SMART PACKAGING: INTEGRATED SOLUTIONS FOR CIRCULAR AND SUSTAINABLE INNOVATION

FuturE-Pack

Designing Smart Packaging for Circular and Sustainable Made in Italy

edited by Erik Ciravegna

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Summary

5. SMART PACKAGING: INTEGRATED SOLUTIONS FOR CIRCULAR AND SUSTAINABLE INNOVATION

Erik Ciravegna, Silvia Barbero, Sara Battistini, Mariapaola Puglielli, Camilla Sartor, Martina Spinelli

Abstract: Smart packaging is redefining the role of packaging as an active, intelligent, and connected interface mediating relations among products, people, and ecosystems. Drawing on research and experimentation within the FuturE-Pack project, it is presented through conceptual definitions and mapped responsibilities that expand traditional functions to meet broader social, environmental, and systemic demands. Building on this framework, smart packaging integrates advanced devices, such as sensors, indicators, data carriers, emitters, absorbers, functional agents, barriers, and temperature control systems, with core digital technologies, including AI, IoT, blockchain, cloud computing, big data, immersive environments, 5G, and production-related solutions such as additive manufacturing and robotics. These technologies extend packaging functions beyond containment and protection to ensure safety, authenticity, traceability, accessibility, and engagement, while enabling circular practices across the entire value chain. Applications analysed across eight domains (product, brand, supply chain, point of sale, end user, society, territory, and environment) are illustrated through case studies that show both practical implementations and systemic value in fostering inclusivity and reinforcing territorial identity. Alongside major opportunities, challenges remain around recyclability, interoperability, implementation costs, and ethical issues related to data and digitalisation. Purpose-driven design is essential to balance these benefits and limitations. Only through such an approach can smart packaging support circular and ethical transitions, while also advancing a transparent, inclusive, and sustainable packaging culture.

Keywords: smart packaging, enabling technologies, design responsibilities, Circular Economy, ethical innovation.

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5.1. Smart packaging: General overview

Amid rapid technological change, environmental degradation, and increasing social complexity, the packaging sector is undergoing a structural transformation. Where innovation meets responsibility, *smart packaging* has emerged as a strategic lever to rethink the meanings, roles, and impacts of packaging systems from a systemic perspective. This chapter examines smart packaging through its definitions, typologies, technological components, application domains, and critical issues. It builds on research and experimentation within the FuturE-Pack project and integrates insights from broader scientific and professional discourse.

According to ISO 6608-1:2024, smart packaging is “a general term to describe a large category of packaging that leverages technology to provide enhanced functionality that goes beyond simply housing a product” (International Organization for Standardization, 2024, p. v). These solutions integrate advanced chemical, physical, electronic, and digital technologies to monitor the condition of products and improve their durability, quality, and safety; to facilitate transparent information exchange between stakeholders across the supply chain; to enhance user experience from purchase to post-consumption; and to support sustainable behaviours and the adoption of circular strategies.

Smart packaging refers to a broad set of solutions that exceed traditional roles of containment, protection, transport, and presentation. The three main typologies are described below. They are not mutually exclusive and often coexist in hybrid solutions. The distinction lies in their functions, while enabling technologies operate across all typologies (fig. 1).

- *Active packaging* interacts with the internal environment of the package to extend shelf life, preserve quality, and ensure safety. It is mainly applied in food and pharmaceutical contexts and integrates components such as absorbers (oxygen, carbon dioxide, or moisture), scavengers (e.g., ethylene), emitters (gas or vapour), functional agents (antimicrobial or antioxidant), barriers (e.g., UV protection), and systems for active heating or cooling.

- *Intelligent packaging* focuses on monitoring and communication. It includes sensors that detect humidity, temperature, gas concentration, or movement, and indicators that translate chemical or physical signals into visible changes, such as colour-shifting inks. It may also integrate data carriers such as barcodes, QR codes, RFID, or NFC tags to provide additional product information.
- *Connected packaging* provides real-time information through interactive digital technologies and internet connectivity. It enables transparent information exchange among supply chain actors and between brands and end users, enriching product interaction and engagement. Typical components include QR codes, RFID or NFC tags, and other digital tools that give access to certifications, multimedia content, or online platforms.

Beyond these categories, intelligent and connected packaging can incorporate advanced components such as GPS trackers, electronic displays, Bluetooth tags, and digital watermarks. These elements are supported by a set of core technologies central to digital transformation: 5G connectivity, immersive environments, blockchain, big data, cloud computing, Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT).

When combined with packaging-specific innovations, these technologies turn packaging into a responsive and communicative interface, able to sense, process, and share information throughout its lifecycle. Packaging is no longer a passive container but an intelligent node in industrial, logistic, social, and environmental ecosystems. This shift represents a fundamental evolution: from static support to dynamic mediator between product, user, and context, consistent with the systemic view of packaging as both cultural and ecological interface. It also highlights broader responsibilities and emerging needs for packaging design.

5.2. Design responsibilities and emerging needs

Smart packaging is not defined solely by its technological components, but by the range of real-world needs it addresses across multiple domains of impact and responsibility. Based on

1. Subcategories of smart packaging and their definitions. Adapted from FuturE-Pack project.

a theoretical framework of packaging responsibilities originally developed by Ciravegna (2022) and later expanded within the *FuturE-Pack* project, thirty-three distinct needs have been identified and articulated across eight macro-categories. Each corresponds to a key area of packaging responsibility.

- At the *product* level, smart solutions address needs such as accurate identification and digital representation of product characteristics, monitoring of environmental conditions, control of quality and integrity parameters, protection against tampering and theft, and optimisation of product preservation and shelf life.
- In relation to the *brand owner* and the broader *brand system*, smart packaging strengthens brand communication and customer loyalty and offers reliable anti-counterfeiting solutions.
- Within the *supply chain*, digital technologies support timely and informed decision-making, enable precise tracking and traceability, and foster optimisation in production, converting, logistics, storage, and last-mile delivery.
- At the *point of sale*, smart packaging facilitates shelf planning and restocking, simplifies and dematerialises sales operations, and enhances the retail experience.
- Focusing on *end users*, smart packaging promotes accessibility and encourages engagement through gamification and reward systems. It also improves the unboxing experience and provides clear instructions for use, reuse, and end-of-life management. In addition, it supports on-the-go consumption and facilitates product return and resale.
- From the *society* perspective, smart packaging enables access to information about the social impacts of products and raises awareness of issues such as diversity, equity, and inclusion.
- Regarding *territory* implications, smart packaging reinforces the recognition of Made in Italy certifications and promotes local production systems and identities.
- Concerning the *environment*, smart packaging aligns with the circular economy framework, which outlines the hierarchical "R-strategies" (Malooly & Tian, 2023; Ellen MacArthur Foundation, n.d.). In this context, it con-

tributes to circularity through multifunctionality (R1–Rethink), material optimisation (R2–Reduce), facilitation of reuse and refill (R3–Reuse), support for repair (R4–Repair), and enablement of refurbishment, remanufacture, and repurposing (R5–R7). It also enhances recyclability and waste management (R8–Recycle), communicates environmental impacts, raises ecological awareness, and helps validate sustainability claims through certifications.

This overview reflects the growing expectation that packaging should act not only as a product container but also as an intelligent and responsible interface contributing to social, environmental, and economic sustainability, in line with the "triple bottom line" approach (Elkington, 1997; Conradie, 2018). It redefines packaging as a system of relations among people, products, technologies, territories, and ecologies, within which innovation becomes meaningful only when guided by shared responsibility and purpose. From this functional and systemic perspective, specific devices and enabling technologies can be identified that support smart packaging functionalities and address key needs.

5.3. Smart devices and core technologies

Integrating digital technologies into packaging is pivotal for advancing sustainability and circular economy strategies. These technologies form a broad set of innovations that improve resource efficiency, reduce waste, enhance traceability, and support sustainable design, production, and consumption across interconnected value chains. From a design perspective, packaging is no longer a static container but a dynamic and intelligent interface that interacts with products, users, and its surrounding environment throughout its lifecycle. What follows is an overview of the digital solutions that drive the development of smart packaging, combining a functional classification of devices with a description of the technological infrastructures that support their operation.

Building on an extensive literature review and an analysis of case studies (Ciravegna et al., 2025), the proposed framework identifies two complementary dimensions: *smart devices*, which are the functional components embedded in packaging systems, and *core technologies*, which provide the enabling infrastructure for data processing, communication, and systemic interaction. Together, these dimensions illustrate the convergence of digital innovation and the evolving functions of packaging in circular and data-driven transitions.

Smart devices comprise a wide range of components that enable real-time monitoring, interaction, and adaptation.

- *Sensors* detect and convert physical, chemical, or biological quantities into electrical signals, allowing packaging to register changes in temperature, humidity, gas concentration, or movement. Applications include quality monitoring, freshness control, and real-time communication of environmental conditions (Subramanian & Alwin David, 2021).
- *Indicators* provide visible cues of key parameters, such as temperature deviations, gas leaks, or product integrity, through colour-shifting inks or other intuitive signals that support user awareness and supply chain decision-making (Ma et al., 2022).
- *Data carriers* such as barcodes, QR codes, RFID and NFC tags, WebAR codes, and digital watermarks transmit information across the supply chain, strengthening traceability, automation, and protection against tampering and counterfeiting (Chrysochou et al., 2009).
- *Emitters* and *absorbers* (*scavengers*) release or remove specific substances to maintain product stability and safety. Emitters can extend shelf life by releasing CO_2, ethanol, or antimicrobial agents (Cordeiro et al., 2025), while absorbers remove oxygen, moisture, or ethylene to prevent spoilage (Sharma et al., 2025).
- *Functional agents*, such as antioxidants and antimicrobials, act at the material level to preserve product quality (Koelsch Sand, 2025).
- *Barriers* restrict the transmission of gases, light, odours, or contaminants by creating controlled internal atmospheres with gas- and UV-blocking layers (Trinh et al., 2023).
- *Temperature control systems*, both passive and active, are especially critical in food, pharmaceutical, and biotechnology sectors. Passive elements include insulation materials or gel packs, while active systems employ thermoelectric

modules or exothermic reactions, often paired with sensors and data logging tools to ensure precise thermal regulation (Coldkeepers, 2025). Self-heating and self-cooling solutions are also used for temperature-sensitive products across distribution chains.
- *Other devices* include components that expand the functional scope of smart packaging beyond the main categories. Examples include electronic displays, GPS trackers, and Bluetooth tags, which enable localisation, dynamic communication, and enhanced connectivity. These heterogeneous solutions strengthen monitoring, transparency, and user engagement, positioning packaging as an active interface across distribution and consumption ecosystems.

Alongside these smart devices, core technologies constitute the digital backbone that enables intelligent functionalities across packaging systems. These infrastructures support connectivity, data processing, human–machine interaction, and systemic integration within increasingly responsive and collaborative supply networks.

- *Artificial Intelligence* (AI) and *Machine Learning* (ML) are central to this digital transformation. AI enables advanced decision-making by processing vast quantities of data, supporting predictive maintenance, demand forecasting, and learning-based automation. Through techniques such as supervised, unsupervised, semi-supervised, and reinforcement learning (Saghiri et al., 2022), AI systems can optimise supply chain operations, monitor energy consumption, and reduce inefficiencies across production and logistics (Samuels & Pelser, 2025; Neri et al., 2025; Varriale et al., 2023). ML, as a subset of AI, enhances performance by recognising patterns and learning autonomously. It underpins predictive analytics, facilitates design for disassembly, and optimises recycling strategies, thereby extending product lifecycles (Bhawna et al., 2024; Wang et al., 2023; Kristoffersen et al., 2020; Rusch et al., 2023; Piron et al., 2024).
- *Internet of Things* (IoT) technologies further expand these capabilities by enabling continuous monitoring and communication between objects and central systems (Lynn

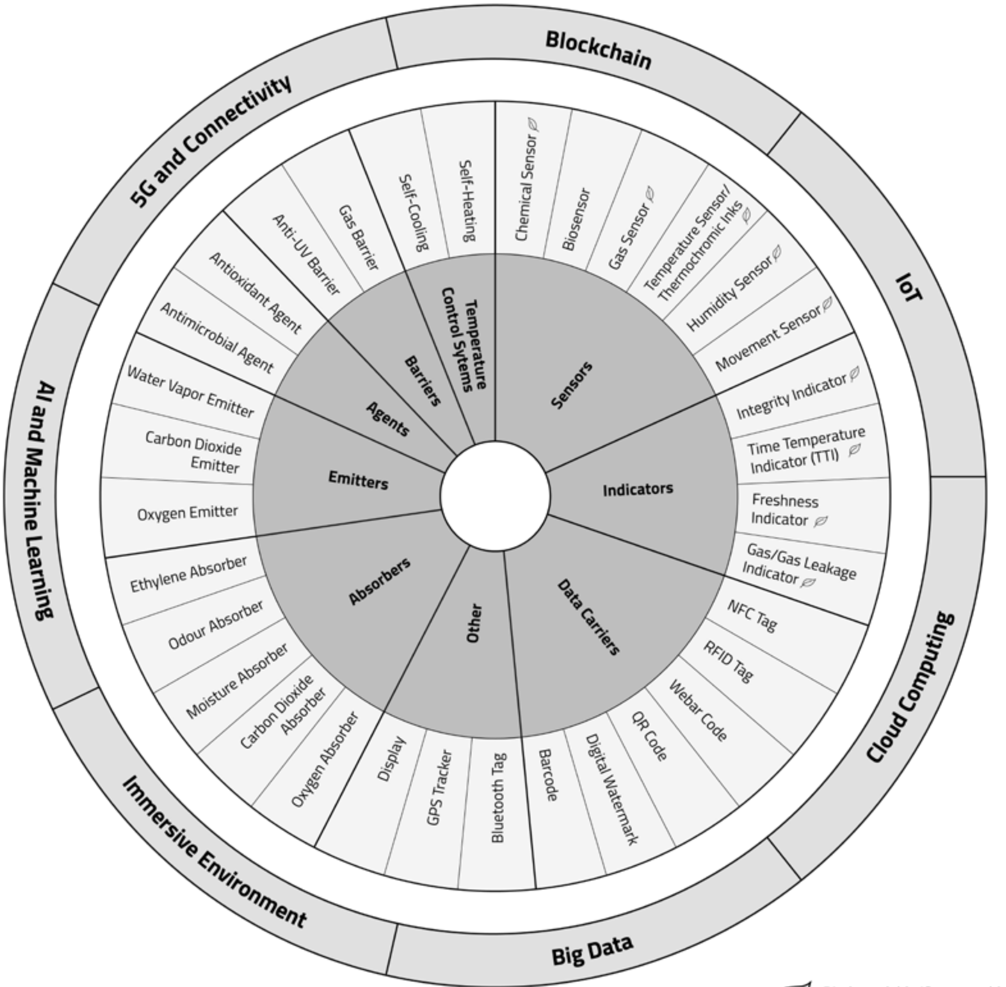
et al., 2020). IoT applications range across consumer domains, such as wearable devices and home automation, and industrial contexts, including predictive maintenance, inventory management, and real-time supply chain adaptation. Embedded sensors allow IoT systems to collect critical environmental data, supporting early defect detection, dynamic logistics adjustments, and improved transparency across operations (Massari et al., 2023; Wang et al., 2023; Kristoffersen et al., 2020).

- *Cloud computing* complements IoT and AI by providing remote access to scalable infrastructures for data storage, processing power, and software services. Deployment models vary from public clouds, managed by third parties, to private clouds restricted to individual organisations, and hybrid or multi-cloud architectures that balance performance, privacy, and operational flexibility. Cloud systems ensure that data from smart devices can be aggregated, analysed, and shared in real time across decentralised platforms without requiring extensive local hardware (Ghobakhloo, 2020; Schilling & Seuring, 2024).
- *Blockchain* technology provides an additional layer of reliability by creating decentralised and immutable records of transactions and product histories. Depending on governance and access protocols, blockchains may be public, private, hybrid, or consortia-based. In the packaging domain, they enable material authentication, monitoring of environmental impacts, and verification of circular business models through smart contracts (Samuels & Pelser, 2025; Varriale et al., 2023).
- *Big data analytics* underpins all these infrastructures, processing high-volume, high-velocity, and high-variety data streams. By drawing on heterogeneous sources such as devices, users, and logistics systems, big data generates actionable insights into consumer behaviour, operational efficiency, and environmental performance. These insights inform strategies for reverse logistics, sustainable sourcing, and risk mitigation, while enhancing transparency, adaptability, and stakeholder engagement (Winkelmann et al., 2024; Agrawal et al., 2025; Neri et al., 2025).
- *Immersive environments*, including Virtual Reality (VR), Aug-

mented Reality (AR), and Mixed Reality (MR), offer interactive, multisensory experiences that facilitate training, simulation, and collaborative design. In packaging contexts, they enable virtual prototyping, user testing, and the optimisation of recycling workflows, contributing to material savings and more intuitive product–user relationships (Rejeb et al., 2022; Harikannan & Vinodh, 2025; Skalli et al., 2022).

- *Automation* and *robotics* also play a crucial role, particularly in combination with *Additive Manufacturing* (AM). AM allows on-demand, localised, and customised production with minimal waste, while supporting repair, remanufacturing, and lightweighting (Massari et al., 2023; Behl et al., 2023). Robotic systems increase precision, automate sorting and disassembly, and reduce overproduction and manual inefficiencies, thereby improving both sustainability and cost-effectiveness (Kristoffersen et al., 2020; Varriale et al., 2023).
- Finally, *5G connectivity* provides the speed and reliability needed for real-time digital packaging systems. With ultra-fast, low-latency data transmission and support for multiple communication protocols, such as UMTS/HSPA, WiMAX, EV-DO, and satellite links, 5G networks enable seamless integration between mobile devices, IoT sensors, cloud platforms, and smart packaging infrastructures (European Commission, 2025).

When combined, smart devices and core technologies transform packaging systems into responsive and communicative interfaces that interact continuously with their environment. No longer an inert container, the system becomes an intelligent agent able to sense, process, and exchange data throughout its lifecycle. This transformation supports traceability, circularity, and systemic responsiveness, while also reinforcing its integration into industrial, logistic, social, and environmental ecosystems. Rather than acting in isolation, the artefact functions as a node within broader networks of production and consumption, contributing to more transparent, adaptable, and sustainable value chains. This shift not only redefines its role across product lifecycles but also underscores its potential as a strategic interface for advancing sustainable, data-driven transitions in both industrial and consumer contexts (fig. 2).



2. Taxonomy of smart devices and core technologies for packaging. Adapted from FuturE-Pack project.

5.4. Functions and application domains

As previously outlined, the responsibilities of smart packaging can be articulated across eight domains that reflect concrete challenges along the value chain. Their scope has been explored and validated through the analysis of 230 case studies, drawn from diverse sectors, product categories, and technological applications (Ciravegna et al., 2025). This framework highlights the evolving role of packaging as an intelligent and proactive agent embedded in complex production, distribution, and communication systems. In this context, digital technologies act as key enablers, allowing smart packaging to mediate between industrial, social, and environmental goals.

In the product domain, digital technologies play a central role in enhancing transparency, safety, and quality control. RFID, NFC, QR codes, blockchain, and digital product passports enable traceability throughout the entire product lifecycle, offering detailed information on origin, materials, conditions, and usage (Hakola et al., 2025). A compelling example is The Box,[1] a reusable logistics container equipped with sensors. It monitors variables such as temperature, humidity, shock, and pressure, while also integrating GPS tracking and digital interfaces that provide real-time data on environmental conditions during transit. This ensures that sensitive goods are protected across multiple delivery cycles and helps reduce waste through reuse. Another relevant case is Mimica,[2] a smart label that changes texture in response to food spoilage, offering a tactile, real-time indicator of freshness. Instead of relying on static expiry dates, the system reflects actual storage conditions, helping to reduce waste and extend shelf life (European Union, 2019). These solutions demonstrate how smart packaging ensures not only product integrity but also a more informed and sustainable user experience.

In the brand domain, smart packaging becomes a strategic medium for communication and authentication. It protects product identity and fosters trust between brands and consumers. Certilogo,[3] used for instance by the Armani Group, allows users to verify product authenticity through a QR code-based system that generates a unique code (Certilogo, 2023). This reinforces brand transparency and supports anti-counterfeiting strategies. At an experiential level, the collaboration between

Blue Bite and Kenwood Vineyards[4] illustrates how dynamic content can deepen brand storytelling. When users scan the bottle's label, they access a personalised digital platform with multimedia content such as tasting notes, food pairing suggestions, and drone footage of the vineyard. The interaction not only enriches the brand narrative but also creates a two-way channel that captures user data and builds emotional engagement. These examples highlight how digital technologies enhance the communicative role of packaging while aligning with brand values and consumer expectations.

Within the production and supply chain domain, digital technologies optimise workflows, improve efficiency, and support the shift towards customisation and automation. Smart logistics and inventory systems, based on RFID, GPS, AI, and machine learning, enable real-time monitoring and decision-making. Sparck CVP Impack[5] exemplifies this approach through the use of 3D scanning and adaptive software to create right-sized packaging for e-commerce shipments. This reduces the need for void-fill, minimises material waste, and lowers transport emissions. Another notable case is Holy Grail 2.0,[6] which applies invisible digital watermarks to plastic packaging. These marks carry information that can be read by optical scanners at sorting facilities, enabling more precise and automated recycling. Importantly, the solution preserves the original packaging design. Together, these cases illustrate how digital packaging technologies contribute not only to operational performance but also to sustainable and circular production practices.

At the point of sale, smart packaging enhances both retail operations and customer interaction. Identifiers such as RFID tags and NFC labels facilitate shelf management, stock control, and automated checkout, while also enabling enriched user experiences. Trax,[7] an AI-powered platform, uses cameras and image recognition to assess product positioning and availability on shelves, helping retailers improve merchandising strategies and reduce stockouts. Decathlon's self-checkout system, based on RFID technology,[8] enables instant recognition of multiple items without manual scanning, reducing waiting times and supporting better inventory tracking. These applications demonstrate how smart packaging supports a more efficient, responsive, and engaging retail ecosystem.

In the territory domain, digital packaging highlights the geographical and cultural origins of products. It supports the valorisation of local identity, craftsmanship, and production transparency, particularly in sectors such as fashion, food, and wine. The Parmigiano Reggiano Consortium,[9] for example, has developed an edible microchip embedded in the cheese rind that documents the entire production process. This solution offers secure traceability while reinforcing the authenticity of Made in Italy. Similarly, Amazon India's Storyboxes project[10] transforms packaging into a storytelling medium, featuring illustrations and QR-based narratives about small-scale producers. These boxes present faces, places, and stories from various Indian regions, forging a human-centred connection between consumers and local communities. By embedding territorial narratives directly in packaging, these initiatives turn logistics into a space of meaning and dialogue between origin and destination.

In the environmental domain, smart packaging supports circular strategies and encourages more sustainable behaviours. Digital solutions help reduce material use, optimise distribution, and support correct disposal or reuse (Palazzo et al., 2023). The Cif EcoRefill[11] system offers compact, concentrated refill packaging that cuts down on plastic consumption and transport-related emissions. A QR code provides information about the product's environmental benefits, promoting transparency and responsible consumer behaviour. Aiming at eliminating economic barriers often faced by low-income households, Algramo,[12] a Chilean start-up, expands this model by combining RFID-tagged reusable containers with IoT-enabled refill stations. Its mobile and in-store dispensing solutions reduce single-use plastic and allow consumers to purchase everyday goods "by the gram," from the Spanish *al gramo*. This approach connects environmental performance with social equity, reflecting how digital packaging can address multiple layers of sustainability.

In the social domain, smart packaging becomes a vehicle for inclusion, equity, and ethical awareness. It can communicate working conditions, promote fair trade, or enhance accessibility (Nordin & Selke, 2010). In the UK, Kellogg's partnership with NaviLens[13] produced cereal boxes with digital codes readable from a distance by smartphones, enabling blind and partially sighted users to hear product information. This promotes independent shopping and raises awareness of everyday accessibility needs. Another example is Tony's Chocolonely,[14] which uses unevenly divided chocolate bars to symbolise inequality in cocoa production. The packaging includes facts and narratives that educate consumers on child labour and the unfair distribution of profits. Both examples show how packaging can serve not only commercial purposes but also social advocacy and education, contributing to a more just and inclusive value chain.

Finally, in the end-user domain, smart packaging establishes a direct relationship between the product and the person using it. It improves access to information, personalises the experience, and encourages responsible usage and disposal. Immertia's[15] solution merges AR, AI, and holographic interfaces to deliver on-pack 3D assistants that answer user queries in real time. This turns packaging into a proactive communication tool that offers guidance and support in a visually immersive way. In a more safety-focused approach, Tostitos' Party Safe[16] campaign introduced a packaging design that detects alcohol on the breath and connects directly to Uber through NFC, encouraging responsible choices and potentially preventing impaired driving. These cases reveal how digital packaging can enhance interaction, foster ethical awareness, promote social advocacy, and empower consumers to make informed decisions in their everyday actions.

Together, these eight domains reveal how identified needs translate into practice through smart packaging. The framework illustrates how digital technologies address real-world challenges while enhancing efficiency, sustainability, ethical practices, and the value of the Made-in-Italy supply chain.

5.5. Designing smart packaging for ethical transitions

The evolution of smart packaging reflects a broader paradigm shift in which packaging is no longer conceived as a disposable container but as a strategic interface between products, people, and ecosystems. Within this expanded and systemic vision, design can contribute to shaping a more ethical, transparent, and sustainable packaging culture. Beyond its technical functions, smart packaging holds a powerful cultural and communicative potential. It can act as a narrative medium that conveys the identity, values, and history of products and brands, while also fostering user awareness and engagement. To fully realise this potential, designers must consider inclusivity, accessibility, and equity as core values, ensuring that technological innovations are comprehensible, usable, and beneficial to stakeholders of all backgrounds and abilities.

From a sustainability perspective, smart packaging generates environmental, social, and economic benefits. Environmentally, it can significantly reduce food waste through freshness monitoring and improved product conservation. It also helps optimise logistics and transport via real-time tracking and supports correct waste management and recycling, for instance, through digital disposal instructions, smart labelling, and lightweight or modular designs. Socially, when designed responsibly, it can enhance accessibility for users with visual or cognitive impairments through augmented reality or voice-enabled interfaces, and encourage conscious consumption through transparent information and educational content. Economically, predictive maintenance and data-driven optimisation can reduce operational costs, support circular business models, and strengthen brand reputation.

Nonetheless, a number of critical challenges must be addressed. Such challenges include the complexity of recycling due to embedded sensors or mixed materials, the short lifespan of electronic components, and the high implementation costs that may exclude SMEs. Ethical concerns emerge around digital surveillance, lack of transparency in data use, and potential greenwashing. Moreover, the absence of common standards and interoperable systems hinders scalability and widespread adoption. There is also a risk that smart features may be misunderstood or underused by consumers, or that excessive digitalisation may lead to unnecessary complexity. Ethical design must therefore be accompanied by policies and standards that promote transparency, data protection, and inclusive access across the entire packaging value chain, ideally aligned with industry-wide principles such as The Ethical Packaging Charter (Baule & Bucchetti, 2015).

Benefits and challenges must be balanced within a design process that is critically aware, ethically grounded, and strategically aligned with sustainability goals. This perspective aligns with the notion of "purpose-driven innovation," an approach that places ethical and social intentions at the core of design and technological development. Drawing on the "Golden Circle" model (Sinek, 2009), this concept encourages organisations to first clarify *why* they innovate, prioritising impact over output, before defining the *what* and the *how*. Such orientation repositions smart packaging as a catalyst for meaningful transitions, where technological advancement serves broader goals of inclusivity, resilience, and environmental responsibility, in line with a planet-centric design perspective that foregrounds ecological interdependence and long-term stewardship (Ciravegna, 2020; Ciravegna et al., 2024).

Only through such an integrated and purpose-driven approach can smart packaging fulfil its promise as a catalyst for circular, inclusive, and forward-looking transitions. In this view, smart packaging is not merely a technological artefact but a platform for shared responsibility, a space where products, people, organisations, societies, and ecosystems intersect. Its intelligence lies not only in embedded circuits or algorithms, but in its capacity to generate awareness, influence behaviours, and foster systemic change. Such an approach calls for design practices that are not only technologically advanced but also culturally sensitive and ethically responsive, capable of navigating complexity with critical clarity and humility. Ultimately, an ethics of limitation should be embraced, recognising not only the potential but also the boundaries of what packaging can and should do. Responsible innovation in this field calls for sobriety, restraint, and humility to avoid technological excess, favouring simpler solutions when they are more sustainable and equitable.

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Notes

[1] https://livingpackets.com/
[2] https://www.mimicalab.com/bump
[3] https://www.certilogo.com/
[4] https://jacklondonpark.com/beauty-ranch/
[5] https://sparcktechnologies.com/solutions/cvp-impack/
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