THE PUZZLE OF SUSTAINABLE PHARMA PACKAGING:
Drivers, Trade-offs, and Best Practices

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Crafting a sustainable packaging strategy for the pharmaceutical industry is complex and requires balancing environmental responsibility with regulatory compliance and operational costs. In this article, we explore the key drivers, challenges, and best practices for developing such a strategy.

INTRODUCTION

The pharmaceutical industry, while essential for global health, faces increasing scrutiny over its environmental footprint, including the realm of packaging. Traditionally designed for safety, sterility, and compliance, pharmaceutical packaging often relies on materials and processes that contribute significantly to waste and carbon emissions. As environmental concerns intensify and regulatory pressures mount, the shift toward sustainable packaging has become a strategic imperative, regulatory requirement, and ethical responsibility.

In recent years, the pharmaceutical industry has increasingly turned its attention to the environmental impact of the waste it generated across its value chain. Previous *Pharmaceutical Engineering®* articles have explored the topic of single-use technology (SUT) waste, reverse logistics, and packaging from various angles. These articles highlight the significant volume of plastic waste generated by SUTs in manufacturing processes, presenting survey findings showing that many manufacturers are willing to pay a premium for improved end-of-life (EoL) treatment options and are examining the challenges of sustainable packaging [1, 2].

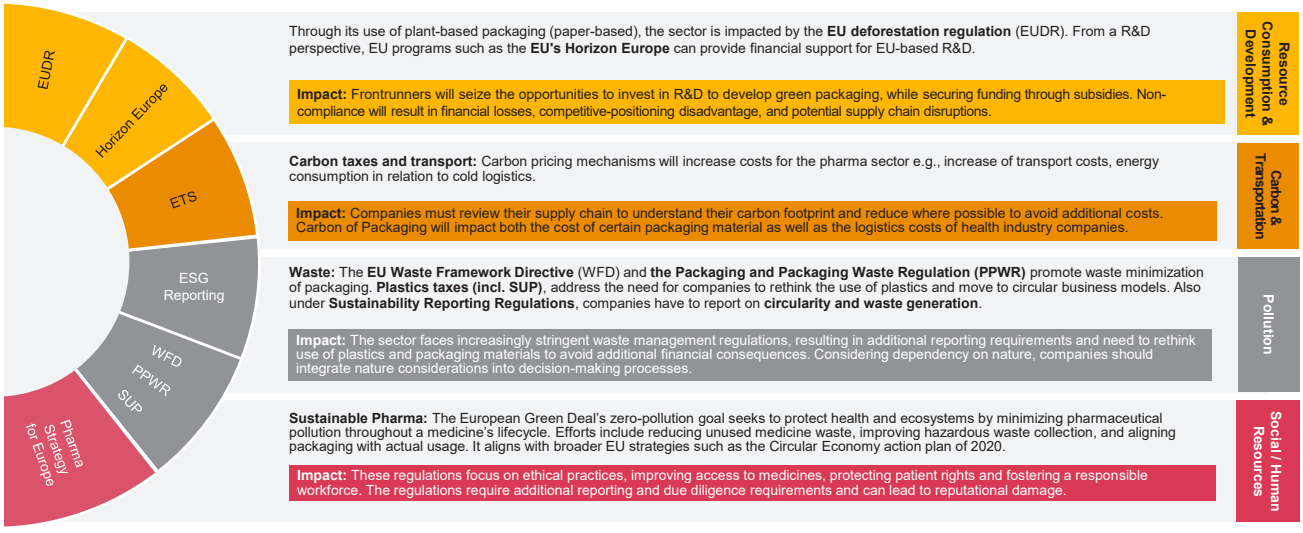
Other articles have provided a case study illustrating the complexity of adapting packaging systems within a fragmented global supply chain governed by diverse local regulations and offered practical insights into implementing packaging validation processes [3–5]. The *ISPE Good Practice Guide: Investigational Medicinal Product Reverse Logistics – Good Returns and Reconciliation Practices* helps improve the reverse logistics of investigational medicinal products [6]. Building on these foundations, this paper aims to share the authors' experience in developing a sustainable packaging strategy. It addresses three key areas:

1. Context and drivers: An exploration of the forces pushing pharmaceutical companies toward more sustainable packaging solutions, including regulatory pressure, environmental responsibility, and evolving stakeholder expectations
2. The puzzle of sustainable packaging: A discussion of the many interdependent factors that must be considered when designing a sustainable packaging strategy, such as operational costs, sustainability metrics, and compliance with various regulations
3. Best practices for implementation: An overview of the best practices to successfully develop and implement a sustainable packaging strategy

Figure 1: Key drivers pressuring the pharmaceutical industry to adopt sustainable packaging practices.



Figure 2: Key EU regulations impacting how the health industry needs to approach packaging.



CONTEXT AND DRIVERS

The pharmaceutical industry is undergoing a significant transformation as it shifts toward more sustainable packaging solutions. This change is driven by a combination of regulatory pressures, cost benefits, stakeholder demands, resource scarcity, and a commitment to environmental stewardship, as seen in Figure 1. Although all those forces are at play in any company, their individual strength will vary from one company to another. Typically, companies will mainly feel the pressure from one of these drivers.

Circular Regulations

One of the primary drivers of this shift is the increasing emphasis on circular regulations. These regulations aim to create a closed-loop system where materials are reused and recycled, minimizing waste and environmental impact. However, balancing the differences in local regulations worldwide presents a significant challenge for global companies. For instance, the extended producer responsibility (EPR; more info in the EPR article) mandates that producers are responsible for the entire life cycle of their products, including EoL disposal. This requires pharmaceutical companies to navigate a complex web of local regulations while striving for global sustainability goals. The EU is pushing on many fronts toward a sustainable healthcare industry. Various new EU regulations (Figure 2) have an impact the packaging mix of EU companies.

Cost Benefits

Adopting sustainable packaging can lead to substantial cost benefits for pharmaceutical companies. Although the initial investment in new packaging materials and technologies may be high, the long-term savings can be significant. Sustainable packaging often results in reduced material usage, lower transportation costs due to lighter packaging, and decreased waste management expenses.

Stakeholder Demand

Stakeholders, including patients, investors, and regulatory bodies, are increasingly demanding more sustainable products. Patients and practitioners are becoming more environmentally conscious and prefer products with ecofriendly packaging. Investors are also prioritizing sustainability in their investment decisions, recognizing the long-term value of companies committed to environmental responsibility.

Regulatory bodies are implementing stricter guidelines to ensure that companies reduce their environmental impact. These pressures are compelling pharmaceutical companies to rethink their packaging strategies and adopt more sustainable practices. Additionally, companies can benefit from enhanced brand reputation and customer loyalty, which can translate into increased market share and profitability.

Resource Scarcity

Resource scarcity is another critical driver for sustainable packaging in the pharmaceutical industry. The depletion of natural resources and the volatile/increasing cost of raw materials necessitate the adoption of more efficient and sustainable packaging solutions. To mitigate these scarcity risks, companies can decide to adopt certain sourcing strategies (like diversifying their supplier base) or they could turn toward circular solutions.

Other industries, like the food and beverage industry, have installed systems to collect and reuse or recycle their packaging. As a result, most of these companies have secured their access to

certain materials such as aluminum-based packaging. Another example is the blister packs that are widely used to package tablets in Europe, while in the United States, many pharmacies provide the medicine in reusable containers.

THE PUZZLE OF SUSTAINABLE PACKAGING

Packaging mix refers to the strategic combination of design, materials, functionality, labeling, and size to package medicines or medical devices. Defining a packaging mix that is fit for the future involves navigating a complex web of forces, often with conflicting objectives. Companies must balance operational considerations, customer perceptions, quality assurance, procurement challenges, sustainability goals, and EoL constraints.

All these different considerations to balance are often spread across various departments in the organization with different hierarchical lines. This makes it complex to align priorities when selecting the future packaging strategy. It is therefore critical in a first step to bring all the parties/departments involved together and align on the key principles that will guide the decision-making through the packaging strategy definition.

Examples of strategic principles can be "future packaging need to reduce operational costs by 10%," "the future packaging mix implementation roadmap need to be aligned with our GHG [greenhouse gas] reduction objectives," or "the new packaging mix needs to be implemented within five years." During this first stage, a clear decision-making governance structure needs to be aligned following the agreed principles. The key elements to consider when developing a packaging mix of the future are detailed next.

Sustainability

Companies will likely have certain sustainability goals (for example, CO_2 emissions, water usage, reduce single-use, or recycled content targets). It is important to highlight the ones where packaging plays a role. Each packaging type will then need to be assessed regarding those objectives. Life cycle assessment (LCA) is one of the critical tools for evaluating the environmental impact of packaging materials. Elements such as GHG emissions or water usage/pollution can be analyzed through the life cycle analysis. A key study from 2024 concluded that "packaging with less material and volume, using materials with lower impacts, and with EoL valorization significantly reduce the life cycle impacts of pharmaceutical packaging" [7].

Certain packaging may end up with conflicting sustainability benefits. For example, one packaging material may have GHG emissions, whereas another may have a reduced water footprint or biodiversity impact. Balancing these benefits will only be feasible if clear strategic principles have been set at the start of the project based on the strategic objectives set by the executive committee.

The regulatory framework will often set the minimum objectives for packaging materials—for examples, the EU Packaging and Packaging Waste Regulation (PPWR) sets objectives on recycled content, design for recyclability. (Note: Active pharmaceutical ingredient [API] residues in packaging are known to cause issues in terms of packaging recycling, which is why burning is still currently the preferred solution for a lot of medicine packages [8].) Circular concepts such as the 3Rs (rethink, reuse, recycle) may help in understanding the available sustainable strategies for packaging:

- Rethink: Is this packaging needed (e.g., is it possible to reduce the size of the packaging to remove empty space)?
- Reuse: Can this packaging be reused (e.g., can reusable containers be used instead of blister packs)?
- Recycle: Is it possible to increase the recyclability of this packaging (e.g., composite materials are known to be more complex to recycle)? Or can recycled content be integrated into packaging?

Operational Considerations

Operational considerations play a crucial role in the transition to a sustainable packaging mix. Decisions on the types of packaging will influence your operational costs in different areas. Factors such as the raw material cost of packaging, packaging lines costs (capital and operating expenses), and logistics cost (including storage, transportation, etc.) must be considered.

To estimate the operational costs of a packaging material, supply chain data need to be used. One packaging material can be bought in one country and be used in a packaging line in another country before being shipped to the customer in a third country. Understanding this flow is a critical effort to evaluate the real operational cost.

Although there may be potential logistical cost savings, other costs may increase, and new investments may be required. For example, companies may need to invest in new packaging lines or modify existing ones to accommodate sustainable materials. These changes can lead to short-term financial burdens but offer long-term operational efficiencies and cost savings.

Patient and Practitioner Perception

Packaging has a significant role to play in the branding of a product. Any change can significantly impact patient and practitioner perceptions. Pharmaceutical companies must ensure that new packaging designs maintain or enhance the product's appeal while meeting regulatory requirements. Instructions for use are sometimes visible on the packaging itself. It is therefore critical to consider how the changes of packaging mix could influence the readability and access to those key instructions. Additionally, new packaging materials may require approvals before the product can be marketed, adding another layer of complexity to the transition process.

Quality

The primary role of packaging material is to protect the product or medicine and ensure its quality. Changing packaging materials may necessitate new tests to verify that the product's integrity and efficacy are maintained. This can be a time-consuming and costly process, but it is essential to ensure that the product remains safe and effective for the patients.

Procurement

Switching to sustainable packaging often involves changing suppliers or sourcing new materials. This can impact the current supply chain and require companies to establish new relationships with suppliers. Effective procurement strategies are essential to ensure a smooth transition and maintain supply continuity.

Artificial intelligence (AI) can be leveraged to better manage supply-chain-related risks (including packaging supply risks). A typical use case is to use AI agents that have been trained on the main cost drivers of the supplied packaging material. Depending on events on the internet and the evolution of certain key market indicators, it can predict future potential price increases/resource shortages. This allows the procurement team to react faster and develop good mitigation strategies before the issue hits the company.

End of Life

Designing packaging that is easy to manage at the end of its life is a critical aspect of sustainability. Regulations are increasingly pushing for packaging that can be easily recycled or disposed of in an environmentally friendly manner. However, each country has different practices for managing EoL packaging, meaning that a solution that works well in one region may not be suitable for another. Companies must consider these regional differences when designing their packaging strategies.

An LCA study from 2024 on various packaging types analyzed the impact of the EoL on the various sustainability impacts in Europe. "The comparative analysis (...) shows that take-back scheme presents lower environmental impacts than waste domestic collection (incineration followed by landfill)" [7]. It also stresses the importance of user behavior and final treatment on the EoL impact, which are often dependent on label instructions and other information provided from the pharmaceutical company.

BEST PRACTICES FOR IMPLEMENTATION

Implementing a sustainable packaging strategy in the pharmaceutical industry is a multifaceted effort that requires careful planning, cross-functional collaboration, and a long-term commitment to balancing sustainability goals with operational and regulatory requirements. The transition to sustainable packaging is typically a multiyear process, fraught with challenges such as supply chain complexity, regulatory compliance, and stakeholder alignment. Drawing on industry insights and best practices, this section outlines key strategies to ensure a successful implementation, including market analysis, pilot testing, long-term forecasting, supply chain continuity, and stakeholder engagement.

Market Access and Competitive Analysis

A robust sustainable packaging strategy begins with a thorough understanding of the competitive landscape and market access requirements. Pharmaceutical companies must analyze competitors' packaging solutions to identify best practices, gaps, and opportunities for differentiation. For example, competitors may already be adopting biodegradable materials or reusable packaging

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systems, as seen in some European markets where blister packs are being replaced with reusable containers in certain contexts (as noted previously). Understanding these trends helps companies position their packaging mix to meet both market expectations and regulatory requirements.

Market access analysis should also consider mapping regional regulatory variations. Mapping these regulations against competitors' strategies ensures that the packaging mix aligns with local compliance needs while maintaining a competitive edge. Additionally, patients and practitioners' preferences should inform the strategy, as stakeholders increasingly favor ecofriendly packaging, with surveys indicating that 70% of consumers prefer brands with sustainable practices [9].

Best practice: Conduct a strengths, weaknesses, opportunities, threats (SWOT) analysis of competitors' packaging strategies and integrate findings into a decision-making framework that prioritizes sustainability, compliance, and market differentiation. Engage with regulatory experts early to anticipate changes in local and global regulations.

Pilot Before Scaling

Piloting new packaging solutions on a smaller scale is critical to mitigate risks and validate performance before full-scale implementation. Pilot projects allow companies to test sustainable materials, assess their impact on product quality, and evaluate operational feasibility. For example, a pilot could involve trialing a new biodegradable film for blister packs in a single market to measure its compatibility with existing packaging lines and its recyclability under local waste management systems. Pilots also provide an opportunity to gather stakeholder feedback, including from patients, practitioners, suppliers, and regulatory bodies.

Best practice: Design pilot programs with clear success metrics, such as material performance, cost impact, and recyclability rates. Use a phased approach, starting with a single product

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line or region, and incorporate lessons learned into the broader strategy. For instance, a pilot in a market with advanced recycling infrastructure (e.g., Germany) can highlight scalability challenges in less developed systems.

Long-Term Forecast Vision

A sustainable packaging strategy must be future-proof, accounting for evolving regulations, technological advancements, and resource availability. Developing a long-term vision involves setting clear sustainability goals—such as reducing CO_2 emissions by 20% by 2030 or achieving 100% recyclable packaging by 2035—aligned with corporate objectives and regulatory mandates like the EU's PPWR. Forecasting should also consider trends in resource scarcity, such as the volatility of petroleum-based plastics, which have seen price fluctuations of up to 30% in recent years due to supply chain disruptions [10, 11].

Best practice: Establish a 5- to 10-year roadmap with measurable milestones, such as increasing recycled content by 10% annually or transitioning 50% of packaging to reusable systems by 2030. Regularly update the roadmap based on emerging regulations, market trends, and technological innovations. Engage cross-functional teams to ensure alignment between sustainability, procurement, and operational goals.

Ensuring Supply Continuity and Minimizing Write-Offs

Transitioning to sustainable packaging can disrupt supply chains, particularly when switching to new materials or suppliers. To ensure supply continuity, companies must map their packaging flow—from raw material sourcing to EoL disposal—and identify potential risks, such as supplier capacity constraints or material shortages. Minimizing write-offs is another critical consideration, as obsolete packaging inventory can result in significant financial losses. A phased transition plan, coupled with robust inventory management, can mitigate these risks.

Best practice: Develop a risk management plan that includes supplier diversification, safety stock strategies, and contingency plans for material shortages. Use AI-driven tools to monitor supply chain risks in real time and implement just-in-time inventory practices to reduce write-offs. Collaborate with suppliers to co-develop sustainable materials tailored to pharmaceutical needs.

Stakeholder Engagement and Governance

Effective stakeholder engagement is the cornerstone of a successful packaging strategy. Establishing a clear governance structure is essential to align these stakeholders on shared objectives, such as reducing single-use plastics or meeting PPWR recycled content targets.

Engagement extends beyond internal teams to include suppliers, customers, and regulatory bodies. For example, collaborating with suppliers to develop recyclable packaging materials can address EoL challenges, while engaging customers through transparent communication about sustainability efforts can enhance brand loyalty. Regulatory engagement is equally critical, as companies must navigate a patchwork of local regulations.

Best practice: Create a cross-functional task force with representatives from all relevant departments to oversee the packaging strategy. Define clear decision-making principles, such as prioritizing recyclability over cost in certain markets, and establish regular check-ins to monitor progress. Engage external stakeholders through workshops, supplier innovation programs, and regulatory consultations to co-create solutions and ensure compliance.

Overcoming End-of-Life Challenges

EoL management remains a significant hurdle in pharmaceutical packaging due to high quality requirements and API contamination risks. Globally, only 10%–15% of pharmaceutical packaging is recycled, with much of it incinerated due to regulatory restrictions on contaminated materials. To address this, companies should adopt the 3R framework outlined previously. For example, rethinking packaging design to eliminate unnecessary layers or adopting reusable containers can reduce waste. Designing for recyclability, such as using mono-materials instead of composites, can also improve EoL outcomes.

Regional differences in waste management infrastructure further complicate EoL strategies. For instance, Europe's advanced recycling systems contrast with less developed infrastructure in other regions, requiring tailored solutions. Pilot programs can help test EoL scenarios, such as partnerships with local recycling facilities to manage API residues.

Best practice: Conduct region-specific EoL assessments to design packaging compatible with local recycling systems. Partner with waste management providers to develop closed-loop systems, such as take-back programs for reusable containers. Advocate for industry-wide standards to address API contamination challenges and improve recyclability.

Continuous Improvement and Monitoring

Sustainable packaging is not a one-time initiative but an ongoing process that requires continuous improvement. Companies should establish key performance indicators (KPIs) to track progress, such as reductions in CO_2 emissions, percentage of recycled content, or waste diversion rates. Regular audits and LCAs can identify

areas for optimization, while feedback from pilot programs and stakeholders can inform iterative improvements.

Best practice: Implement a continuous improvement framework, such as Plan-Do-Check-Act (PDCA), to monitor and refine the packaging strategy. Use data analytics to track KPIs and share progress reports with stakeholders to maintain transparency and accountability.

CONCLUSION

The pharmaceutical industry's journey toward sustainable packaging is no longer a peripheral initiative. It is a strategic transformation that touches every facet of the value chain. As this paper has shown, achieving meaningful progress requires more than just material substitution; it demands a systemic rethinking of packaging design, supply chain integration, regulatory navigation, and stakeholder engagement.

Looking ahead, the most successful companies will be those that embed sustainability into their core decision-making frameworks, leveraging tools like LCA, AI-driven procurement, and cross-functional governance to drive continuous improvement. Moreover, the industry's ability to collaborate across departments, with suppliers, and even with competitors will be critical in overcoming shared challenges such as EoL treatment and regulatory fragmentation.

Ultimately, sustainable packaging is not just about reducing environmental impact. It is about building resilience, enhancing brand trust, and future-proofing operations in an increasingly resource-constrained and regulation-driven world. By embracing innovation and aligning sustainability with business value, pharmaceutical companies can lead the way in shaping a more circular, responsible, and competitive healthcare ecosystem.

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