

Germany's Waste Management Model in the Context of Circular Economy Adoption

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Abstract: This study examines Germany's leading role in waste management through circular economy policies that aim to optimize resource use and minimize waste. Germany's legal framework—such as the Circular Economy Act (KrWG), Packaging Act (VerpackG), and Electrical Equipment Act (ElektroG)—supports this approach. Innovative measures like waste separation, reuse, and advanced recycling have been successfully implemented. The German model extends beyond safe waste disposal to transform waste into valuable economic resources. It also reduces environmental impact while promoting sustainable development. The study concludes that adopting this model can help other countries improve resource efficiency, reduce pollution, and achieve sustainability goals.

Keywords: Circular Economy; German Model; Sustainability; Waste Management

1. Introduction

In light of increasing environmental challenges, there is a growing need to develop alternative economic models to the traditional linear model, which is based on resource consumption followed by disposal. This model is no longer sustainable in the context of the global shift toward comprehensive sustainability concepts. The circular economy represents an integrated environmental culture and ecological awareness aimed at modifying trends, behaviors, and consumption patterns, with the goal of contributing effectively to sustainable development.

The economic development model based on the exploitation, consumption, and disposal of natural resources has led to negative environmental impacts affecting the climate, economy, and society. This situation has necessitated a re-evaluation of resource utilization methods and the transition from a linear economic model to a circular economy. Accelerated production and consumption patterns since the Industrial Revolution have been among the primary factors contributing to the depletion of natural resources, exacerbating greenhouse gas emissions, spreading various forms of pollution, and generating massive amounts of waste. These processes have contributed to the degradation of ecosystems and threatened the sustainability of natural resources and essential ecosystem services upon which humanity depends.

Consequently, attention has shifted toward an alternative model known as the circular

economy, regarded as a strategic option for mitigating the environmental problems arising from the linear model. The circular economy promotes the integration of resources into closed production and consumption cycles, optimizing their use and encouraging reuse. It has emerged as a comprehensive developmental vision aimed at eliminating the negative impacts of linear production and consumption while addressing major global challenges such as climate change and environmental degradation.

Currently, waste management constitutes one of the most pressing environmental issues worldwide, driven by rapid demographic changes, population growth, and the dynamic nature of economic and social transformations. These factors have contributed to a steady increase in the annual volume of waste generated.

Within this context, waste management is no longer merely a disposal activity; it is now focused on maintaining environmental balance, safeguarding public health, and contributing to the achievement of sustainable development goals, which emphasize resource efficiency, reducing environmental footprints, and promoting responsible production and consumption patterns.

Germany serves as a global leader in waste management and recycling, having adopted this innovative approach as part of its comprehensive waste treatment strategy.

1.1. Research Problematic

Based on the foregoing, the problem of this study can be formulated in the following question: What are the most prominent circular economy practices in waste management within the German model?

1.2. Research Hypotheses

This study is guided by the following hypotheses:

- The circular economy in the German experience relies on programs and mechanisms that position it as a leading model in the field of waste management.
- The German circular economy model incorporates practices that contribute to supporting the achievement of sustainable development.

1.3. Research Aims

The aim of this study is to highlight the importance of the circular economy in managing environmental resources in a sustainable manner and its role in achieving the Sustainable Development Goals (SDGs). The circular economy is approached as a new economic pathway that ensures the optimal and rational use of resources, while conserving energy and the environment. This is achieved by examining the key economic and environmental contributions of the circular economy, particularly in transforming waste into an economic resource capable of generating added value on the one hand, and reducing the risks associated with it to foster economic, environmental, and social sustainability on the other. Furthermore, the study seeks to explore the potential of benefiting from the German model in the transition toward a circular economy to ensure sustainability.

1.4. Significance of the Study

The significance of this study stems from the increasing risks of climate change and resource depletion caused by human and industrial activities across various sectors. The challenges associated with environmental resource management have generated an urgent need to implement the circular economy model as one of the key drivers toward achieving sustainable development.

1.5. Research Methodology

To address the research problem and achieve the stated objectives, the study adopts both the descriptive and analytical approaches, as they are most suitable for defining the concept of the circular economy and for exploring its economic and environmental dimensions. In

addition, an analytical review of the German model in this field is undertaken.

1.6. Review of Previous Studies

The concept of the circular economy has gained significant scholarly attention as a modern economic model capable of replacing traditional linear production systems and supporting sustainable development. Previous studies have examined international experiences and practical implementations of this model.

For instance, Rahmani (2022) analyzed China's transition to a circular economy, highlighting the importance of a decentralized, multi-level policy approach, international best practices, and the support of governmental actors. The study also emphasizes ongoing political, technological, and social challenges, suggesting that Algeria could benefit from adopting similar strategies to promote sustainable consumption and production. Similarly, Ogunmakinde (2019) reviewed circular economy models in China, Germany, and Japan, showing that effective policies, strong legislative frameworks, and active stakeholder engagement are key factors for successful implementation.

Building on these insights, the present study focuses on the state of circular economy practices between 2010 and 2022, with particular emphasis on the German model and progress achieved through selected circular economy indicators..

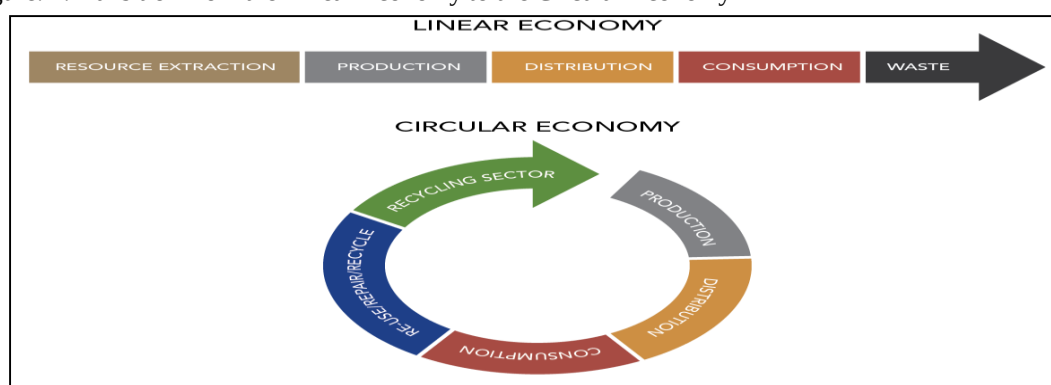
2. The Essence Of The Circular Economy

2.1. Definition and Core Principles of the Circular Economy

The prevailing linear economic model, based on the principle of "take, make, dispose," has long been the driving force behind industrial development and a source of growth. This model relies heavily on the abundance of raw materials and energy at low and easily accessible costs. However, increasing challenges—such as price volatility, supply chain risks, and mounting pressures on resources—have underscored the need to reconsider how materials and energy are utilized. Consequently, many argue that the time has come to harness the potential benefits of the circular economy. (Ellen MacArthur Foundation, *Towards a Circular Economy: Business Rationale for an Accelerated Transition*, p. 2).

The transition from the linear economy to the circular economy has occurred through the stages as depicted in the following figure.

Figure. 1. Transition from the Linear Economy to the Circular Economy



Source: Breene, 2016

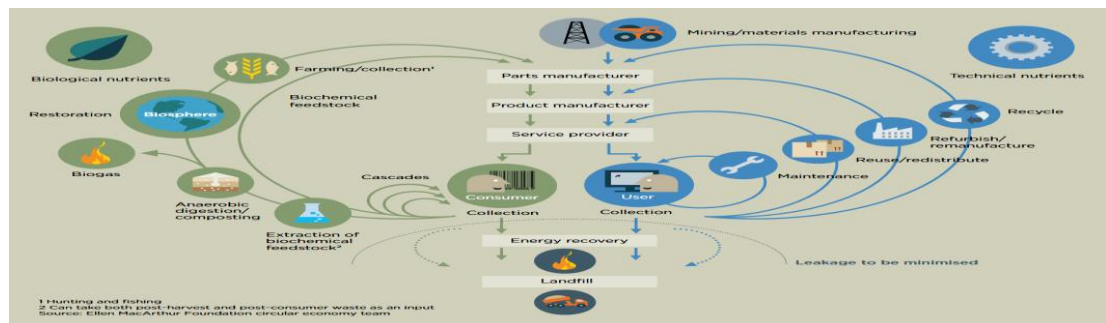
The notion of the circular economy was first introduced in 1989, in the context of the publication of *The Economics of Natural Resources and the Environment* by David Pearce and R. Kerry Turner. This work articulated the conceptual integration between the economy, the environment, and natural resources, highlighting ecological imbalances and their economic implications. It further drew a distinction between the open linear model—predicated on the continuous consumption of resources—and the circular model, which is

grounded in recycling and reuse. Within this framework, the circular economy is defined as an economic system that strives to retain the economic value of products, materials, and resources for the longest possible duration. This is achieved by minimizing waste generation, enhancing resource efficiency, and mitigating pollution through anticipatory design for recycling from the earliest stages of production, thereby aligning with the broader objectives of sustainable development. (غلاب ، 2021 ، صفحة 446)

This paradigm emphasizes the construction of sustainable supply chains, the reinforcement of reuse and remanufacturing, and the systematic exclusion of spent materials as waste. It seeks to ensure that products remain embedded within the economic cycle for the maximum possible lifespan before being recovered and reintegrated, while simultaneously reducing adverse environmental externalities and curbing the economic costs associated with production and consumption. (داودي و دقيش ، 2019 ، صفحة 124)

Furthermore, the circular economy constitutes a novel economic paradigm that seeks to generate new value by reclaiming resources from end-of-life products (waste) and reintegrating them into new production cycles through advanced recycling processes. (بن موسى، 2022 ، صفحة 35)

Figure. 2. Circular Economy



Source: The Ellen MacArthur Foundation, 2013

The circular economy is also underpinned by a set of fundamental principles: (غلاب 2021 ، صفحة 448)

- Waste as nutrients: ensuring their reintegration into both the economic and environmental systems.
- Diversity as a source of resilience: the greater the diversity of products, materials, and systems, and the more interconnections and layers among them, the stronger their capacity to withstand external shocks, as opposed to systems designed solely for maximum efficiency.
- Systems thinking: this principle entails viewing components as interconnected elements within an integrated whole.
- Pricing and feedback mechanisms: in a circular economy, prices should reflect the true cost of products and services..

2.2 .The Importance of the Circular Economy

The growing significance of the circular economy stems from the pivotal roles it can play, which include the following: (بن موسى، 2022 ، صفحة 39)

- Preserving the value of products as well as managing inventories and capital;
- Enhancing resource efficiency by optimizing the use of resources throughout the entire product life cycle, from design to end-of-use;
- Extending product lifespans and eliminating waste.

3. Definition Of Waste And Its Types

3.1. Definition of Waste

The concept of waste is linguistically defined as residues or remnants discarded by an individual due to their unsuitability for consumption or use. According to the World Health Organization, waste refers to materials or objects that the owner no longer requires due to their lack of significance or value. From an environmental perspective, waste constitutes a source of risk that begins the moment it interacts with its surrounding environment, either directly or following treatment processes. Over the years, uncontrolled disposal methods have demonstrated that such interactions are inevitable. From an economic standpoint, waste also carries implications. (سعود و فرحات، 2019، صفحة 69)

Waste management is defined as the monitoring and regulation of processes involved in the generation, storage, retrieval, recycling, treatment, transportation, and final disposal of waste. These processes are designed to eliminate or reduce waste, reuse it, treat it, physically break it down, or chemically neutralize its toxicity. (سعود و فرحات، 2019، صفحة 69)

According to the well-known Basel Convention framework, waste is defined as materials or elements that are disposed of, intended to be disposed of, or required to be disposed of under applicable local laws. The United Nations Statistics Division considers waste as resources that are not deemed valid products and therefore cannot be utilized by manufacturers in any other industrial, production, transformation, recycling, or consumption activities, or materials that must necessarily be discarded. (أحططاش، 2021، صفحة 763)

3.2. Classification of Waste

Table 1. Classification of Waste

FBER

97

Classification	Subcategories
By Hazard Level	Hazardous waste and non-hazardous (benign) waste
By Source and Nature	Household waste, industrial waste, commercial waste, agricultural waste, medical waste, construction and demolition waste, mining waste, waste resulting from wastewater treatment, radioactive waste, electrical and electronic waste.
By Physical State	Liquid waste, gaseous waste, solid waste

Source: سعود و فرحات، 2019، صفحة 70

4. The German Model In Waste Management

4.1. The Legal Framework

The fundamental elements of the circular economy in Germany were established in the Circular Economy Act (KrWG) of 2018. This legislation transposes the European Waste Framework Directive into national law, forming the legal foundation of the circular economy and incorporating several key principles. These principles begin with the legal definition of waste and specifically include:

- **The "Polluter Pays" Principle:** making those who cause pollution responsible for its costs.
- **The Waste Hierarchy:** consisting of five steps that prioritize waste management practices.
- **Producer Responsibility:** holding producers accountable for their products even after disposal.
- **Waste Prevention:** focusing on reducing waste at its source.

- **The Duty of Care:** imposing responsibility on distributors and traders to manage their goods diligently.

These principles aim to demonstrate the achievements that citizens can attain in collaboration with municipalities and the industrial sector and to provide examples for other countries seeking to close their material loops in an environmentally sound manner. The circular economy is considered a global endeavor, and German companies, scientific institutions, and municipal actors can contribute valuable expertise, services, and modern technologies (Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection [BMUV], 2023, p. 5).

Extended Producer Responsibility (EPR) constitutes a core pillar of the German legal framework. (Waste Management in Germany, 2023). This policy requires manufacturers and distributors to assume financial and operational responsibility for managing their products post-consumption, thereby promoting sustainability across the value chain. EPR in Germany is implemented through specific legislation for each product category. (EPR Compliance in Germany, n.d.). The German Packaging Act (VerpackG) aims to avoid or minimize the environmental impact of packaging. It prioritizes waste prevention at the source, and where that is not possible, it encourages the reuse or recycling of packaging materials at the highest possible quality. Comprehensive registration and reporting obligations apply to all companies placing packaging on the German market, regardless of type. (The German Packaging Act, n.d.).

The Electrical and Electronic Equipment Act (ElektroG) obliges producers to register electrical devices with Stiftung EAR, provide warranties, and assign a system for recycling electronic waste. (Ahattash, 2021).

Finally, the Battery Act (BattG) requires the registration of batteries with Stiftung EAR and the assignment of an approved take-back system for the collection and sorting of batteries. (Waste Management in Germany, 2023).

4.2. Policies and Mechanisms Supporting Sustainable Development

Germany also applies a waste hierarchy (R-ladder), defined as a five-level hierarchy in the Circular Economy Act (KrWG) or as a ten-level R-hierarchy in the National Circular Economy Strategy (NCES). (Circular Economy, n.d.).

The NCES is built on the 10-step R-ladder, which classifies key circular economy strategies based on their ability to promote the principle of a closed-loop system. This approach complements the waste hierarchy established by the German Circular Economy Act. (Circular Economy, n.d.).

a) The upper levels (R0–R2: Refuse, Rethink, Reduce) focus on waste avoidance from the outset. These strategies target:

- **Consumers:** encouraging critical evaluation of their needs for products and services.
- **Manufacturers:** promoting product and service redesign to align with circular economy principles.

b) The middle levels (R3–R7: Reuse, Repair, Refurbish, Remanufacture, Repurpose) emphasize extending the lifespan of products or their individual components, as well as enhancing intensive usage. These strategies include:

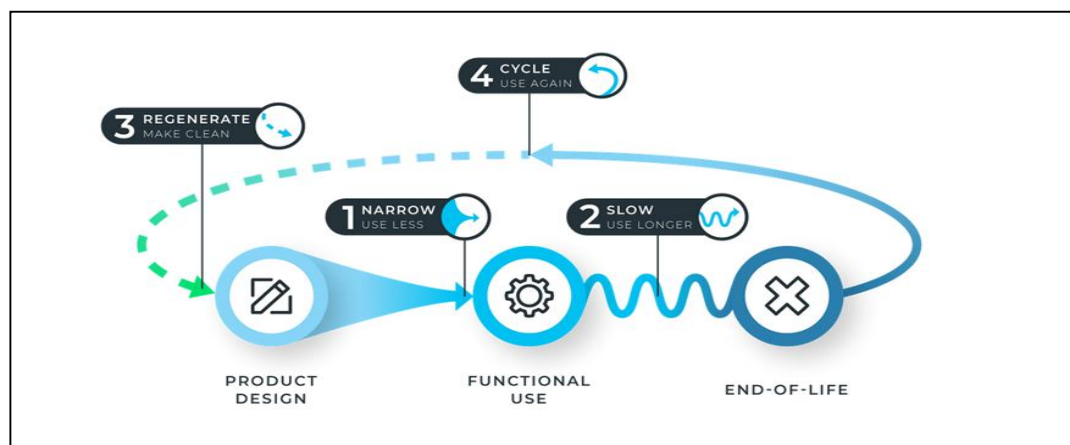
- Reuse
- Repair
- Refurbish

- Remanufacture
- Repurpose

c) The lower levels (R8–R9: Recycle, Recover) focus on resource recovery, aiming to improve recycling processes and other recovery operations to maximize resource efficiency. These strategies include:

- Recycle
- Recover

Figure. 3. Core steps of the circular economy



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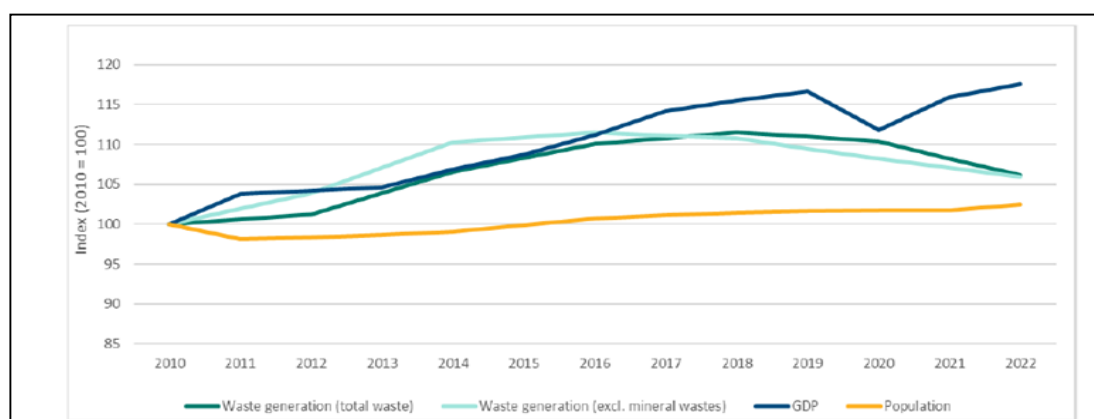
Source: The Circularity Gap Report 2023

5. Waste Generation And Treatment Trends In Germany

99

5.1. Total Waste Generation

Figure. 4. Waste generation (total waste excluding major mineral wastes), population, and economic development, 2010–2022

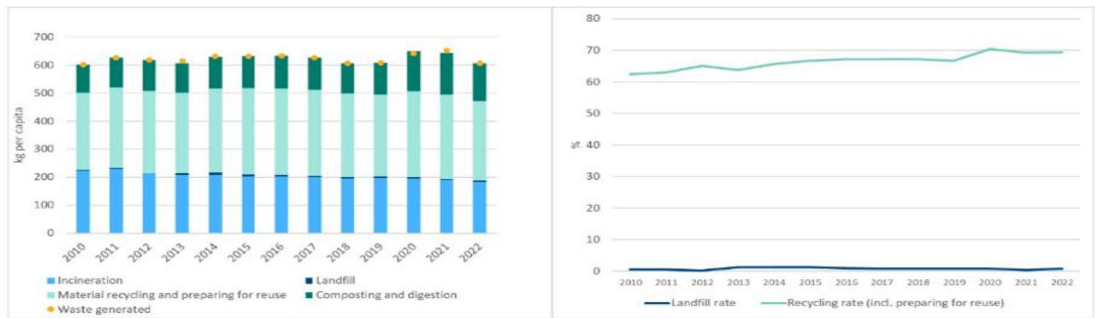


Source: agency, 2025, p. 2

The total amount of waste generated in Germany experienced a slight increase during the period 2010–2019. This increase is observed in waste excluding metal waste, as well as in mixed and recyclable waste categories. At the same time, a decline in waste generation was recorded across most categories relative to Germany's GDP growth up to 2019, with a notable decrease in 2020 resulting from the COVID-19 pandemic. It is also noteworthy that there was a convergence between waste generation growth and economic growth over the period 2010–2022. (Agency, 2025, p. 2).

5.2. Municipal Waste

Figure. 5. Municipal waste management 2010–2022.



Source: agency, 2025, p. 3

- Vertical axis: percentage
- Horizontal axis: years (2010–2022)

Municipal waste generation in Germany remained relatively stable between 2010 and 2022, as shown in the figure above. In 2022, the amount of municipal waste generated reached 606 kg per capita, which is significantly higher than the EU-27 average of 513 kg per capita. New rules for calculating recycled municipal waste were introduced in line with the targets set out in Article 11.2 of Directive 2008/98/EC, in order to adjust calculation points by excluding rejected materials from recycling facilities. Germany adopted these rules for the first time in 2020. (agency, 2025, p. 3).

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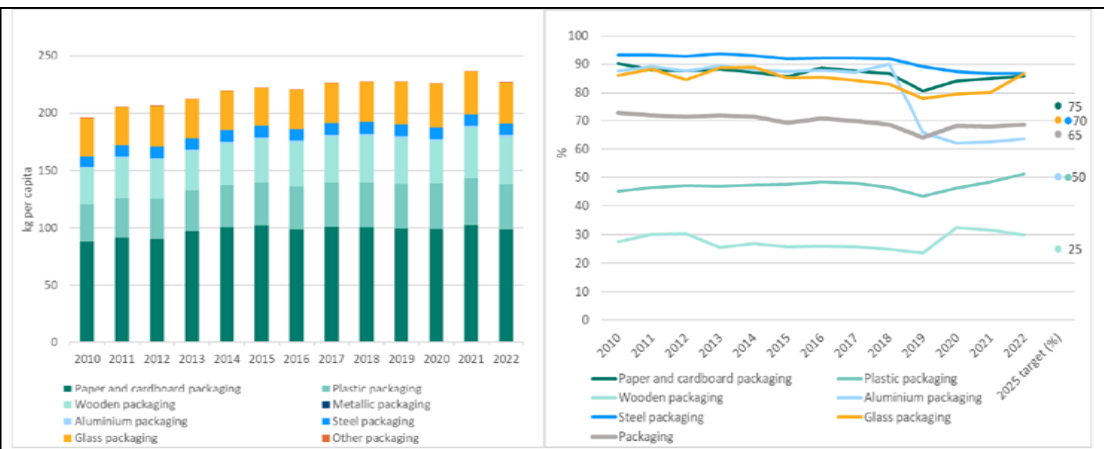
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Vertical axis: kg per capita

Horizontal axis: Years (2010–2022)

The reuse and recycling rate of municipal waste in Germany has remained consistently high, reaching 69% in 2022, which is significantly above the EU-27 average of 49% for the same year. Incineration decreased slightly to 30% in 2022, while landfilling remained at a marginal level. (agency, 2025, p. 3).

Figure.6. Municipal waste management 2010–2022.



Source: agency, 2025, p. 4

Packaging waste generation in Germany has shown a notable increase since 2010, as illustrated in Figure (06). In 2022, packaging waste amounted to 227 kg per capita, which is

significantly higher than the EU-27 average of 186 kg per capita. It is worth noting that this average may be affected by the fact that some EU Member States have not yet fully implemented the reporting rules as required by the European Commission Implementing Decision (2019/665).

Over the past decade, Germany's packaging waste recycling rate has consistently exceeded 65%—with the exception of 2019—and reached 69% in 2022. The overall recycling rate is largely influenced by paper and cardboard packaging, given their high share and elevated recycling rate. In 2019, a marked decline was observed in the recycling of paper, cardboard, glass, metals, and plastics, resulting in a slight drop in the overall recycling rate. (agency, 2025, pp. 3–4)

6. Policies Adopted To Promote Waste Prevention Measures And Increase Recycling In Germany

6.1. Collection And Separation Systems

Germany implements a comprehensive separate waste collection system that exceeds the requirements of the European Union Waste Framework Directive, thereby supporting recycling efficiency. (Germany's Circular Economy | Recycling & Waste Management, n.d.).

This system relies on the use of different colored bins to facilitate source separation: the black bin for residual non-recyclable waste, the blue bin for paper and cardboard, the brown or green bin for organic waste (food scraps and garden waste), and the yellow bin for recyclable packaging materials (e.g., empty cans and plastic packaging). (Germany's Circular Economy | Recycling & Waste Management, n.d.).

Mandatory separation of organic waste, paper, metals, plastics, and glass has been in effect since January 1, 2015. (Principles of the Circular Economy, n.d.).

6.2. Advanced Treatment Technologies

Advanced waste management technologies complement the legal framework and collection systems in Germany, enhancing resource efficiency and reducing environmental impact through:

Recycling and Composting: Recycling is a key process in the circular economy, converting end-of-life products and materials into usable resources. (Principles of the Circular Economy, n.d.).

Waste-to-Energy (Incineration): Waste-to-energy plants incinerate non-recyclable or non-compostable household waste, generating heat or electricity. Germany currently operates 99 waste-to-energy plants, the second-highest number in the European Union. (Germany's Circular Economy | Recycling & Waste Management, n.d.). The circular economy sector in Germany is expected to grow annually by more than five percent, reaching a market volume of EUR 32 billion by 2030.

6.3. Mechanical-Biological Treatment (MBT)

Mechanical-Biological Treatment (MBT) is used to treat residual waste before landfilling, aiming to reduce its volume and decrease landfill gas emissions, particularly methane, thereby supporting climate protection. (Waste Management in Germany – Development to a Sustainable Circular Economy, n.d.).

7. Conclusion

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101

The transition from a linear economic model to a circular economy has become imperative. To ensure the availability of resources for future generations, many governments have developed programs and mechanisms aimed at providing a healthy and safe working environment, while minimizing environmental harm by adopting production and consumption patterns based on circular resource flows. These patterns are characterized by reduced energy consumption, lower emissions, decreased waste generation, and higher resource-use efficiency.

The circular economy requires the adoption of clean production methods within institutions, the development of eco-industrial clusters, and integrated resource-based planning to support sustainable development goals. Leading countries in this field have rapidly implemented this model as an optimal means of achieving added value across social, economic, and environmental dimensions. This is achieved through integrated strategies encompassing legislative, legal, productive, and financial measures, with active participation from all stakeholders: governments, international organizations, local communities, the public and private sectors, civil society, and consumers.

Waste management is a critical element in this transition, transforming waste from an environmental and economic burden into a valuable resource that can be reused in the economic cycle, thus supporting sustainable development.

The study revealed that Germany's waste management model represents a pioneering experience. This is evident through the adoption of a waste hierarchy, the implementation of Extended Producer Responsibility (EPR), the promotion of technological innovation, and the encouragement of community and private sector participation. Germany has sought to make waste an economic resource and a source of renewable energy, which has contributed to reducing dependence on primary resources and enhancing economic competitiveness. These findings indicate that the circular economy is no longer merely an option but a practical necessity for achieving comprehensive sustainability, positioning the German model as a reference for other countries, particularly those facing growing challenges in waste management.

Based on the study's findings, the following recommendations can be proposed:

- Develop national legislation similar to Germany's Circular Economy Act (KrWG).
- Implement Extended Producer Responsibility (EPR) by obliging companies to assume responsibility for their products post-consumption.
- Enhance infrastructure for sorting and recycling technologies.
- Engage civil society and the private sector through intensified environmental awareness campaigns.
- Promote international cooperation and leverage global expertise in circular economy practices through agreements and partnerships.

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