

FULL LIFE CYCLE CONSIDERATIONS

The Three Pillars of
Sustainable Produce Packaging
Decision-Making

Fresh produce often travels a long and resource-intensive journey before it reaches the consumer's plate. From the inputs such as water and nutrients, labor, and energy invested in farming to transportation and handling across packing/processing, distribution, and retail operations, every step of the supply chain represents an environmental investment. Packaging plays a vital role in protecting that investment by preventing food loss and waste. Many sustainable packaging requirements and regulations focus solely on the disposal and processing of packaging material at the end of its functional life. This narrow focus on the end-of-life fate of packaging materials paradoxically risks increasing food loss and waste, production and commodity costs, and greenhouse gas (GHG) emissions. When selecting packaging for produce, it is important to consider the full life cycle of the product from cradle to grave (1).

To guide decision-making, packaging can be evaluated across three key pillars: the environmental cost of creating the packaging (upstream), the core role of protecting the contents (functionality), and the end-of-life management (downstream). Focusing on only one of these three pillars' overlooks critical trade-offs. For example, a material that appears environmentally friendly upstream may be functionally ineffective (i.e., does not prevent food loss), while highly effective, or 'functional', packaging may fail downstream if it cannot be recycled, composted, or otherwise kept out of the landfill. A balanced, holistic approach to product life cycle ensures that packaging truly supports functionality while being sustainably produced and disposed of (2,3).



Upstream: Materials Science and Sourcing

Upstream considerations for food packaging materials involve material science and sourcing, where decisions must be informed by life cycle assessment (LCA) data that correctly prioritizes the material's environmental impact and its ability to prevent food loss and waste over materials reduction or substitution. The most effective tool for upstream evaluation is a LCA because it measures impacts such as GHG emissions, water usage, land use, and energy demand from raw material extraction through manufacturing and transport (4). It also focuses on the environmental footprint of the packaging material itself, long before the packaging holds any produce. The LCA takes a critical look at the material's source, for example, whether it is derived from recycled materials, from finite, non-renewable resources such as petroleum (e.g., traditional plastics), or from renewable sources such as trees, corn, or sugarcane (e.g., paper, bioplastics) (5). A decision at this stage sets the foundation for the overall sustainability profile of the packaging. Material choices span a spectrum and can include:

- Traditional plastics (PET, HDPE, LDPE, PP, etc.): Derived from petroleum and dependent on finite fossil fuels. These materials are the most common and are lightweight and efficient (2).
- Recycled plastics (PET, HDPE, PP, Low-Density PE): Offer reduced upstream emissions but depend on the availability of clean, food-contact, high-quality recycled feedstock. These materials may vary in recycled plastic content (6).
- Bioplastics (PLA, PHA, Bio-PE, Bio-PET, PBAT, etc.): Derived from renewable sources such as corn or sugarcane, but their sustainability depends heavily on agricultural practices, supply chain requirements, and waste management infrastructure (7).
- Fiber-based materials (paper, molded fibers): Renewable and biodegradable but often resource-intensive to manufacture and prone to moisture-related failures (8).
- Reusable packaging (plastic, glass, wood, metal): Designed for multiple use cycles and typically made from durable materials. Logistics and length of the supply chain have been a major barrier to adoption.

Functionality: Protecting the Investment in Food

Functionality describes the critical performance features that packaging requires to effectively perform throughout its entire life cycle and should be the core principle of all sustainable packaging design. One of the major challenges facing the fresh produce industry is that functional and sustainable packaging decisions often collide with public perception and regulatory pressure. Here emerges the "sustainability paradox": the imperative to prevent food and materials waste while reducing GHG emissions, versus the public and regulatory pressure to eliminate or change packaging to fit a narrative rather than a science-based understanding of full life cycle performance and environmental impact (9).

Fresh produce is grown and transported using valuable resources, such as water, land, energy, and labor. When the packaging or supply chain fails and food becomes food loss and waste, the entire environmental investment in that food is lost. To prevent greater waste, quantifying functionality ensures the packaging performs the core protective duties across the entire supply chain journey. This includes extending shelf life, reducing damage or spoilage, and improving utility and safety in production, processing, and transport as well as for the retailer, and consumer. Prioritizing the functionality of fresh produce packaging is essential because it aligns sustainability efforts with the primary purpose of packaging: to protect and preserve the food it contains.

Downstream: End-of-Life Realities

The downstream pillar addresses the packaging material's end-of-life or disposal. Downstream considerations include lightweighting, designing for compatibility with available waste management infrastructure, and navigating the trade-offs between high-performance multi-layer materials and more easily recycled mono-materials (10). Designing packaging materials for a circular system avoids delegating waste into landfills or worse, the natural environment.

Effective downstream management begins with a clear understanding of how packaging is actually processed after use. Even if a material is theoretically recyclable and compostable, it offers little benefit if the local infrastructure does not support recycling or composting (11). For example, mechanical recycling streams for plastics such as polyethylene terephthalate (PET) and high-density polyethylene (HDPE) are well-established in many regions, while flexible films and compostable bioplastics often lack consistent recovery pathways (1,12). Compostable and biodegradable materials also require careful evaluation. While they can return to Earth under specific conditions, they depend on industrial composting facilities that are capable of composting them but may not exist in many regions (7). Without access to those composting systems, such materials end up in landfills just like conventional plastics.

Ultimately, mitigating pollution and conserving resources depends on whether packaging materials are widely and easily recyclable or compostable within existing infrastructure or designed to be biodegradable under specific environmental conditions that are commercially impractical. A packaging choice that lacks a clear and viable end-of-life pathway creates a long-term environmental burden, undermining any upstream or functional benefits.

Fresh produce packaging must be understood through the lens of its full life cycle, guided by three pillars: upstream sourcing and impacts, core functionality in protecting food, and downstream end-of-life management. A packaging solution that performs strongly in all three pillars will not only minimize waste and emissions but also protect the immense environmental investment that goes into growing, transporting, and distributing fresh produce. By adopting a holistic three-pillar approach to packaging, the fresh produce industry can move toward viable packaging strategies that maintain functionality and advance sustainability.

References

1. [Food wastage along the global food supply chain and the impact of food packaging | Journal of Consumer Protection and Food Safety](#)
2. [Can bioplastics always offer a truly sustainable alternative to fossil-based plastics? - Serrano-Aguirre - 2024 - Microbial Biotechnology - Wiley Online Library](#)
3. [Frontiers | Sustainable food packaging: An updated definition following a holistic approach](#)
4. [Waste to energy: Trending key challenges and current technologies in waste plastic management](#)
5. [The 7 Different Types of Plastic | Plastics For Change](#)
6. [Which Plastic Can Be Recycled? | Plastics For Change](#)
7. [The future of bioplastics in food packaging: An industrial perspective](#)
8. [Guide to Fiber Packaging | Good Start Packaging](#)
9. [Bioplastics for Food Packaging: Environmental Impact, Trends and Regulatory Aspects](#)
10. [National Overview: Facts and Figures on Materials, Wastes and Recycling | US EPA](#)
11. [Frequently Asked Questions about Plastic Recycling and Composting | US EPA](#)
12. [Flexible Film Recycling: Collection Methods of Today and the Future - Sustainable Packaging Coalition](#)



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