

Sorting for a circular future: How new technologies unlock new opportunities in paper-based packaging recycling

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INTRODUCTION:

As Europe races toward ambitious recycling targets, one question is emerging as central to the future of circular packaging: how can we sort increasingly complex paper-based materials accurately, efficiently, and at scale?



As the shift toward a more circular economy accelerates, paper-based packaging has emerged as a leading example of sustainable design. As a wider range of paper-based packaging enters the market, there are opportunities for investments in new technologies and processes that ensure high-quality, recyclable packaging is collected, sorted and recycled at scale.

The latest Guidance on the Improved Collection and Sorting of Paper-Based Packaging for Recycling created in a collective effort by the 4evergreen alliance lays out both the challenges and promising breakthroughs that can contribute to the future of Europe's paper recycling infrastructure.

This updated version of Guidance aims to help policymakers, municipalities, waste operators, and industry partners understand best practices for collection and sorting in Europe. The document maintains its recommendation for separate household collection systems:

- One stream for paper and board materials (P&B)
- One stream for lightweight packaging (LWP)

This approach reduces contamination, increases yield, and ensures that materials reach the appropriate recycling infrastructure, whether it is a paper mill with conventional or specialised recycling process.

Together with the recently updated Circularity by Design Guideline and the Recyclability Evaluation Protocol, the Guidance forms an integral part of 4evergreen's Toolbox. Through its findings, the alliance is dedicated to perfecting the circularity of paper-based packaging, thereby supporting the transition towards a circular and sustainable society. By working together, the shared ambition is to raise the recycling rate of paper-based packaging in Europe to 90% by 2030. Bringing together more than 100 industry leaders from the entire paper-based packaging value chain - including pulp, paper, and board manufacturers and recyclers, as well as packaging producers, converters, food and beverage brand owners, retailers, and waste management companies - the alliance fosters robust collaboration across the sector.



A Fragmented System in Need of Harmonisation

Materials recovery facilities (MRFs) across Europe are equipped with a wide mix of technologies, from mechanical screens to sophisticated optical sorters. While these tools can handle most conventional paper packaging, challenges can start when packaging contains components that are hard to handle in widely used paper recycling processes or other disruptors:

- Integrated plastic windows confuse the optical signature.
- Thick outer coatings can conceal the fibre-based substrate underneath.
- Carbon-black pigments absorb NIR (near infra-red light), making objects “invisible” to scanners.
- Metallised surfaces scatter near-infrared (NIR) signals, making identification difficult.

As a result, these items may be wrongly sorted, rejected, or diverted to lower-value streams. Once they miss the correct path, they rarely return.

What’s missing, according to industry experts, is a harmonised, Europe-wide sorting protocol – an area where standardisation discussions are currently underway at European level.

In practice, each technology provider and sorting facility applies its own tests and thresholds. For packaging designers, this makes it complex to predict real-world recyclability.

The Technologies Powering Today’s Sorting

1. Mechanical Treatment: The First Gatekeeper

Before sensors, algorithms, or air jets come into play, waste first passes through a series of mechanical “gatekeepers.” Rotating trommels, screens, and ballistic separators loosen compacted material and sort it by size and shape. This step may seem purely preparatory, but it already shapes the recycling outcome: what is separated out here will never reach more advanced sorting stages.

Most paper-based composites end up in the mid-sized fractions – typically between 50 and 220 mm – that are then sent forward for optical analysis. If materials are misdirected at this early stage, even the most advanced downstream technology can’t recover them.

2. Optical Sorting with NIR–VIS Systems

Once materials reach the optical line, near-infrared and visible-light systems take over. These NIR-VIS (near-infrared visible) sorters are the backbone of modern facilities, identifying materials based on how they reflect and absorb light rather than how they look to the human eye.

They perform reliably with well-established paper streams such as:

- graphic papers,
- corrugated board
- liquid packaging cartons, whose distinctive fibre-plus-polymer structure makes them relatively easy to recognise

The challenge emerges as packaging formats diversify: Multilayer structures, coatings, foils, and unconventional shapes can blur optical signals or mimic other materials. As a result, optical sorting can no longer carry the system on its own.



The Next Frontier: From AI to Digital Watermarks

The industry is rapidly pivoting towards smart sorting technologies designed to overcome the limitations of mechanical and optical systems.

Artificial Intelligence (AI) and Deep Learning

Leading companies are already integrating AI-driven recognisers into sorting lines. Trained on thousands of images, these systems can:

- Identify packaging by shape, texture, print, or brand
- Detect materials invisible to NIR
- Improve accuracy in mixed or contaminated streams
- Replace or support manual quality checks

AI doesn't rely solely on spectral signatures. It "sees" the packaging much like a human sorter would, offering a powerful complement to traditional optical systems.

Digital Watermarking: A Quiet Revolution

Another promising innovation doesn't rely on bigger machines or sharper sensors; it comes in the form of invisible digital watermarks printed across packaging surfaces, creating a persistent information layer that travels with the product from production, through use, and all the way to its end-of-life

These near-invisible codes contain detailed information about the product: its material layers, recyclability stream, food/non-food status, and more.

When scanned in high-speed MRFs:

- Watermarks can precisely guide each pack to the correct recycling stream.
- Even complex FBCP could become reliably sortable.
- False detections could drop dramatically.

This future-ready technology is already being piloted internationally, with strong involvement from packaging manufacturers and sorting-technology suppliers.

Why Sorting Matters Now More Than Ever

Under the EU's Packaging and Packaging Waste Regulation (PPWR), achieving "recycled at scale" status requires that materials be:

- Separately collected
- Reliably sorted using established technology
- Recycled in operational facilities at significant volumes

To meet the 4evergreen key target of a 90% recycling rate of paper-based packaging by 2030, each of these steps must be aligned. Incorrect sorting doesn't just reduce recycling rates, but it affects the fibre quality available to paper mills, disrupts mill operations, and increases environmental and economic costs across the value chain.

Towards a Harmonised Sorting Protocol

Annex 4 of the 4evergreen Guidance highlights the need for a unified testing framework applicable across equipment suppliers and countries. Such a protocol could:

- Assess how packaging behaves in real sorting plants
- Establish minimum performance thresholds for detection
- Help designers ensure new packaging is sortable in practice

Help unlock investment in new sorting infrastructure This would close the gap between design for circularity and actual recyclability, ensuring packaging design innovations don't outpace the systems meant to process them.

The Bottom Line: A Smarter System for a Circular Economy

Europe's recycling ecosystem is on the cusp of an exciting transformation. While current mechanical and optical technologies already process much of today's paper-based packaging, ongoing innovation is paving the way to efficiently manage the increasingly complex materials of the future. Without action, the result could be more mis-sorted materials, reduced fibre yield and a slower transition to circularity.

The good news?

AI, robotics, and digital watermarking offer critical enablers to transform sorting into a powerful driver of recycling success, helping to accelerate progress towards a more sustainable future.

The members of the 4evergreen Alliance are committed to ensuring that these opportunities are translated into tangible progress across Europe's recycling systems.

