

Introduction

Relevance of the research. With around 2.2 billion tons of waste generated in the EU every year, the EU is renewing its waste management legislation to encourage the transition to a more sustainable model known as the circular economy. Circular economy principles are oriented towards a more sustainable future and encourage companies to change traditional business models by reorienting towards durability, reparability and recyclability. With a strong emphasis on environmental conservation, social accountability, business growth and innovation, the circular supply chain network creates connections and promotes innovative solutions in logistics. Technologies driven by Industry 4.0 connect the physical and digital worlds, unlock the benefits of digitization, improve organizational sustainability and in turn increase the development of the green economy.

Research object. Digitization of warehousing processes based on circular economy principles.

The aim. To reveal the possibilities of using circular economy principles in the digitalization of warehousing processes.

Research tasks:

1. Describe the importance of digitization of warehousing processes in the context of circular economy.
2. Identify opportunities for sustainable solutions by digitizing warehousing processes.

Research methods: systematic analysis and synthesis of scientific literature.

It is expected that by 2030 world population will reach nearly 9 billion people, including 3 billion new middle-class consumers. This puts unprecedented pressure on natural resources to meet future consumer demands (World Economic Forum, 2024).

The European Commission adopted the new Circular Economy Action Plan (CEAP) in March 2020. It is one of the main elements of the European Green Deal, the new European agenda for sustainable growth. The EU's transition to a circular economy will reduce pressure on natural resources and boost sustainable growth and job creation. It is also a necessary condition for reaching the EU's 2050 climate neutrality goal and stopping the loss of biodiversity. A shift to more reliable products that can be reused, refurbished and repaired would reduce waste. Packaging is a growing problem and on average each European is responsible for nearly 180 kilograms of packaging waste per year. The aim is to tackle the problem of excess packaging and improve its design to encourage reuse and recycling (European Parliament, 2023). Unlike the "take-make-throw" model, the circular economy aims to reduce waste and resource use as much as possible through advanced product design, product reuse and repair, recycling, sustainable consumption and innovative business models that, for example, offer an alternative to purchasing a product the service of renting, lending or sharing it (Wikipedia, 2023).

IoT can be used to pinpoint the exact location of materials in a warehouse and monitor the condition of the material from anywhere in the warehouse (Manvalan et al., 2019). Most environmental conservation practices can be applied to the manufacturing sector, as manufacturing companies are also involved in transportation, warehousing and packaging activities in the production and handling of products. The only difference is that recycling cannot be found in the logistics sector as a circular economy principle (Jayarathna et al., 2023).

Methodology

To achieve the goal of the study, the method of systematic review of the literature was used.

Articles registered in international journals from Scopus, MDPI and Google Scholar databases since 2013 to 2023 were collected and analyzed.

The combination of keywords used during the search: „digital technologies in warehousing“ OR „digitalization for circular economy“ OR „benefits of digital technologies in warehousing“ OR "challenges integrating digital technologies".

According to the applied combinations of keywords, 195 articles were found.

Full-text articles were used for analysis. The analysis of the articles was carried out in three stages:

- 1) review of the title,
- 2) review of the summary,
- 3) review of the entire text.

Excluded articles that did not align with the research objectives or lacked empirical data on the integration of digital technologies in warehousing. As a result of the selection 34 suitable scientific articles were included in the systematic analysis.

By employing a systematic and rigorous approach to literature analysis, the research aimed to provide a thorough understanding of the current state of knowledge regarding the integration of digital technologies in warehousing processes for advancing the principles of a circular economy.

Results

By optimizing operations, reducing waste, and exploring opportunities for collaboration and resource recovery, warehouses can contribute to the circular economy, simultaneously reducing their environmental impact (Huff, 2023). The digitization of warehousing processes involves transitioning from traditional manual or paper-based warehouse management to digital technology and process automation, utilizing various information technology solutions.

Real-time tracking and monitoring through IoT devices provide a granular view of inventory movements, enabling agile decision-making and reducing the likelihood of stockouts or overstock situations. Robotics and automation technologies streamline order fulfillment, inventory replenishment, and material handling, improving operational efficiency and reducing labor-intensive tasks. Furthermore, advanced warehouse management systems (WMS) powered by AI facilitate intelligent decision-making by analyzing historical data, current trends, and external factors. This ensures optimal resource allocation, efficient order batching, and improved overall warehouse performance.

The adoption of a technology mix is supported by Attaran (2020), who indicated that artificial intelligence and robotics, cloud computing, 3D printing, advanced analytics, blockchain, augmented reality, RFID, the Internet of Things, and cloud technologies foster digital trends and changes in the supply chain.

The authors of the article have summarized the digitalization practices of warehousing processes toward the circular economy (see Figure 1).

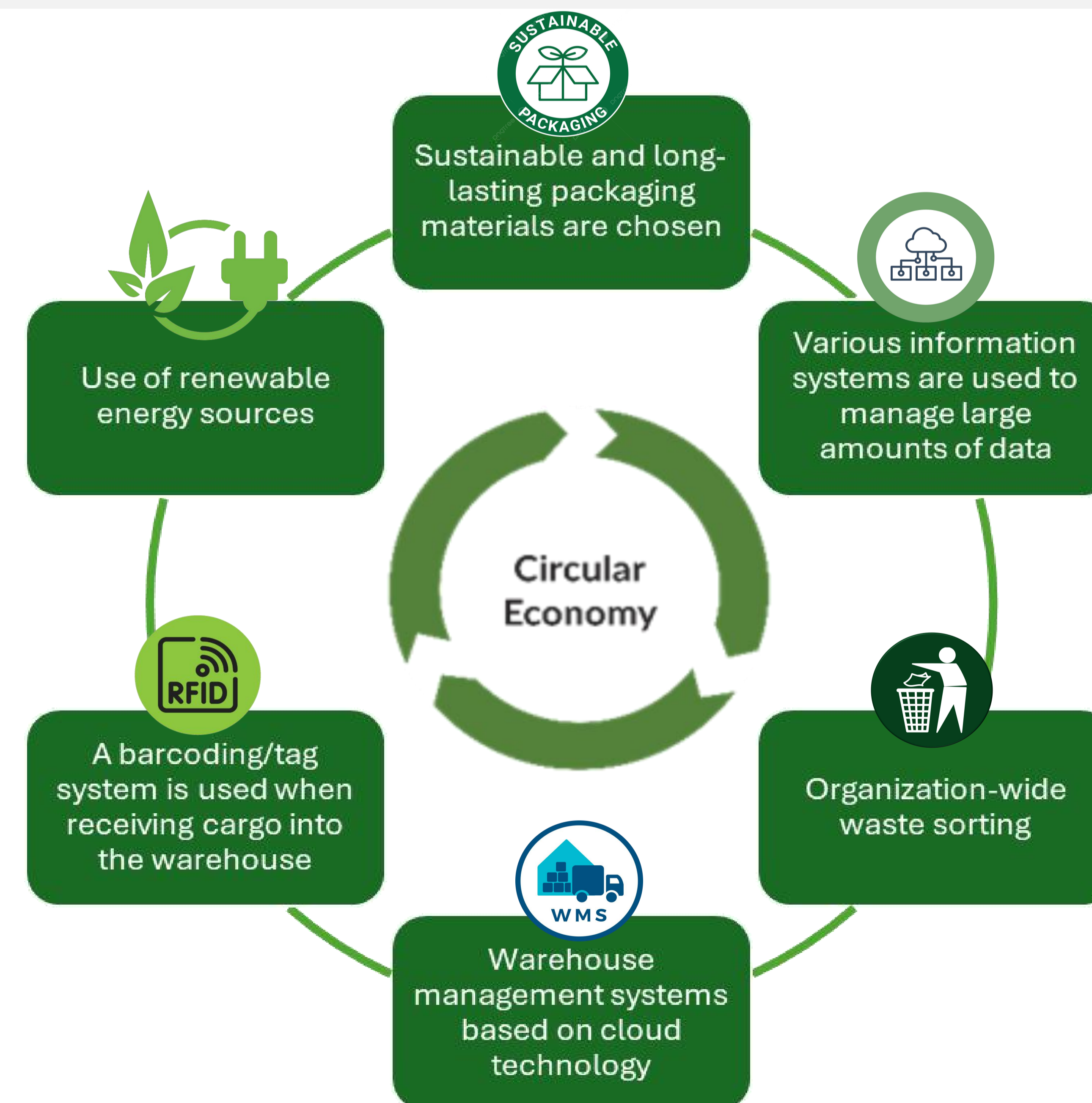


Figure 1. The intersection of digitization of warehousing processes and the circular economy.

Main conclusions

- The circular economy aims to move away from the traditional linear model of production and consumption towards a more regenerative and sustainable approach. One critical aspect of achieving this transition is the optimization of warehousing processes through digitalization.
- This research underscores the importance of digitalization in optimizing warehousing processes toward a circular economy. By embracing Digital technologies, businesses can enhance efficiency, reduce waste, and contribute to a more sustainable and regenerative economic model.
- Through the optimization of inventory management, companies can minimize excess stock, leading to lower waste generation and decreased reliance on raw materials.
- AI and robotics, cloud computing, 3D printing, advanced analytics, blockchain, augmented reality, RFID, the Internet of Things, and cloud technologies not only increase efficiency and reduce operating costs, but also play a decisive role in achieving environmental sustainability and resource optimization in a circular economy system. Integrating these technologies is critical seeking to adapt to global sustainability goals and build resilient, environmentally friendly supply chains.
- While the benefits are substantial, there are challenges and barriers to the widespread adoption of digital technologies in warehousing. Security concerns, initial investment costs, and workforce adaptation are among the key challenges.
- Addressing these challenges requires a holistic approach, involving collaboration between industry stakeholders, government bodies, and technology providers.