sustainability performance of air cargo routes.

The methodology followed a structured three-step approach:

- Analysis of available Life Cycle Assessments (LCA) to establish a foundational understanding of the environmental impacts of tertiary packaging options.
- One-to-one interviews with packaging providers to gather industry insights, identify the most relevant criteria and formulate simple questions to evaluate each criterion. The participating providers were Cold Chain Technologies, Corplex, Emball'iso, Envirotainer, Exam Packaging, QProducts & Services, and SkyCell.
- Online workshop with decision-makers (Life Science Manufacturers, Freight Forwarders, Airlines) to validate or refine a sustainability evaluation framework. 35 participants collaboratively challenged and defined key criteria for selecting tertiary packaging solutions.

This data-driven process aligned with industry current and innovative practices to create a customized evaluation grid, consolidating key sustainability criteria (climate, water, biodiversity, materials etc.) and defining simple questions for assessment.

WP 4 - Dissemination and Communication

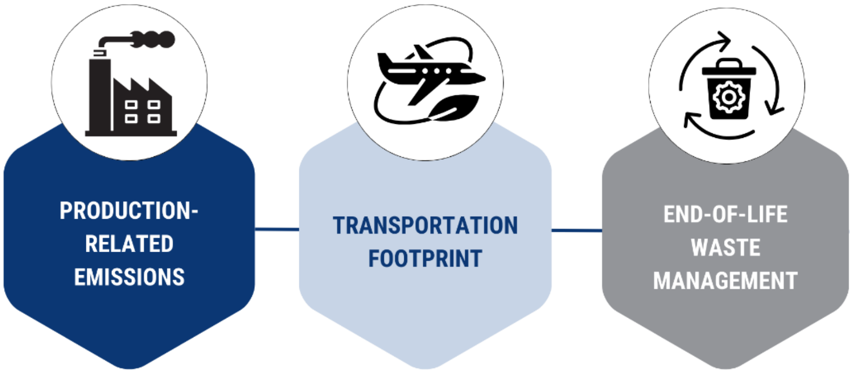
The project team gathered the research findings, insights, and conclusions in this comprehensive Technical Report (exclusive for Pharma.Aero membership). A high-level White Paper will be shared with the broader audience, in the spirit of continuous knowledge dissemination and industry collaboration.

III. Setting the Scene

1. Tertiary Packaging for Life Science Shipments

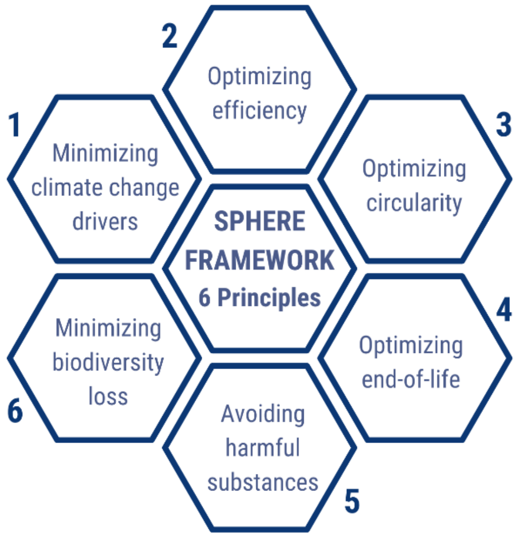
Tertiary packaging is essential for protecting Life Science products from damage and environmental risks, but it significantly impacts sustainability by contributing to energy consumption, greenhouse gas emissions, and waste management challenges throughout its lifecycle in the global supply chain.

a. Environmental Impacts



- Production-related emissions: Virgin cardboard, plastic, and wood generate high GHG emissions, with cardboard consuming water and energy and plastics increasing CO_2 output.
- Transportation footprint: Heavier materials like wooden crates raise emissions, while lighter options like corrugated cardboard reduce them. Cold chain logistics adds insulation and protective layers for temperature-sensitive products, increasing weight, complexity, and carbon footprint.
- End-of-life waste management: Improper disposal of tertiary packaging contributes to landfill waste, with plastics breaking down into harmful microplastics. Despite recyclable advancements, logistical barriers often hinder collection and processing, limiting recycling efficiency. Single-use materials like shrink wrap and insulation panels often persist as waste due to low recyclability.

Developed by the World Business Council for Sustainable Development (WBCSD), the SPHERE framework offers a comprehensive approach to evaluating and enhancing packaging sustainability. It integrates six key principles to guide organizations in minimizing environmental footprints while maximizing functionality.



b. Operational Challenges

- Balancing cost and sustainability: Sustainable packaging can lower long-term costs (e.g., lighter weight reducing shipping expenses), but high initial costs and complex qualification processes hinder adoption. Businesses must balance operational efficiency with sustainability, especially for temperature-sensitive products requiring extensive packaging.
- Regulatory compliance related to distribution: The Life Science industry must meet strict regulations to ensure product integrity, requiring documentation for traceability, risk management for disruptions, and validated temperature-controlled packaging. For temperature-sensitive shipments, the use of validated temperature-controlled packaging, continuous monitoring with data loggers and adherence to cold chain standards like ISTA protocols are essential.
- Regulatory compliance related to waste and emissions: Governments and industry bodies are imposing stricter regulations on packaging waste and carbon emissions. For instance, the EU Packaging and Packaging Waste Regulation (November 2024) aims to enforce sustainable packaging solutions and improve recyclability.

2. Research: Current Tertiary Packaging Types

a. Traditional Tertiary Packaging

- Cardboard boxes: recyclable but energy-intensive in production, recyclability often hindered by contamination or logistical inefficiencies.
- Shrink wraps and plastic films: lightweight and moisture-resistant, yet unsustainable due to their low recycling rates.
- Wooden pallets: reusable, but contribute to deforestation and are bulky, increasing shipment weight and transport emissions.

b. Temperature-controlled Containers

- Active systems: powered cooling ensures precise temperature control but increases weight, energy use, and emissions.
- Passive systems: insulated containers with pre-conditioned cooling agents offer lower-emission options but require high energy for pre-conditioning.
- Insulation panels and cooling elements (gel packs: water-based or PCM, dry ice, batteries) also affect sustainability.

c. Airfreight Consumables

While cargo nets, straps, corner protectors secure shipments, thermal blankets protect against weather, radiation, and temperature fluctuations. Although some consumables are single-use, nets, straps, and thermal blankets can be incorporated into closed-loop systems controlled by airlines. Innovations in biodegradable and reusable consumables enhance sustainability.

d. Unit Load Devices

ULDs are reusable containers or pallets built to aircraft standards for efficient cargo transport, optimizing space and protecting shipments. Made from lightweight materials like aluminum or composites, they are managed by airlines and freight forwarders as key infrastructure investments. Unlike consumables, ULDs are all designed for repeated use.

The Life Science industry must prioritize sustainability in packaging decisions by:

- Promoting the design of recyclable and reusable packaging systems.
- Implementing reverse logistics for recovery and reuse.
- Reducing the carbon footprint of manufacturing and operational processes.

As the industry moves toward greater sustainability, understanding the environmental impact of these packaging types is becoming increasingly important. By categorizing and analyzing these packaging solutions, the Life Science air cargo industry can better align its practices with operational, regulatory, and environmental priorities, ensuring functionality and sustainability in equal measures.

3. Innovative Solutions and Emerging Trends

Benchmarking existing or emerging solutions used in other industries could benefit the Life Science sector.

Smart packaging technologies: Embedded sensors track temperature and humidity, ensuring compliance while reducing excess protective materials.
Artificial intelligence (AI) in packaging optimization: AI enhances material use, space efficiency and route planning, cutting waste and emissions.

Biodegradable and recycled consumables: Eco-friendly alternatives like biodegradable air peanuts, corrugated bubble wrap, recycled cardboard and plastic reduce waste as they decompose naturally or are reused multiple times.

Innovative materials:

- Bio-based & biodegradable: renewable materials (e.g., mycelium, seaweed, plant-based polymers) are biodegradable or compostable and reduce reliance on plastic and fossil fuels.
- Lightweight & high-performance: new materials (e.g., advanced composites, aerogels) improve insulation and protection while significantly reducing weight
- Smart materials: Integrated sensors enhance monitoring temperature, humidity, and other critical parameters and enhance product safety and traceability

4. Air Cargo Industry Examples of Sustainable Packaging

While packaging providers develop eco-friendly materials and logistics solutions, innovations in sustainable packaging and cargo handling are also being driven by air cargo users, including airlines, freight forwarders, and ground handling agents. These stakeholders integrate biodegradable plastics, lightweight materials, and reusable packaging to reduce environmental impact, optimize operations, and align with global sustainability goals.

The Bibliography section collects some press releases on initiatives implemented across the Life Science air cargo sector.

5. Systemic Impacts Across the Life Science Value Chain

Each phase of a packaging solution life carries unique sustainability challenges and trade-offs. From material sourcing to end-of-life recovery, the value chain reveals critical leverage points—as well as systemic frictions—that influence both environmental performance and operational viability. The following analysis highlights key impacts at every stage:

	Design phase Packaging can be customized, integrating real-time tracking and temperature sensors. However, this flexibility creates market fragmentation, hindering standardized solutions. Regulatory compliance and limited data on long-term sustainability further complicate the adoption of new, environmentally beneficial packaging.
	Material selection Efforts focus on lighter, recyclable, and bio-based materials to balance sustainability and thermal performance in Life Science packaging. Biodegradable and recycled alternatives exist but remain costly and limited. The challenge lies in balancing weight reduction for lower emissions with durability to prevent product loss.
	Production and process Standardized processes improve efficiency, and localized production reduces transport costs. However, regulatory inconsistencies hinder global harmonization, and high energy consumption limits the ecological benefits of some materials.
	Distribution Centralized hubs aid availability of reusable packaging, but repositioning costs and regulatory differences impede reuse. While tracking technology improves transparency, lack of universal standards hinders seamless implementation.
	Use phase While reusable packaging gains traction for large shipments, benefiting from better temperature monitoring and tracking, concerns over contamination, strict traceability, and underdeveloped recovery infrastructure hinder circular economy implementation.
	Repair and reconditioning Repair and reconditioning help reduce waste and enhance cost-effectiveness. Some manufacturers use modular systems to replace damaged panels instead of discarding entire containers. However, managing returns and repairs is complex, especially in trade-imbalanced routes where empty containers accumulate, making return logistics expensive and challenging for reusable packaging solutions.
	Collection and waste recovery Emerging collection systems help recover packaging, sometimes managed by suppliers. However, implementation is limited, efficiency varies, and small-unit recovery is often costly and economically unviable.
	Next use and recycling Reintegrating recovered materials reduces virgin resource use and supports circularity. Some packaging finds reuse in other industries, but regulatory constraints, lack of recycling infrastructure, and limited financial incentives hinder large-scale adoption.

IV. GAPL 2 Industry Consultation - Key Findings and Takeaways

1. Survey results

The GAPL 2 project survey (Appendix B – Survey Questions) highlights the diverse approaches to sustainability in the Life Science air cargo sector. Key stakeholders, including airlines, airports, packaging providers, ground handling agents (GHAs), and Life Science manufacturers, are actively exploring ways to reduce the environmental impact of packaging and air cargo consumables. Sustainability factors such as reusability, recyclability, and Life Cycle Assessments (LCAs) are inconsistently applied across the chain.

What level of sustainability criteria is currently used in operational decision-making?

Over 80% of respondents do not request Life Cycle Assessments (LCAs) to evaluate the environmental impact of systems and consumables, and 70% of airports and GHAs lack measurable targets for waste reduction. Airlines emphasize reverse logistics and lightweight materials for their consumables, while airports and GHAs implement waste tracking, recycling, and stakeholder education. Packaging providers focus on innovation, such as passive and active solutions with potential for reverse logistics.

Learnings: There is a growing interest in environmental performance, but the tools to evaluate it (such as LCAs) are still underused. This limits data-driven decision-making and the ability to benchmark progress.

What are the actual practices being adopted to reduce packaging and consumable waste?

While 60% of companies report implementing practices such as recycling and reuse, and 70% consider sustainability a key criterion, industry-wide gaps in setting clear sustainability targets highlight the urgent need for standardization, collaborative strategies. and actionable solutions to drive the industry towards more sustainable practices.

Criteria	Life Science manufacturers	Packaging providers
Temperature range protection	38.5%	39%
Duration of protection	34%	35%
Price	27%	28.5%
Weight/Dimensions	23%	22%
Assembly Time	18%	14%
Sustainability	17%	18%
Traceability	17%	16%
Others	6%	7%

Selection criteria for tertiary packaging (Question addressed: What criteria do Life Science manufacturers and packaging providers prioritize when selecting tertiary packaging systems?)

Learnings: Performance remains the top priority, with thermal protection and cost ranking highest. Sustainability is acknowledged but still secondary in the decision-making process, indicating a need for stronger incentives or regulations to shift priorities.

Criteria	Airlines	Airports	GHA	Packaging providers
Reduce	57%	33%	80%	71%
Reuse	100%	33%	80%	100%
Repair	57%	0%	40%	71%
Remanufacture	14%	17%	20%	43%
Recycle	100%	67%	60%	71%
Recover	43%	33%	20%	57%
None	0%	33%	0%	0%
Other	-	17%	20%	29%

*Adoption of sustainable practices (*Question addressed: What circular practices (Reduce, Reuse, Repair, etc.) are currently implemented across stakeholders in the air cargo chain?)

Learnings: Airlines and packaging providers are the most advanced in reusing and recycling practices, whereas airports and GHAs show inconsistent adoption. Notably, repair and remanufacturing remain underdeveloped, despite their potential to extend product lifecycles. The presence of "None" among airports also highlights a lack of engagement or resources in certain segments.

2. Current Practices of Selecting Tertiary Packaging

Tertiary packaging selection in Life Science balances product protection, cost, efficiency, and sustainability, but price remains the top priority. Interviews conducted as part of this Pharma.Aero project confirm that safety and quality outweigh sustainability, with purchasing departments focusing on budgets over green solutions. The findings align with a 2024 McKinsey study which found that while companies want sustainable packaging, they won't pay the premium required. Some now consider ISO 20400 - Sustainable Procurement — guidelines, but cost remains the deciding factor.

a. Criteria for Selection: Dominance of Functional Attributes

Temperature and duration of protection are the top priorities for Life Science packaging, ensuring integrity for vaccines and biologics. Price remains key, while sustainability ranks lower, often behind weight and traceability. The lack of standardized sustainability metrics limits adoption, with many relying on broad principles over measurable impact.

b. Sustainability Metrics: The Challenge of Life Cycle Assessments

Limited Life Cycle Assessment (LCA) adoption hinders sustainable packaging, with few companies requesting or sharing LCA data due to confidentiality and inconsistent methods. Nonetheless, some organizations stand out in their efforts to integrate sustainability into their operations. For example, all our interviewees actively promote reusable packaging, lightweight materials, and reverse logistics programs, offering circular solutions to minimize waste. However, progress across the industry remains slow due to the absence of standardized sustainability frameworks.

c. Reverse Logistics: An Untapped Opportunity

Reverse logistics represents a significant avenue for enhancing the sustainability of tertiary packaging by enabling packaging reuse, reducing waste, and supporting circularity. Some providers run global collection and refurbishment networks, using local refurbishing or cost-efficient sea freight for repositioning. However, high costs, infrastructure gaps, and complex coordination hinder adoption, especially in regions with limited capabilities. Emission comparisons must factor in repositioning complexities and transport modes, as costs and emissions vary by lane.

d. Good Practices and Innovations

Despite these challenges, pockets of innovation are evident across the industry with leaders adopting repair, reuse, recycling, and recovery. Lightweight, modular and flat-packable solutions reduce environmental footprints while optimizing operational efficiency. Companies adopting these practices highlight the potential for scalable solutions that balance functionality and sustainability. For instance, lightweight packaging not only reduces shipping costs but also minimizes carbon emissions associated with transport. Similarly, modular designs enhance storage efficiency and streamline repositioning, making them attractive options for cost-conscious stakeholders.

e. Adoption Gaps: The Need for Harmonization

A recurring theme among surveyed stakeholders is the lack of uniformity in sustainability practices, with some companies prioritizing eco-friendly solutions while others focus on speed and reliability. Industry-wide harmonization of sustainability criteria is essential to drive consistency in tertiary packaging adoption. Bridging these gaps requires standardized metrics, supply chain collaboration, and scalable innovations that balance environmental and operational goals.

3. Reimagining Logistics: A Framework for Sustainable Transformation through Four Strategic Questions

The Life Science logistics industry stands at a junction where environmental responsibility meets operational efficiency. Through careful analysis of key challenge areas and implementation of targeted strategies, the industry can achieve significant reductions in environmental impact while enhancing operational performance and long-term sustainability.

a. Sustainable Packaging Innovation

How might we… Rethink single use packaging materials, to meet 100% recycling targets, and to avoid landfill waste?

The industry's first major challenge centers on rethinking single-use packaging materials to maximize recycling and eliminating landfill waste requires biodegradable and compostable materials, optimized designs, and reusable packaging. Industry collaboration is key to standardizing formats, expanding recycling infrastructure, and developing closed-loop systems with data-driven optimization.

b. Strategic Container Repositioning

How might we… Rethink repositioning strategies, to meet our goal of lowering CO_2 emissions, and to avoid transporting empty containers by airfreight?"

Optimizing container repositioning with real-time data and predictive analytics can cut emissions. Industry collaboration, trade lane optimization, container sharing, and sustainability initiatives, including carbon offsetting, are key to success.

c. Cost-Effective Reverse Logistics

How might we… Reduce the cost of reverse logistics for reusable pallet shippers, to meet our cost-saving targets, and to avoid new production cycles?

Cost-saving opportunities lie in shipment consolidation and strategically placed regional hubs to reduce empty returns and transportation costs. Industry collaboration is crucial for standardizing protocols and sharing best practices. Data analytics enhance operational efficiency, while circular economy principles maximize resource utilization. Additionally, innovative financing models can support the widespread adoption of these initiatives.

d. Thermal Blanket Reuse Initiative

How might we… Reuse 100% of thermal blankets, to minimize waste, and to avoid additional costs?

A successful approach requires regulatory support, incentives, and industry collaboration for standardized cleaning, repair, and reuse procedures. Developing secondary markets, optimizing reverse logistics, and conducting regular life cycle assessments ensure cost-effectiveness and long-term viability.

Implementation Framework

Insights from the workshop held during the Pharma Logistics Masterclass in Dallas Fort Worth highlight that, through committed implementation of these strategies, the Life Science logistics industry could significantly reduce its environmental footprint while improving operational efficiency. The successful execution of these strategies requires:

- Strong cross-industry partnerships and standardization efforts.
- Investment in data analytics and emerging technologies
- Development of robust reverse logistics infrastructure
- Creation of supportive regulatory frameworks
- Continuous monitoring and optimization of processes

4. Packaging Providers' Perspective on Sustainability Practices and Challenges

Obtaining LCAs for the study proved challenging, reflecting the limited accessibility of such data and the complexities involved in evaluating the sustainability and potential improvements of various packaging types.

To address this gap, we engaged with selected tertiary packaging providers. Drawing on their experience across multiple industries, they shared valuable practices and insights tailored to Life Science solutions. Their inputs underscore that there is no universal solution; instead, a customized approach is required to align with each solution's unique characteristics and the specific needs of customers. This chapter synthesizes their insights, exploring the practices, challenges and solutions that define sustainable tertiary packaging. The analysis, supported by use cases from participating packaging solution providers, highlights the advantages and limitations of proposed approaches and outlines the criteria necessary for selecting effective solutions.

a. Standardizing Sustainability Metrics

Achieving sustainable packaging requires clearly defined and measurable metrics. The lack of standardization in environmental performance evaluation hinders solution comparisons. While Life Cycle Assessments (LCAs) are not widely adopted or consistently shared, providers emphasize the need for metrics encompassing lifecycle CO_2 emissions, carbon footprint reduction, energy and water consumption (distinguishing renewable and non-renewable sources), average reuse cycles, repair and replacement modularity, regional reverse logistics adaptability, and material recyclability.

To enhance transparency, Cold Chain Technologies developed an 'eco calculator' quantifying environmental benefits and providing analytics on seasonality, return rates, and missing boxes. This complements their use of independent third-party LCAs for reusable solution evaluation. For more details, see Appendix E – Use Cases: Cold Chain Technologies.

Some providers, like SkyCell, have quantified impacts through proprietary methodologies. SkyCell's evaluation model, combining lifecycle CO_2 emissions assessment, reverse logistics optimization, and packaging reuse efficiency, suggests a potential 58% CO_2 emissions reduction on certain routes, using the MIT-developed DECARBONIZE tool. Learn more from Appendix E – Use Cases: SkyCell.

However, without a standardized sector-wide benchmarking framework, these figures are difficult to compare objectively. This underscores the importance of industry-accepted sustainability metrics, enabling transparent and harmonized packaging assessments. A few providers are leading by integrating Science-Based Targets and carbon offset initiatives, paving the way for standardized benchmarks. Yet, achieving broad adoption of these standards remains a challenge, highlighting the need for collaborative industry guidelines.

b. Scaling Reverse Logistics Systems

Reverse logistics remains a critical but underutilized strategy. Although these systems are central to reducing waste and extending the lifecycle of packaging materials, their effectiveness is dependent on shipper and logistics providers operational modes. For packaging suppliers, ensuring quality control in reverse logistics can be particularly challenging when reliant on client-driven processes. As a result, adoption remains inconsistent across the industry, despite clear sustainability benefits.

However, successful implementations exist. Concrete examples have demonstrated the feasibility of optimized circular logistics model in Life Science air cargo. By implementing a structured refurbishment and reverse logistics system, Emball'iso achieves a 94% return rate for reusable packaging, reducing reliance on single-use materials and avoiding landfill waste (Appendix E – Use Cases: Emball'iso). For reverse logistics, maritime returns emit 0.02 to 0.07 tons of CO_2 per pallet, compared to 3 to 6 tons for air freight, significantly cutting emissions. However, longer transit times in maritime transport require a larger volume of circulating equipment to maintain operational efficiency.

Strengthening collection, refurbishment, and redeployment networks require regional infrastructure investment, modular designs, and quality return protocols. While beneficial, reverse logistics faces complexities on intercontinental routes and requires adaptable infrastructure. Success depends on balancing reuse cycle benefits with operational costs, making case-by-case evaluations essential for sustainability and efficiency.

c. Lightweight and Modular Packaging Solutions

Reducing packaging weight directly lowers fuel consumption and CO_2 emissions in air freight. Modular, lightweight solutions enable cargo optimization and environmental efficiency without compromising thermal performance or regulatory compliance. QProducts & Services has tested the viability of replacing active containers with thermal blankets and demonstrated the thermal performance, payload capacity improvement and circularity efficiency on a controlled door-to-door route (Appendix E – Use Cases: QProducts & Services).

d. The Role of Cooling Agents

Cooling agents like Phase Change Materials (PCMs) (organic/inorganic) and water-based hydrogels are essential for temperature-sensitive shipments. PCMs offer high thermal performance and are often reusable, while hydrogels may have a lower carbon footprint in specific cases but are not direct PCM substitutes. Lifecycle assessments are needed to evaluate environmental impact. The selection of a cooling agent must balance thermal performance, sustainability, and logistical factors, considering reverse logistics and shipping conditions.

e. Eco-Design

Eco-design, or Design for Environment, minimizes environmental impact throughout a product's lifecycle, emphasizing prevention, efficiency, and circularity. Exam Packaging's eco-designed freighter pallet shipper (Appendix E – Use Cases: Exam Packaging) exemplifies this by integrating building sector materials for dual-purpose use: Life Science transport followed by repurposing for building insulation. This approach, rooted in lifecycle thinking and stakeholder collaboration, significantly reduces waste and carbon emissions, demonstrating how eco-design can create sustainable, cross-sector solutions.

f. Recycling and End-of-Life Management

Waste reduction and resource efficiency rely on solutions like incineration with energy recovery, which offsets emissions and minimizes waste. However, recycling multi-material packaging is challenging due to limited regional facilities and the complexity of material separation.

g. Leveraging Technological Solutions

Innovations like advanced analytics assess CO_2 emissions across a packaging's lifecycle, while IoT-enabled systems (QR codes, RFID tags) improve reverse logistics and reuse tracking. These tools enhance efficiency, reduce waste, and cut emissions but require significant investment and supply chain integration. Despite challenges, they are key to long-term sustainable packaging strategies.

h. Avoiding Overengineering

Overengineering in packaging design increases emissions and material use, often due to excessive insulation or added weight for extreme conditions. Digital tools like data loggers help align packaging performance with real conditions, preventing overdesign while ensuring safety and effectiveness. This approach enhances efficiency and sustainability without compromising functionality.

i. Fostering Collaboration across Stakeholders

Collaboration between VCS is key to developing sustainable solutions. Leveraging global networks for packaging collection and refurbishment reduces logistical costs and supports circular economy principles. By pooling resources and expertise, stakeholders can address challenges such as reverse logistics and cost barriers, creating a scalable industry model.

j. Promoting Best Practices and Industry Leadership

Sharing success stories and proven strategies, demonstrating how practical innovations can simultaneously enhance sustainability and operational efficiency, providing valuable blueprints for other stakeholders, can inspire industry-wide adoption of sustainable practices.

In conclusion, sustainability in tertiary packaging requires an integrated approach, combining measurable metrics, lifecycle thinking, and collaborative efforts across the supply chain. Lightweight, modular, and reusable solutions hold significant promise but must be tailored to realistic needs and regional capabilities. By adhering to clearly defined criteria and leveraging innovative technologies, the pharmaceutical industry can reduce its environmental footprint while ensuring product safety and logistical efficiency. This comprehensive approach positions stakeholders to meet the evolving demands of sustainability-conscious markets and regulatory requirements.

V. Defining the Criteria to Assess Sustainability of Tertiary Packaging

1. The Role of Procurement, Logistics and Corporate Social Responsibility (CSR) Departments

The assessment should be carried out through a cross-functional collaboration among procurement, logistics/operations and CSR managers within the Life Science manufacturer, freight forwarder or airline. The Life Science manufacturers will mainly focus on finding the most adequate packaging solution within their existing portfolio of qualified solutions.

The logistics manager shall provide the technical criteria necessary for the choice of packaging in terms of quality criteria. These must comply with current regulations and the type of products to be shipped. The CSR manager shall be able to assist the purchasing manager in assessing the sustainability criteria.

The weighing between the three elements: price, quality and CSR indicators could be, for example, 40/40/20. The breakdown is to be determined by the purchasing department. Sustainable market practices tend to progressively reduce the weight of price in relation to other elements.

This would enable the various players in the sector to focus not just on price, but also to take into account factors that would, in the long term, improve scope 3 and the impact level of the company concerned, while at the same time contributing to enabling tertiary packaging companies to make their R&D efforts profitable.

2. Tertiary Packaging Sustainability: Guiding Principles

Drawing upon desk research findings and insights gained from interviews with packaging providers, this assessment employs a product lifecycle approach. It is guided by various principles, and its impacts are intended to be considered holistically.

- Climate impact: elements that make it possible to measure the level of impact in terms of CO_2 emissions and energy consumption.

- Packaging efficiency: elements that make it possible to identify the level of recycled materials used in the design of the packaging.
- Service life: factors that enable to assess ease of use and the level of re-use (to avoid waste).
- End of life optimization: factors that help to identify the level of recyclability of the packaging.
- Reducing the impact on biodiversity: elements that enable to identify the level of dependence on incoming resources (water and land use)
- The supplier's commitments: elements that enable to assess the tertiary packaging provider's level of commitment in terms of sustainability.

3. Operational Considerations

To make informed packaging choices, operational factors must be considered alongside sustainability criteria. The following operational inputs, while not exhaustive, should be collected:

- Temperature range protection
- Protection duration
- Volumetric weight per unit
- Preconditioning capability at point of use
- Mode(s) of transport
- Storage area available for empty packaging
- Recycling capability at arrival point
- Number of units per shipment
- Number of shipments per month
- Shipping location (packaging point of use)
- Receiving end: consignee/own site
- Lane risk assessment score (if available)
- Distance travelled

4. Tertiary Packaging Sustainability Assessment Framework

When selecting tertiary packaging, manufacturers, freight forwarders, or airlines should utilize the proposed indicators to assess sustainability aspects. Information should be requested from the packaging provider. This assessment grid applies to all tertiary packaging types. Due to the wide variety of packaging solutions, qualitative questions are necessary.

This project has identified various indicators and sub-indicators, covering the full lifecycle. It is crucial to assess all leading indicators. To facilitate adoption, sub-indicators are classified into 'Must-have' criteria (level 1)—universally applicable to tertiary packaging solutions, enabling initial harmonization—and 'Nice-to-have' criteria (level 2)—allowing for refined assessments.

For optimal use of the table, it is not necessary to request information for all sub-indicators. Instead, based on product requirements, lane, and operations, select the most suitable sub-indicator(s) under each leading indicator, although multiple metrics per principle can be chosen. The list has been cross-checked with packaging solution providers, who confirmed the availability of the required information. Data input is required at the packaging solution level, not the provider level. This means providers will be asked to supply information for each of the solutions offered.

Similar to the GAPL 1 - Focus on Green Lane initiative, this project applies a uniform weighting system. By assigning equal weight to all indicators, it recognizes their equal importance and offers a practical approach when the relative significance of individual indicators is unclear.[2]

The intent of this framework is to enable comparison across a wide range of solutions, including those in different categories such as active and passive, to aid decision-making. A universal scoring system is not possible; scoring should be specific to company or portfolio contexts due to the extensive variety of solutions and the numerous operational variables. Appendix F – Example for scoring and threshold setting provides an example of indicator scoring and guidance for threshold setting, illustrating their use in sustainable procurement within a company. For some indicators, evaluators assess a narrative provided by the supplier, while others rely on market averages, which fluctuate over time. These indicators can be used to compare suppliers and identify areas for improvement.

Leading Indicator & related UN SDG categories	Sub-indicators	Unit	Primary Questions	Priority level
(1) Sustainability Roadmap	Corporate Sustainability Strategy	Narrative	**Does your company have a formalized sustainable strategy with a defined environmental policy including target commitments and concrete action plans?**	1
	Circular Economy Initiatives	Narrative	**Does your company have a portfolio of eco-design / circular economy-related projects aligned with the sustainability strategy?**	1
		%	**Which % of turnover is invested in Circular Economy initiatives?**	1
	Corporate Sustainability Governance & Management	Narrative	Does your company have sustainability targets for its leadership team and employees, as well as suppliers code of conduct to achieve its sustainability targets?	2
(2) ESG Engagement	ESG-related Certifications	Narrative	**Is your company certified according to ESG standards [BCorp, ISO14001, EMAS, etc.]?**	1
	ESG Assessment scores	Narrative	Has your company been scored according to ESG assessment frameworks (i.e. BCorp, EcoVadis, ESCI, etc)?	2
	Waste Commitment	Narrative	Does your company publicly commit to achieving zero waste to landfill?	2
	UN Global Compact	Narrative	Is your company a signatory of the UNGC?	2

[2] GAPL1 Technical Report, VI. 2 - LSRI's Measurement and Weighting Approach

(3) Design & Production of Packaging Unit	Emissions and Climate	t CO_2e	**What are the GHG emissions per unit of packaging?**	1
	Circular Inflow	%	**What's the actual portion of recycled and/or renewable material in packaging?**	1
	Energy Consumption	Fossil fuel use (MegaJoule) / %	What is the energy consumption per unit? What is the portion in % that comes from renewable energies?	2
	Water consumption	Liter	What is the water consumption per unit of packaging?	2
(4) Use phase of packaging	Material Efficiency	Number	**What is the weight-to-volume of your solution?**	1
	Reusability	Narrative / Number of cycles	**Does the packaging maintain its functionality and integrity after repeated use ? If yes: What is the average reusability rate (Indicate '1' if single use)?**	1
(5) End Of Life Optimization	Recyclability	% of the total packaging product	**What is the theoretical % of recyclability of the packaging solution?**	1
	Actual recycling	%	**What's the actual efficiency of the recycling process of the packaging solution?**	1
			What's the recovery rate of the current existing recycling chain? (output as usable recycled material obtained from the total waste input)	1
	Biodegradability	Y / N % of recyclability (End of life)	**Is the packaging biodegradable?** (certification to provide)	1
			What is the % of biodegradable components in the packaging unit? What's the actual % of packaging that is bioprocessed?	1
	Circular Outflow	% recovery potential (recycling, reuse, downcycling) x % actual recovery	**What is the actual portion of packaging that becomes circular through either reuse or recycling or downcycling or biodegradation?**	1
	Ease of Disassembly (eDIM) capability	% / Number	Disassembly potential of your product: Which % of the product can be disassembled? What is the theoretical number of use cycles of the packaging unit? (Indicate '1' if single use)	2
(6) Reverse Logistics	Traceability rate of returned product	%	What's the percentage of returned products actually tracked? What is the share of tracked returns fully traceable (%)?	2
	Recovery rate of returned product	%	What is the percentage of return product recovered?	2

GAPL 2 Assessment Framework: Leading indicators and sub-indicators for sustainability assessment of tertiary packaging

a. Indicators Based on the Lane Sustainability Readiness Index (from GAPL 1 project)

Corporate Sustainability Roadmap (1)

The first common leading indicator comprises four sub-indicators. While the first one "Corporate Sustainability Strategy" assesses whether the stakeholder has formalised their sustainability targets supported by concrete action plans, the second one 'Corporate Sustainability Governance Management' takes into consideration the targets for their leadership team and employees, as well as suppliers.

This leading indicator is enriched with two additional sub-indicators applicable to tertiary packaging providers. One that shows company's commitment towards circular economy. Another one is on existing Life Cycle Assessments, which show the depth of knowledge of the provider about its impacts. Moreover, when LCAs include the human health impact, it also shows that the provider has broadened the scope to health impacts.

These aspects demonstrate companies' commitment to embark on their sustainability journey, and their will to align the leadership and mobilize their employees, as well as value chain partners.

ESG Engagement (2)

The second common leading indicator is about ESG engagement. The first sub indicator asks whether the company is certified to existing standards (ESG Accreditations/Labels). Globally recognised sustainability accreditations/labels, audited and certified by industry or regulatory bodies, complement the Corporate Sustainability Roadmap, demonstrating the entity's commitment to ESG and ensuring responsible conduct aligned with sustainable practices through disclosure requirements. Further, many certification programs require continuous improvements in sustainability performance, driving positive industry change. Appendix G – Certifications and labels presents a selection of globally and/or industry- recognised ESG accreditations/labels (not exhaustive list).

The second sub-indicator focuses on ESG assessment frameworks. The most used frameworks are:

- Ecovadis, which is related to your value chain and evaluates 4 pillars (environment, Social, sustainable procurement and ethics).
- Bcorp which is related to 5 pillars: governance, workers, community, environment and customers).
- ESCI stands for Environmental, Social, Circular, and Innovation, which represents a holistic approach to sustainability and responsible business practices.

The third sub-indicator is about the waste commitment. Committing to zero waste to landfill is crucial for reducing environmental impact and promoting a circular economy. Landfills generate methane, a potent greenhouse gas, and contribute to soil and water pollution. Diverting waste through recycling, composting, and reuse conserves natural resources, lowers emissions, and reduces the need for raw material extraction.

The fourth sub-indicator investigates whether the company is signatory of the United Nations Global Compact, an internationally recognized standard that can be a differentiating factor in a comprehensive ESG assessment, showing the intent of operating in ways that, at a minimum, meet fundamental responsibilities in the areas of human rights, labor, environment and anti-corruption.

b. Indicators Specific to Tertiary Packaging

Design & Production of Packaging Unit – Before Use (3)

This indicator gives information of the environmental impact of packaging (CO_2, energy consumption water...) beyond its direct operations. It gives insights into the specific performances of the different packaging options.

This indicator covers various dimensions to be considered when designing a packaging solution: carbon, water and energy footprints as well as recycled / renewable content. The less footprint and the more recycled / renewable content, the less impact on biodiversity and resource scarcity. More specifically, integration of renewable material contributes to the path towards carbon-neutral raw material used in packaging/

Use of Packaging Unit - During Use (4)

This indicator focuses on the optimization of use of packaging through 2 strategies: on the one hand by limiting the amount of packaging material used per unit and on the other hand by extending material lifespan through reuse.

Minimizing material use contributes to reduce the extraction of virgin material; reuse and minimizing single use packaging will reduce the impact on biodiversity, on virgin resource extraction and on water/marine/soil pollution (eg : microplastics) ; reuse should be favored vs end-of-life recovery strategies as it is much less energy-intensive.

The weight-to-volume ratio (Volume (V) /Weight (W)), also known as density, allows Life Science manufacturers to evaluate the actual charge based on dimensional weight (volumetric weight) rather than actual weight. A high weight-to-volume ratio means higher shipping costs due to heavier loads.

End Of Life Optimization - After Use (5)

This indicator gives an overall picture about packaging end-of-life performance regarding circularity and its actual contribution to avoided "linear" waste treatment (landfill or incineration).

It explores product performance through key strategies that allow to maximize circular end-of-life: ease of disassembling, biodegradability, actual recycling rate[3], biodegradability and bioprocessing.

[3] Recycling Rate = (Weight of Recyclable Materials / Total Weight of Packaging) × 100

A mixed implementation of such strategies will significantly contribute to the reduction of the environmental impact: the more content diverted from landfills, incineration and dispersion, the less impact on biodiversity and virgin resource extraction.

Caution: actual recycling rates must consider not only the packaging itself but also the actual performance of existing recycling chains. Having 100% recyclable packaging and a recycling chain that can absorb only 10% of the material leads to an actual recycling rate of...10%.

Reverse Logistic (6)

These questions are only applicable to reverse logistics. The information should be requested from the entity responsible for reverse packaging. The indicator measures the performance on return and hence loss in recycling / reuse opportunities. By reducing such losses, it prevents products from being either landfilled or dispersed in the environment.

5. Integration to the LSRI Lane Sustainability Readiness Index

The GAPL 2 Tertiary Packaging Sustainability Assessment Framework can be used independently to evaluate tertiary packaging solutions. Alternatively, it can be integrated to the LSRI, which is designed to be inclusive, acknowledging the vital role each logistics stakeholder plays in a lane's sustainability readiness. By incorporating tertiary packaging selection, the enhanced LSRI provides a more comprehensive lane sustainability assessment framework, supporting stakeholders' improvement efforts. Among the multiple applications identified in 'GAPL1: Focus on Green Lane'[4], two stand out for incorporating sustainability assessment of packaging:

- Compare different tertiary packaging solutions on sustainability criteria, in addition to performance and price.
- Enhance the sustainability component in Lane Risk Assessments with the additional dimension of Packaging when:

(a) the tertiary packaging solution is proposed by the airline, and that the user is evaluating different lanes operated by different airlines

(b) the proposed tertiary packaging differs according to overall LSRI of the transit hub. E.g., if a transit hub is rated as Excellent by the LSRI, less complex tertiary packaging could be used to protect the shipment

The enhanced LSRI is a valuable tool for manufacturers, forwarders, and airlines to make informed transportation decisions and promote sustainable air cargo practices. Providing a transparent and objective measure, the LSRI drives positive change and reduces the environmental impact of air cargo transportation.

[4] GAPL 1 Technical Report VI. 4. Lane Sustainability Readiness Index (LSRI) Applications (The Technical Reports are available exclusively to Pharma.Aero members only. Members can access them by logging into the Member Area of our website, www.pharma.aero)

VI. Conclusions

1. Key Takeaways

The Life Science industry's focus on human health necessitates a strong commitment to environmental sustainability. Integrating circular economy principles into tertiary packaging is crucial for minimizing resource depletion and ensuring medicine availability.

Packaging providers have demonstrated leadership in developing sustainable solutions, including lightweight designs and reusable systems. Their pioneering efforts in closed-loop systems provide a foundation for further progress.

To accelerate the adoption of sustainable tertiary packaging, the GAPL 2 project proposes integrating key criteria into the Lane Sustainability Readiness Index (LSRI) developed in GAPL1 project, supporting Scope 3 emissions reduction targets. Whether in purchasing or operations, decision-makers who select packaging solutions require sustainability training to incorporate sustainability criteria into their sourcing decisions. Providing them with appropriate tools and clear priorities will facilitate the evaluation of suppliers and the adoption of innovative, sustainable packaging.

Notwithstanding, achieving true circularity requires a collaborative, system-wide approach. The Life Science manufacturers must prioritize sustainable aspects in procurement and actively participate in closed-loop initiatives. Logistics service providers (LSPs) are essential for optimizing reverse logistics and ensuring efficient packaging returns. Airports can facilitate these efforts by providing necessary infrastructure. Regulatory bodies can further incentivize sustainable practices through clear standards and policies.

Some categories of stakeholders, particularly packaging providers, have already incorporated some of these criteria into their tertiary packaging design considerations. Being upstream in the value chain, their approach often extends beyond these initial criteria. If the sector as a whole aims to adopt a sustainable approach, it will need to come together to collectively improve the entire value chain. Therefore, all stakeholders in the Life Science logistics ecosystem are urged to embrace a shared vision and coordinated action to unlock the full potential of circular economy principles.

Finally, recognizing that sustainability is a dynamic field, Pharma.Aero commits to regularly reviewing and updating the LSRI to ensure its continued relevance and effectiveness in meeting the evolving needs of the industry. This ongoing commitment to improvement will ensure the LSRI remains a valuable tool for driving sustainable practices in Life Science logistics.

2. Potential Spin-off Projects or Opportunities to Investigate

Pharma.Aero's project GAPL 2 Tertiary Packaging paves the way for further exploration and deep dives into specific areas aimed at achieving sustainable Life Science air freight logistics.

a. Data-driven Mutualized Platform

The initiatives presented in this report could be enabled through a secure, one-stop shop, customer portal for Data-Driven Optimization offering:

- Curated Packaging Solutions Database: A comprehensive, searchable database of pre-assessed, sustainable tertiary packaging solutions, evaluated against the project's defined criteria. This resource would empower users to quickly compare options, access key performance data, and make informed procurement decisions.
- Real-time Tracking and Tracing: Utilizing digital technologies (e.g., RFID, blockchain) to monitor the real-time location, condition (e.g., temperature, battery level), and journey of reusable packaging throughout the entire supply chain. This enables proactive issue resolution and optimized transportation routes.
- Fleet & Inventory Management: Leveraging data analytics to optimize inventory levels, automate order placement for both supply and return, and improve the overall efficiency of the reusable packaging fleet. This includes features such as automated alerts for low inventory, predictive maintenance, and optimized routing (including mode of transport) for container pickups and deliveries.
- Data-driven Decision Making: Collecting and analyzing data from all stages of the packaging lifecycle to identify areas for improvement, optimize resource allocation, and make informed decisions across the entire supply chain. This includes utilizing data to assess the environmental impact of different packaging options, predict future demand, and identify opportunities for cost reduction and efficiency gains.
- Reporting dashboards with critical KPIs driven by advanced analytics
- Carbon Emission calculations and ability to extend analytics into Corporate Sustainability Reporting Directive (EU CSRD).

By developing and using such a mutualized platform, the Pharma.Aero members could significantly reduce the environmental impact of their packaging and logistics operations, while also achieving cost savings, improving overall supply chain efficiency but also reaching a wider customer base. This could position them at the forefront of driving sustainable air freight practices throughout the Life Science industry.

b. Repository of Industry Best Sustainable Practices

In decarbonizing air transportation, all stakeholders, as presented in the GAPL 1 project: airlines, airports and ground handlers, and in GAPL 2 focusing on Tertiary Packaging: packaging solution providers but also Life Science manufacturers and freight forwarders, are undertaking a myriad of sustainable pathways and solutions. Some are already at the forefront in the development of technologies and innovations. As the LSRI gains wider industry recognition, with a wider scope encompassing Tertiary Packaging, a repository of best sustainability practices could be created, thereby fostering collaboration within air cargo and propelling a ripple effect of positive change. This resource tool would not just be a resource for Pharma.Aero members, but also a catalyst for a more sustainable and collaborative air cargo industry.

c. Adopting a Standard for Circularity Assessment: The Product Circularity Datasheet

The International Organization for Standardization (ISO) has developed the ISO 59000 family of standards to harmonize the understanding, implementation, and measurement of the circular economy. Specifically, ISO 59040:2025, titled "Circular economy — Product circularity data sheet (PCDS)", provides a standardized format for documenting a product's circularity. This data sheet allows stakeholders to assess a product's circularity performance and understand its intended circular pathway. The PCDS offers a standardized format for presenting reliable data without assigning scores or rankings.

The structure of the PCDS system is inspired by the Material Safety Data Sheet (MSDS) system, which provides standardized information for the safe handling of chemical products and mixtures.

The secure platform Terra Matters allows to create, share and consult PCDS.

The recent ISO publication (February 2025) strongly echoes the indicators developed in the GAPL 2 project and detailed in this report. Facilitating the adoption of the ISO 59040 standard within the Pharma.Aero community, through a dedicated platform, offers a powerful opportunity to advance circularity in tertiary packaging used in life-sciences logistics. This initiative would position pharma.aero at the forefront of collaborative innovation in sustainable practices.

d. Pharma.Aero Project Food & Farm for Health

Globally, the major export markets for Life Science are India, Europe and North America, particularly for finished therapeutic products. A significant volume of critical Life Science products is also transported by air to continents such as Sub-Saharan Africa, Asia and South America, which heavily rely on imports for medical goods that are not produced locally. For many countries, treatment is crucial for preventing infectious diseases with high deformity or mortality rates particularly in children, expectant mothers and vulnerable population.

It is a well-known fact that African and South American countries (amongst others) are key recipients of funded aid, relief & immunization programs that entail large scale transport of vaccines and therapies that are time & temperature sensitive.

Conversely, air cargo capacity is optimized to transport perishable commodities for consumption in the rest of the world, driven by the demand for diverse fresh food and farmed products. Although environmental concerns frequently dominate discussions about these cargo flows and consumption patterns, the trade directly contributes to economic growth in export regions, while helping to reduce carbon dioxide emissions by stimulating large-scale agricultural activity.

Based on both products' value chain analysis, it will give valuable information to airlines, freight forwarders and airports. It will generate sufficient evidence to support further investments needed and strategic choices to be made in these combined trade lanes.

e. Unused Medicines

The improper disposal of unused medicines poses significant environmental and public health risks, including water contamination, ecosystem disruption, and potential for misuse. Extending the project's expertise in Life Science logistics, a spin-off project could focus on optimizing the reverse logistics of both medicines take-back programs and reusable tertiary packaging. This initiative would explore synergies and efficiencies between the two reverse logistics streams. For medicine take-back, it would involve efficient and cost-effective methods for collecting unused medications from various points (pharmacies, hospitals, community collection sites) and transporting them to designated disposal facilities. For reusable tertiary packaging, it would focus on the efficient return of packaging components to designated collection points for cleaning, refurbishment, and reuse. The project would involve collaboration with Life Science manufacturers, packaging solution providers, logistics service providers (LSPs), waste management companies, and potentially even exploring innovative transportation solutions tailored to the specific requirements of returns and reusable packaging logistics. Optimizing the combined reverse logistics network would be crucial for maximizing the effectiveness and reach of take-back programs while also reducing the environmental footprint and cost of reusable packaging systems. This integrated approach could create economies of scale and streamline operations, benefiting both initiatives. Through these initiatives, Pharma.Aero aims to leverage collective expertise and resources to drive forward sustainable practices within the Life Science and MedTech logistics industry, thereby contributing to a greener and more resilient future for healthcare logistics.

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News articles illustrating the adoption of more sustainable practices in Tertiary Packaging:

- Menzies Aviation, American Airlines Cargo, WFS

Leading air cargo companies like WFS, American Airlines Cargo, and Menzies Aviation are replacing traditional plastics with BioNatur Plastics™ to reduce waste. WFS pioneered the shift in 2019, eliminating the equivalent of 27 million water bottles annually. American Airlines Cargo adopted biodegradable stretch wrap in 2023, reducing 68 tons of plastic waste across major hubs. Menzies Aviation followed in August 2023 at LAX, SFO, and MIA, aiming to cut over five million water bottles annually. These biodegradable plastics decompose within 8-12 years without microplastic residue, supporting net-zero goals and driving sustainable air cargo practices.

- Bolloré

In February 2024, Bolloré Logistics adopted a sustainable packaging solution for air shipments between Paris and Chicago, reducing 12 kg per shipment. Two pallets have already been transported, with more planned in collaboration with major airlines. This initiative aligns with the company's Recycle Program, which promotes reusable packaging and reverse logistics. In the Americas, Bolloré has been using eco-friendly solutions like reusable pallet covers and collapsible boxes, saving over two tons of plastic since 2021.

- Cargolux Airlines

In April 2017, Cargolux Airlines became the first airline to adopt squAIR-timber, a lightweight, recyclable cardboard fiber beam replacing traditional wooden beams. Used for pharmaceutical shipments from Luxembourg, it reduces weight by 80%, allowing for higher payloads and lower fuel consumption, cutting emissions by an estimated 1,200 tons annually. Durable and humidity-resistant, squAIR-timber also improves cargo handling efficiency while being fully reusable and recyclable.

- DHL

DHL promotes sustainable packaging to reduce waste, cut carbon footprints, and align with consumer demand for eco-friendly solutions. They highlight biodegradable materials, optimized packaging sizes, and renewable energy use in production. This approach lowers costs, enhances brand perception, and supports green logistics.

- Lufthansa Cargo

Since January 2023, Lufthansa Cargo has been using bio-based "Pallet Net Zero" nets, halving weight and saving 140 tons of fuel and 440 tons of CO_2 annually. In September 2022, it introduced a thinner plastic film with 10% recycled content, cutting 2 kg of film per flight to reduce plastic waste.