



A Study of Advanced Smart Packaging Technologies in Plastic Waste Sorting and Recycling

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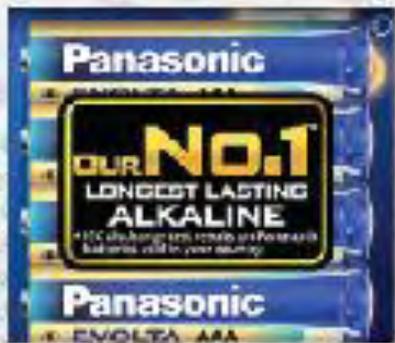
Appalachian State University

Plastic Packaging

- In packaging, plastics are particularly valued for being lightweight, cost-effective, and high-performing.
- While it is important to pursue strategies that minimize plastic usage, such as reducing single-use plastics, transitioning to alternative materials, and optimizing packaging designs, plastic's versatility and efficiency ensure its continued relevance in the packaging industry.



Panasonic Introduces Paper-Based Packaging for Batteries



Starbucks Tests Compostable Fiber-Based Cups for Cold Beverages

McDonald's McCafé Introduces Compostable Espresso Capsules

Best Buy Collaborates with Sealed Air on Sustainable Packaging Solutions



The Challenge of Plastic Waste



- 95% of the material value of plastic packaging is lost after just one use. After the first use, only about 5% of its value is recovered.
- Only about 14% of plastic packaging is collected for recycling, with the remaining 72% being landfilled, incinerated, or lost through leakage.
- Due to the wide variety of plastic types, contamination, and inadequate recycling infrastructure, the process of recycling is both costly and inefficient.



Plastic Waste Recycling

- Plastics must be sorted by type. When mixed, they can result in low-quality recycled products that are less valuable and harder to process.
- The complexity of plastic recycling is further heightened by the wide variety of materials and compositions in circulation. Multilayer and composite materials, which are often not designed for recycling in standard systems, require additional effort to separate and process.
- To address these challenges, the plastics industry must adopt a new business model that drives the transition toward a true circular economy. An essential part of this transformation is improving traceability and information sharing among all stakeholders involved in the plastics supply chain.

Linear Life Cycle

RESOURCE
ACQUISITION



MANUFACTURE



PACKAGING AND
TRANSPORTATION



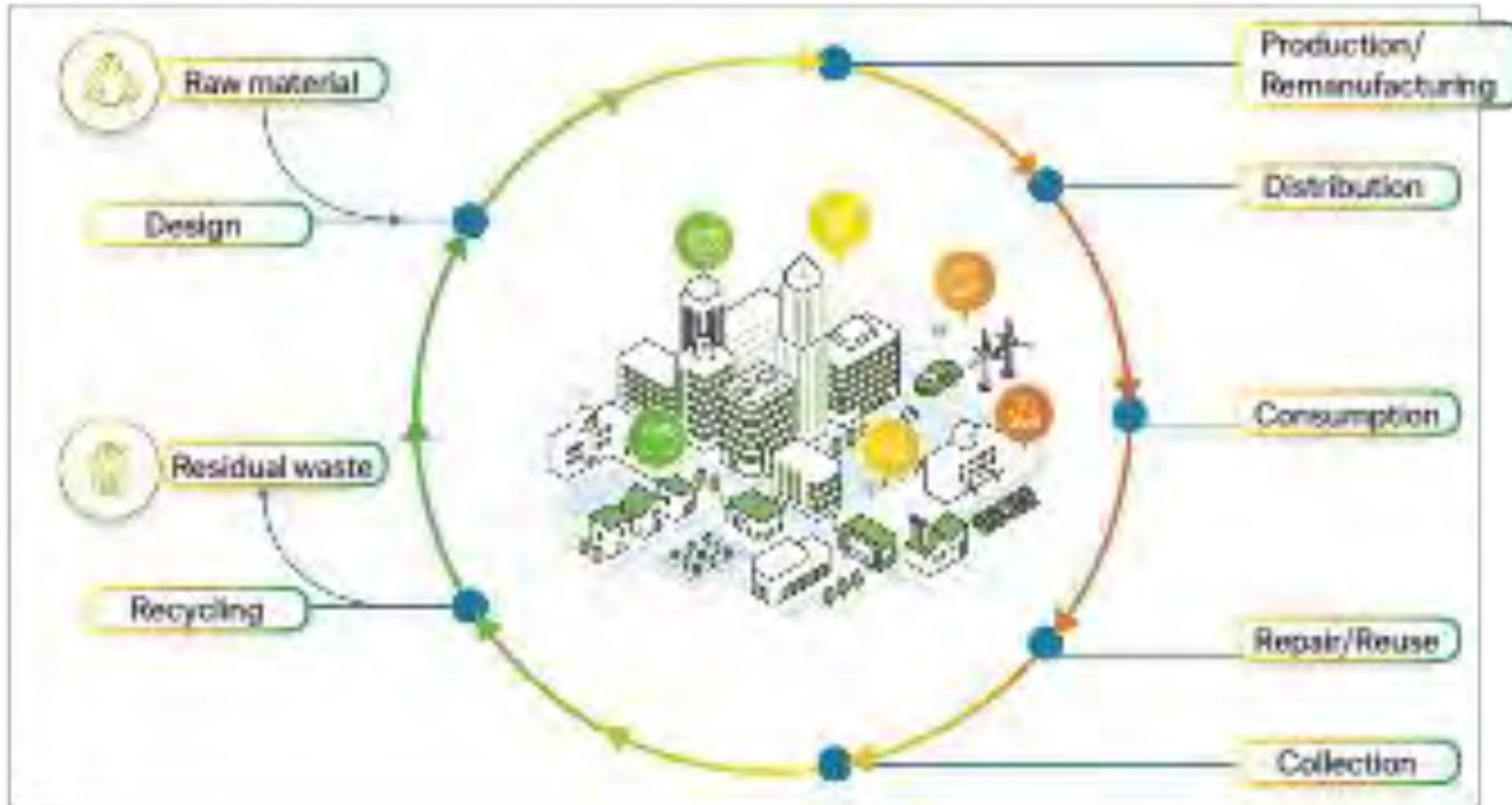
USE



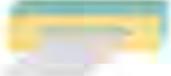
END-OF-LIFE

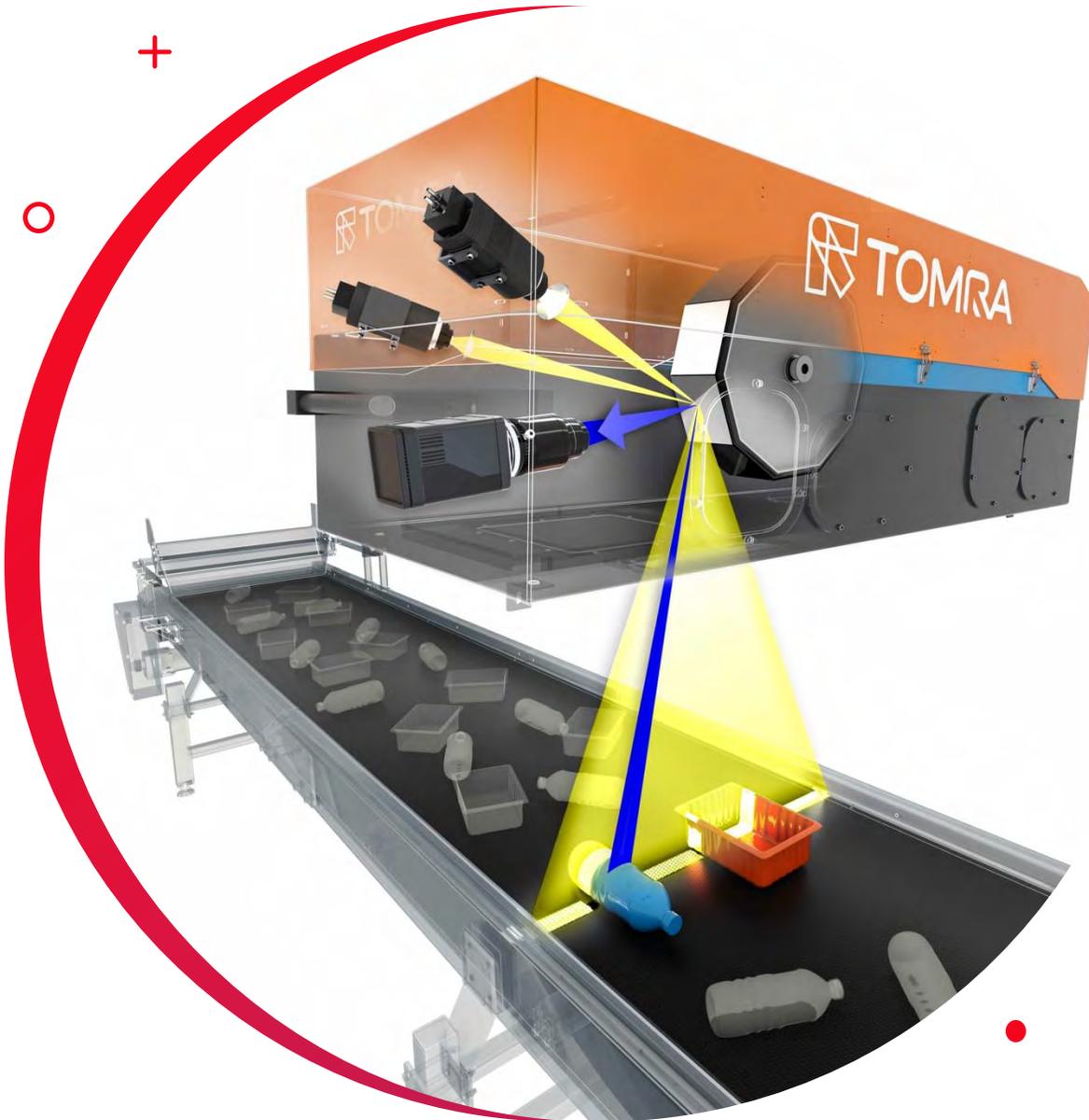


The Circular Economy



			Common products:	Recycled products:
	PET Polyethylene Terephthalate		soda and water bottles, cups, jars, trays, clamshells	clothing, carpets, clamshells, soda and water bottles
	HDPE High-Density Polyethylene		milk bottles, freezer bags, dip tubs, crinkly shopping bags, ice cream containers, juice bottles, shampoo, chemical and detergent bottles	detergent bottles, flowerpots, crates, pipes, decking
	PVC Polyvinyl Chloride		cosmetic containers, commercial cling wrap	pipe, wall siding, binders, carpet backing, flooring

			Common products:	Recycled products:
	LDPE Low-Density Polyethylene	 	squeeze bottles, cling wrap, shrink wrap, rubbish bags	trash bags, plastic lumber, furniture shipping envelopes, compost bins
	PP Polypropylene	 	microwave dishes, ice cream tubs, potato chip bags, and dip tubs	paint cans, auto parts, food containers, hangers, plant pots, razor handles
	PS Polystyrene	 	cd cases, water station cups, plastic cutlery, imitation 'crystal glassware', video cases	picture frames, crown molding, rulers, flowerpots, hangers, toys
	Others	 	polycarbonate, nylon, acrylonitrile butadiene styrene, acrylic, polylactic acid	electronic housings, auto parts



Enhanced Optical Sorting

- Near-Infrared (NIR) spectroscopy is a widely used technique in plastic sorting systems.
- It uses near-infrared light to scan plastic materials and identifies them based on how they absorb and reflect different wavelengths of light.
- The technology is capable of distinguishing between 12 types of plastics.

Enhanced Optical Sorting Limitations

- **Carbon-black-colored plastics** are a major issue.
 - Companies like Lanxess have developed new black pigments based on iron oxide, which allow for NIR reflectivity.
 - Other techniques, such as mid-infrared spectroscopy, hyperspectral imaging, and fluorescence imaging, are being developed to complement NIR.
- Another significant issue in plastics recycling is **the growing use of multilayer packaging and composite materials**.
 - Trinamix has developed a mobile NIR spectroscopy solution that uses robust hardware combined with intelligent data analysis and a mobile app.
 - Researchers from Aarhus University in Denmark have introduced a new NIR camera technology that offers more accurate sorting based on the chemical composition of the polymers.
 - Tomra's Autosort system combines multiple technologies—including NIR spectroscopy, laser, electromagnetic, and AI-based camera sensors—to provide more precise sorting and separation.

TOMRA AUTOSORT Sorting



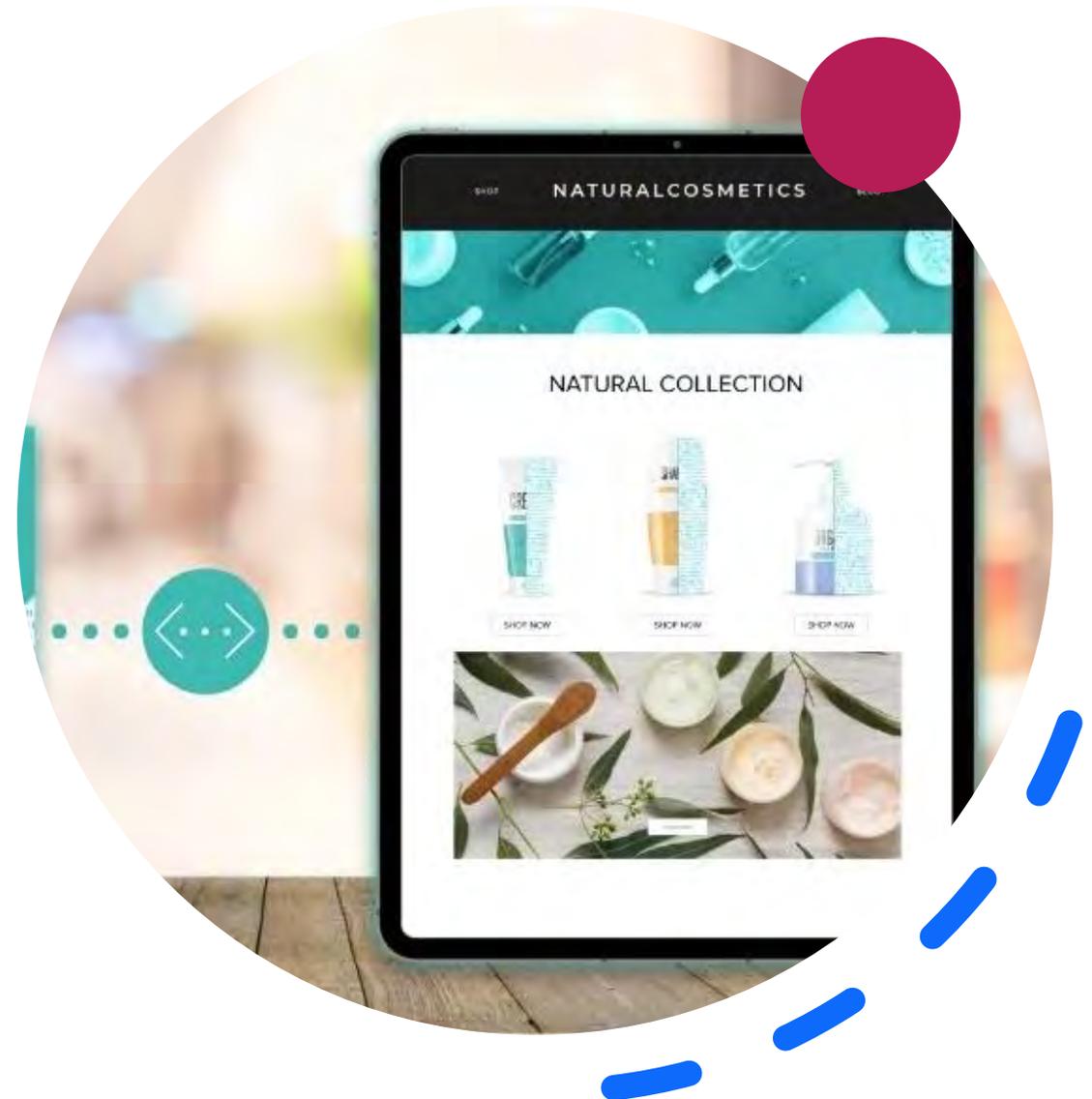
Digital Watermarks



- Digital Watermarks are imperceptible barcodes applied to the surface of packaging, either on in-mold or sleeve labels or directly on the product itself.
- Using a technique called “pixel-scattering,” digital watermarks create codes that are invisible to the naked eye but can be easily detected by high-resolution cameras equipped with special software.
- This design ensures the watermarks can be scanned from any angle, making it easy to detect the code regardless of the package's orientation during the sorting process.

Digital Watermarks

- One of the primary benefits of digital watermarks is their ability to store detailed information about the packaging material.
- This information can include key attributes such as the manufacturer, SKU, type of plastics used, the composition of multilayer objects, and whether the packaging is for food or non-food products. This level of detail provides essential data for accurate sorting of materials once the packaging reaches a waste-sorting facility.



DIGIMARC Digital Watermarks

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HolyGrail 2.0



- HolyGrail 2.0 is a collaborative initiative designed to tackle the growing challenges in plastic recycling.
- HolyGrail 2.0 brings together over 160 companies across the entire packaging value chain, including major global brands like Procter & Gamble, Nestlé, PepsiCo, and Danone.
- The key technology at the heart of the project is digital watermarking, which provides a way to identify and sort different types of packaging more efficiently.
- A central player in this initiative is Digimarc, which provides the digital watermarking technology that underpins the project. Its solution, Digimarc Recycle, integrates covert digital watermarks with a cloud-based product attributes database.

Digital Watermarks & HolyGrail 2.0



AI-based Waste Management

- AI models used in material recovery facilities (MRFs) typically consist of three components: **computer vision technology** for recognizing and categorizing materials, **AI learning systems** for making decisions based on that data, and **sorting robots** that physically handle the materials.
- Key Innovations in AI-Based Sorting include:
 - **Glacier's** AI technology provides real-time trend analysis of material streams at MRFs.
 - **AMP Cortex** achieves up to 99% accuracy in sorting materials at speeds of 80-120 picks per minute; **AMP Clarity**, a material-characterization and robot-performance software that monitors real-time performance and material composition. **AMP Vortex** targets film and flexible packaging recovery.
 - **EverestLabs'** AI system uses deep learning and robotics to improve recovery rates at MRFs.
 - **RecycleOS** provides real-time analytics on plant operations and offers a granular look at environmental impacts.
 - **TrashBot** is a smart recycling bin powered by AI, which uses computer vision and machine learning to sort waste with up to 95% accuracy.

AI Robot Application



Conclusions

- Optimizing materials for recyclability is crucial to ensure that after-use plastics remain valuable within the economy. The recycling pathway is often preferable over biodegradability, as it allows plastic to be reused and repurposed, reducing waste.
- The improvement of collection systems and recovery infrastructure is key. Traceability systems can provide transparency, ensuring plastics are properly collected, sorted, and recycled.





THANK YOU