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From Policy to Practice: EU Circular Economy Legislation and Slovenia's Implementation Challenges—A Systematic Review

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Abstract

The Circular Economy (CE) has become a foundation of the European Union's sustainability strategy, aiming to dissociate economic growth from resource use. This article examines the legislative and monitoring frameworks underpinning the European Union's CE transition, with a particular focus on Slovenia. A systematic review conducted in accordance with the PRISMA 2020 guidelines, EU-level policy analysis, and national indicator evaluation, this article explores the alignment between Slovenia's national strategies and EU objectives. While Slovenia has demonstrated policy ambition and performs well in municipal recycling, it underperforms in circular material use and domestic material consumption. Governance fragmentation, limited sectoral integration, and monitoring challenges are key barriers. The study contributes to CE research by offering a country-level perspective on policy translation and performance. Recommendations are proposed to strengthen governance, data systems, and sector-specific roadmaps. These conclusions offer valuable insights for scholars and policymakers involved in implementing CE across multi-level governance systems.

Keywords: circular economy; EU legislation; Slovenia; policy implementation; governance; monitoring indicators; sustainability transition

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1. Introduction

There are several different aspects of the Circular Economy (CE) in the scientific literature. The article relies on the definition set by the Ellen MacArthur Foundation, saying: "The circular economy is a system where materials never become waste and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacturing, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources" [1].

According to the European Commission (EC), the European Union (EU) aims to transition to a CE to make Europe cleaner and more competitive. The EC introduced measures under the action plan, which aim to "make sustainable products the norm in the EU, empower consumers and public buyers, focus on the sectors that use most resources and where the potential for circularity is high, ensure less waste, make circularity work for people, regions and cities, and lead global efforts on the circular economy" [2].

The main research question of this article is the following: What is the status of the implementation of the circular material use and domestic material consumption in Slovenia? This article examines the legislative and monitoring frameworks underpinning the EU's CE transition, with a particular focus on Slovenia. Based on a systematic review conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines, EU-level policy analysis, and national indicator evaluation, this article explores the alignment between Slovenia's national strategies and EU objectives.

The study contributes to CE research by offering a country-level perspective on policy translation and performance. Recommendations are proposed to strengthen governance, data systems, and sector-specific roadmaps. These conclusions provide valuable insights for scholars and policymakers involved in the implementation of CE across multi-level governance systems.

While the EU has established an ambitious and multidimensional framework to guide Member States toward a CE, significant variation persists in how these strategies are translated into national-level implementation [3]. Although aggregate EU monitoring systems have matured, relatively few studies provide in-depth insight into the performance, institutional capacities, and sectoral challenges of smaller Member States such as Slovenia. Furthermore, existing literature often focuses on legal compliance or waste-related indicators, overlooking the cross-sectoral dynamics and governance barriers that shape CE transformation in practice [4].

The article addresses this gap by conducting a focused case study on Slovenia, analyzing how its national CE policies and performance indicators align with EU objectives. It integrates legal, institutional, and indicator-based data to critically assess the country's progress and limitations. While a growing body of literature has addressed the European Union's CE strategy and monitoring mechanisms [5], relatively few studies have focused on how smaller Member States operationalize these frameworks. Examining this dimension holds scientific value, as it not only sheds light on the diversity of national pathways within a common EU framework but also contributes to understanding the contextual drivers, institutional constraints, and governance practices that shape the translation of high-level strategies into practical measures. Slovenia represents an important case due to its early commitment to CE and its geographic, institutional, and economic characteristics. Yet, gaps persist in evaluating how national efforts translate EU strategic objectives into measurable outcomes. This article contributes to bridging the gap between EU-level CE strategies and their translation into national contexts, with a focus on Slovenia. It seeks to answer: To what extent does Slovenia's CE policy and monitoring framework align with EU objectives, and what barriers hinder implementation?

The article is structured as follows: Section 2 introduces the EU's CE strategy and Slovenia's position within it. Section 3 outlines the methodology. Section 4 reviews EU-level CE legislation and action plans. Section 5 firstly presents the literature review, monitoring frameworks, and Slovenia's indicator performance. Section 5 secondly discusses the findings, with a focus on governance and implementation challenges. Section 6 concludes with recommendations, policy implications, and directions for future research.

2. Literature Review

2.1. Circular Economy and the European Commission Policies

The core mission of European environmental policy is to prevent, mitigate, and rectify negative environmental impacts at their source and to ensure that polluters pay for their own negative impacts—the 'polluter pays' principle [6]. The multiannual environmental action program serves as the framework for future actions in all areas of environmental policy, as they are implemented through horizontal strategies and considered in international

environmental negotiations. After the release of the European Green Deal policy by the EC, environmental policy has become the main driver of economic growth in the EU [7].

Over the past few decades, the EU's over 300 policies and initiatives have led to a high level of environmental protection in the EU by imposing EU legislation on international markets and requiring market players to adapt to its changes. Green transformation and EU environment policies will be effectively executed in the future through green investment and the mobilization of resources from Member States' budgets and the private sector. One such initiative is the European Strategy for Plastics in a Circular Economy, presented in 2018. It emphasizes that all plastic packaging placed on the EU market should be either reusable or recyclable in a cost-effective manner by 2030 [8]. It is estimated that 95% of the value of plastic packaging is lost after its first phase of use due to the mechanical recycling process for processing mixed plastic waste streams. As a result, most recycled plastic is often downcycled. The transition to genuine CE in plastic will be achieved when plastic waste is recycled into products of the same or equivalent value. A true CE should balance economic, environmental, and social impacts. Although demands for suitable CE packaging are rising, so too are requirements for food packaging, resulting in an increase in multilayer packaging. Around 17–20% of plastic packaging consists of multilayer materials, which are increasingly used in packaging for food, pharmaceuticals, medicines, cosmetics, and electronics; however, such packaging is challenging to recycle. The pace of innovation in recycling processes has not kept up with the rapid advancements in packaging material technologies. This highlights the importance of adopting a diverse range of approaches and considering the entire value chain of large-volume packaging (LWP) in order to achieve future recycling targets and, ultimately, a CE. Progress could be made by introducing innovative techniques and methods, replacing multilayer packaging with mono-material alternatives, implementing eco-design guidelines for distributors, and developing a more transparent and harmonized system for all stakeholders involved in the packaging value chain. Additionally, legal requirements specifying standardized packaging solutions for each product category could help limit the material combinations that need to be managed [9].

The CE is another precondition for the successful execution of EU environmental policies, which, at its highest conceptual level, represents how the EU plans to address growing economies, limited resource consumption, and environmental capacity [1]. The Circular Economy Action Plan, published in 2015 by the EC, lists activities that lead to lower carbon emissions, resource efficiency, and competitive economies while ensuring jobs, economic growth, and investments [10]. The Action Plan outlined 54 actions and four legislative proposals related to waste. The EC put forward these legislative proposals along with the Action Plan. They included targets for landfill, reuse, and recycling to be met by 2030 and 2035, along with new obligations for separate collection of textiles and biowaste [11,12].

Although the CE has become a global buzzword and is no longer only a trend but represents a modern way of living, the EU and other countries still have a long path ahead before plans turn into actions, and its competitive advantage is fully evident in the economy [13]. The most obvious positive aspects of the CE include providing new business opportunities and models, as well as developing new markets within the EU and internationally. Much work remains to be performed to apply the updated waste legislation and expand markets for secondary raw materials. On the other hand, specific actions enabling the transition from a linear to a CE have already been put into motion at the EU level, but their execution will need to be accelerated for their effects to become visible [13].

As emphasized by the EC (2022), A New Circular Economy Action Plan is one of the crucial building blocks of the European Green Deal, Europe's new agenda for sustainable growth [14]. The EU's transition from a linear to a CE will reduce pressure on natural resources and create sustainable growth and jobs [15,16]. It is also a prerequisite to achieving the EU's 3. climate neutrality target and halting biodiversity loss. A New Circular Economy Action Plan announces initiatives along the entire life cycle of products. It targets how products are designed, promotes CE processes, encourages sustainable consumption, and aims to ensure that waste is prevented and that the resources used are kept in the EU economy for as long as possible [11,17]. The explicit document emphasizes that the transition from a linear to a CE requires the critical engagement of all target groups—industry, policymakers, businesses (especially SMEs), HEIs, and NGOs as civil society stakeholders [18]. Finally, the transition also requires citizens' active engagement in changing consumption patterns [19].

2.2. Slovenia, a Small Market for Business and Waste

Within this broader EU context, Slovenia plays a distinct role. As a small, export-oriented economy with a high dependence on imported materials and energy, Slovenia is highly exposed to global supply shocks and resource volatility. At the same time, its compact industrial base and strong environmental tradition provide opportunities for systemic circularity interventions [20]. Slovenia adopted its first "Roadmap towards the Circular Economy" in 2018 [21], setting strategic directions in areas such as secondary raw materials, industrial symbiosis, digitalization, and green public procurement. These ambitions were integrated into the Slovenian Development Strategy 2030 and linked to the country's Sustainable Development Goal commitments (notably SDG 8 and SDG 12) [22].

However, the implementation of CE principles in Slovenia is constrained by several factors [23]. These include regulatory and institutional fragmentation, a lack of regional administrative authority, and challenges in tracking subnational progress through indicators. Recent research, such as the SmartER Slovenia study, highlights the need for enhanced policy coherence and effective regional governance mechanisms to fully leverage the country's CE potential.

2.3. Conceptual Foundations and Previous Studies

The EC envisions a climate-neutral economy by 2050, aligned with the Paris Agreement and operationalized through the European Green Deal and successive Circular Economy Action Plans. These frameworks aim to decouple economic growth from resource use, promote sustainable innovation, and support the transition toward a regenerative, low-emission society [24]. Building on the EU's international commitments, the CE framework was introduced as a key policy tool for achieving sustainability goals. The first Circular Economy Action Plan (2015) [25] and its updated version in 2020 [26] set the foundation for legislative and financial instruments to promote product reuse, recycling, eco-design, and waste prevention [27]. These action plans prioritize "designing out waste and pollution," "keeping products and materials in use," and "regenerating natural systems" across the full life cycle of products and services [28].

The traditional linear economic development model, based on the "take-make-dispose" approach, no longer meets the needs of modern societies in a globalized context. "Natural resources (raw materials, energy) are scarce, and their prices are unstable. In this way, the CE development necessitates the use of clean, ecological, and environmentally beneficial sources [29]. The CE is a regenerative double-loop system that promotes environmentally friendly goods and resource efficiency. It provides economic and commercial benefits, emphasizing the importance of considering the field's definition to assess and enhance its complexity and diversity [30]. A closed-loop cycle is created through the utilization

and recycling of resources, energy, and waste, as well as the reduction in input resources, effluent flows, and greenhouse gas (GHG) emissions [31,32].

The CE is not only an environmental framework but also an economic and social one. It supports the decoupling of economic growth from environmental degradation while promoting innovation in product design, new consumption models (e.g., sharing economy), and cross-sectoral collaboration. The CE framework aims to reduce GHG emissions, preserve biodiversity, and promote competitiveness by integrating innovation in design, consumption, and service-based economic models. Transitioning from product ownership to service-based consumption models (e.g., sharing economy) creates job opportunities across all skill levels—from maintenance and repair services to innovations in materials, technologies, and artificial intelligence [15].

The European Green Deal, launched by the EC, serves as a cornerstone of this transition, setting ambitious targets for waste reduction, resource efficiency, and carbon neutrality [14]. Through a series of legislative measures, directives, and action plans, the EU has sought to institutionalize CE principles across various sectors and industries, laying the groundwork for a more sustainable and resilient economy [33].

One of the key aspects of EU CE policy is the development of a robust monitoring framework to track progress towards circularity objectives. The monitoring framework provides valuable insights into resource use, waste generation, and recycling rates, enabling policymakers to assess the effectiveness of existing policies and identify areas for improvement in waste [31,32,34,35]. By employing a combination of indicators and performance metrics, the EU aims to enhance transparency, accountability, and data-driven decision-making in the pursuit of CE goals.

In support of this, the EC launched the Circular Economy Monitoring Framework in 2018, revised in 2023, which includes key performance indicators such as the circular material use rate, waste generation per capita, and recycling rates of municipal and packaging waste [36]. The CE is thus positioned as a cross-sectoral policy agenda with implications for environmental protection, economic innovation, and employment, particularly in energy- and resource-intensive sectors.

Ellen MacArthur Foundation (2020) [1] notes that circularity has deep historical and philosophical origins (see Figure 1). The concept of feedback, as well as cycles in real-world systems, is ancient and has resonances in various schools of philosophy. While the concept of CE cannot be traced back to a single date or author but rather to different schools of thought [37], legislation on CE at the EU level officially began in 2015. A chronological overview of the key milestones that are crucial in the context of the article is given below [38]:

Aiming to drive Europe towards a sustainable future, the New Circular Economy Action Plan serves as a linchpin of the European Green Deal, offering a comprehensive strategy to reduce resource pressure, promote sustainable consumption, and minimize waste [21]. This transition requires concerted efforts from various stakeholders, including industry, policymakers, businesses, academia, and civil society, underscoring the importance of citizen engagement in promoting sustainable consumption patterns [21].

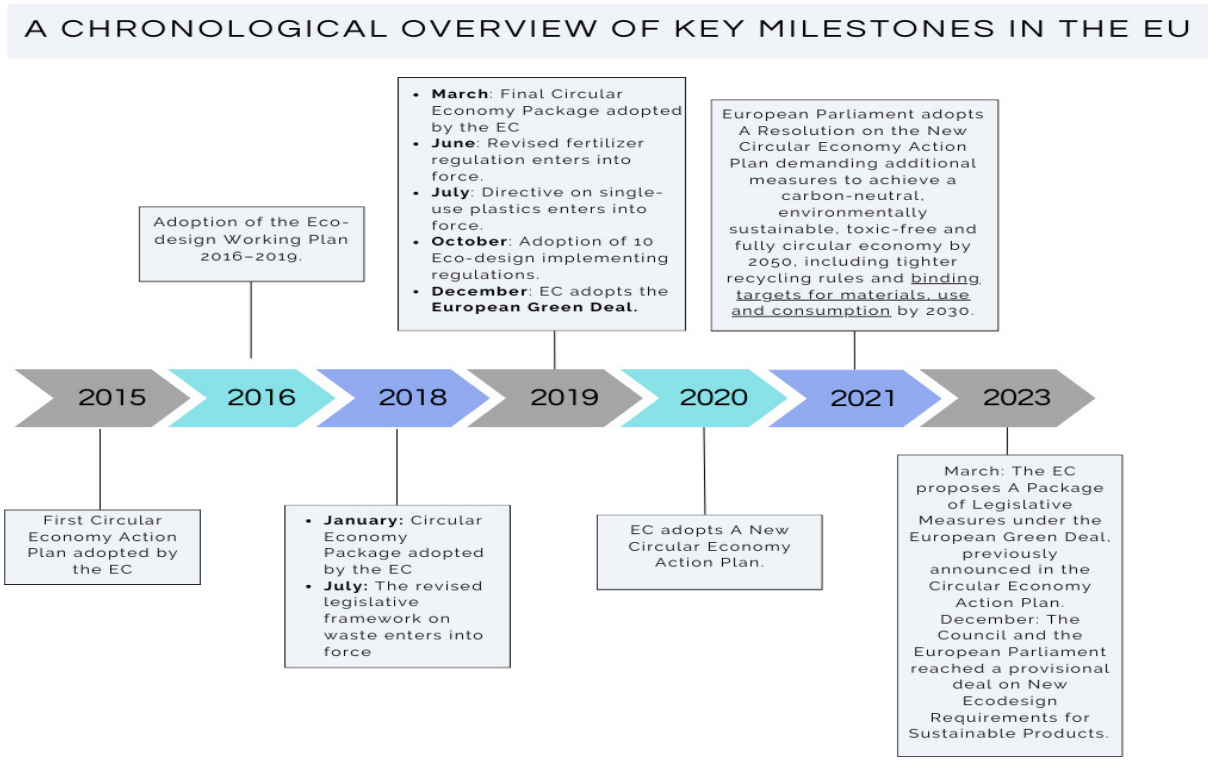


Figure 1. Chronological overview of key milestones in the EU. (Source: [1]).

3. Methods and Analysis

The conducted research tries to enlighten the current state of the European Commission's CE policies in the member states, specifically in Slovenia. As the framework for implementation is set, the question of national-level adaptation remains. As the existing literature often focuses on legal compliance or waste-related indicators, it overlooks the cross-sectoral dynamics and governance barriers that shape CE transformation on the ground. To address these gaps, the research focused on a case study of Slovenia, aiming to analyze the national legislation and its alignment with performance indicators in relation to EU objectives. In accordance with the research needs, the following methodology was selected.

This study employs a structured systematic literature review, aligning with the PRISMA guidelines developed by Page et al. [39]. With an emphasis on the Slovenian national context, the methodology aims to ensure transparency, reproducibility, and comprehensiveness in identifying and synthesizing scholarly and policy-related literature related to the CE legislative framework, monitoring indicators, and implementation practices at the EU level.

In the first phase, the literature search was conducted using Scopus, Web of Science, and ScienceDirect to ensure comprehensive coverage of peer-reviewed academic work across disciplines. Google Scholar was used selectively to capture relevant gray literature, such as institutional reports and EU policy documents, which are central for understanding practical implementation of CE frameworks—alongside institutional sources such as Eurostat, the European Environment Agency, and the EC's policy portals. Searches were limited to titles, abstracts, and keywords to balance breadth with precision. Full-text searches were not conducted to avoid irrelevant results. Search results were exported and organized using Microsoft Word and Excel, which enabled systematic screening, removal of duplicates, and coding of inclusion/exclusion criteria. In addition, Zotero was used as the primary reference management tool to store and organize bibliographic data, ensuring consistency

in citation management and facilitating transparent documentation of the review process. The combination of these tools enhanced the reproducibility of the review, allowing the research team to document decisions at each step of the screening and coding process. The search covered the period from 2014 to 2024, corresponding to the timeline from the launch of the first EU Circular Economy Action Plan from 2015 to the most recent updates of the Circular Economy Monitoring Framework from 2023. The search string included terms such as "circular economy," "monitoring indicator(s)," "resource efficiency/efficiencies," and "sustainable development strategy/strategies (SD)". These terms were selected based on their centrality in EU CE frameworks. Variations in singular/plural and acronyms were tested to ensure inclusiveness and capture relevant material. Inclusion criteria were publications in English, peer-reviewed articles and institutional reports, and studies addressing CE monitoring, indicators, or policy frameworks. Exclusion criteria were studies dealing solely with technological/material innovations. Following the PRISMA protocol, the process included (i) identification of records from databases, (ii) screening of abstracts, and (iii) inclusion of eligible studies after full-text review. The PRISMA flow diagram (Figure 2) shows that in total, 251 records were identified from databases and registers, of which 205 were screened after duplicate and ineligible removal. Following screening, 150 reports were sought for retrieval, with 146 assessed for eligibility and 138 included. An additional 317 records were identified from other sources, of which 4 were included. In total, 146 studies were included in the final sample (142 identified via databases and 4 via other sources).

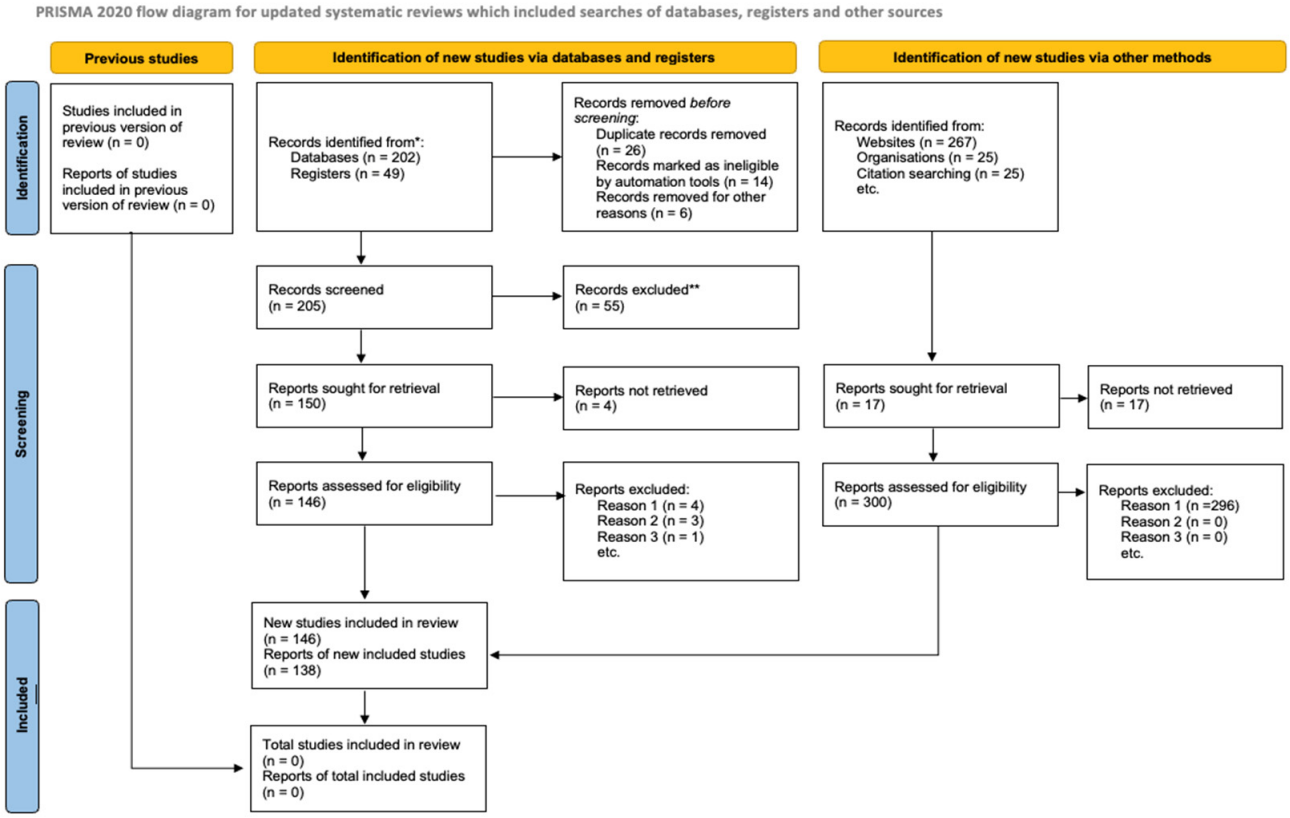


Figure 2. PRISMA 2020 flow diagram for updated systematic reviews, which included searches of databases, registers, and other sources. (Source: [39] and authors). * Databases and registers searched: Scopus, Web of Science, ScienceDirect, Google Scholar, Eurostat, and European Commission policy databases. ** Records excluded after screening correspond to those removed based on titles and abstracts that did not meet inclusion criteria (e.g., not addressing Circular Economy legislation, monitoring indicators, or EU/Slovenia policy frameworks).

All records from the databases were merged, and duplicates were removed using Zotero, supplemented by manual checks where metadata differed. This ensured each study was only considered once. Documents were included if they explicitly addressed CE legislative or policy instruments at the EU or Slovenian level, discussed implementation tools or monitoring practices, or provided data or analysis on CE performance indicators. The systematic review was designed to synthesize evidence on CE monitoring frameworks and indicators, providing a basis for comparing EU-level strategies with Slovenia's national implementation and for identifying knowledge and policy gaps. Additionally, the selection process involved checking for duplicates and ensuring a balanced disciplinary scope, thereby representing both policy-oriented and academic perspectives [40]. The review protocol was prospectively registered in PROSPERO (International Prospective Register of Systematic Reviews) under the registration number CRD420251146279.

In the second phase, a qualitative content analysis was conducted to systematically assess the selected literature. Four core thematic categories guided the analysis: (1) legislative architecture, focusing on the EU directives and national legal instruments shaping CE policy; (2) monitoring frameworks, particularly the Circular Economy Monitoring Framework by the EC and its national adaptations; (3) strategic alignment, analyzing how Slovenia's CE roadmap and national development strategy correspond to EU CE goals; and (4) institutional mechanisms, identifying challenges and enablers in multi-level governance, stakeholder coordination, and implementation structures. This analytical grid allowed for consistency in reviewing diverse sources and facilitated the comparison of EU-wide frameworks with Slovenia's national pathways.

In addition to peer-reviewed academic literature, this study incorporated gray literature sources—such as national policy documents, EU institutional reports, and strategy roadmaps—particularly where empirical data on CE implementation in Slovenia was limited. To ensure credibility, only gray literature from recognized public institutions (e.g., EC, Eurostat, the Statistical Office of the Republic of Slovenia) and official government sources was included. Each document was cross-validated for consistency with EU communications and triangulated with statistical indicators to strengthen reliability. During the second phase of qualitative analysis, which focused on extracting themes across legislative texts, monitoring frameworks, and national plans, content was categorized into four predefined typologies: (i) energy and material consumption, (ii) obligation schemes, (iii) audit and management systems, and (iv) waste heat and efficiency policies. Researchers conducted manual coding, with iterative peer review by a second reviewer to minimize subjectivity. While no formal inter-coder reliability score was computed, all extracted themes and classifications were discussed and agreed upon to ensure internal coherence [41]. No formal risk of bias tool was applied; however, only peer-reviewed and institutional sources were included to minimize bias. The approach provided sufficient flexibility for refining inductive themes while maintaining transparency in coding decisions [37]. No statistical effect measures (e.g., risk ratios) were applied, as the synthesis was qualitative. After completing all stages of the PRISMA protocol, Figure 2 summarizes the flow of records from initial identification to the final sample of 142 studies.

Table 1 highlights the representative categories of included studies; a full list of all reviewed sources is provided in the References section. The table highlights representative categories of evidence—European and national policy frameworks, official statistical datasets, institutional reports, and academic studies. This structured overview illustrates the diversity of evidence informing the analysis, from legislative strategies to quantitative monitoring and conceptual debates in the literature. Additional sources were also reviewed and are cited throughout the article.

Table 1. Characteristics of the most relevant included studies in the review. Table 1 highlights representative categories of included studies; the full list of reviewed sources is provided in the References. (Source: authors).

Author/Year	Country/ Context	Type of Study/Document	Focus	Key Findings
European Commission [14,25]	EU	Policy framework/Action Plans	EU Circular Economy Action Plans (2015, 2020)	Set the strategic direction for CE at the EU level, introducing the CE Monitoring Framework and emphasizing waste, recycling, resource efficiency, and the use of secondary raw materials.
Republic of Slovenia [42,43]	Slovenia	National strategy/Roadmap	Roadmap Towards the Circular Economy in Slovenia	Defined Slovenia's CE priorities; aligned with EU objectives; emphasized waste reduction, eco-innovation, and stakeholder involvement.
Government of Slovenia [44]	Slovenia	National strategy	Slovenia's Development Strategy 2030	Integrated CE into long-term development; linked to SDGs; focused on green growth and sustainable consumption/production.
Eurostat [22,31,32,35,45–50]	EU/Slovenia	Statistical dataset	CE Monitoring Indicators	Provided harmonized indicators (CMU, DMC, recycling rates); Slovenia performs well on recycling, poorly on CMU.
Kirchherr et al. [51]	EU/global	Academic survey	CE definitions and perceptions	Found a lack of unified CE definition; mismatch between academic, policy, and business understandings.
Ghisellini et al. [52]	Global	Systematic review	Global CE strategies and practices	Synthesized CE practices worldwide; underlined governance challenges and need for policy coherence.
Stanef-Puică et al. [16], Broughton et al. [15]	EU	Literature review	Employment, skills and green jobs in CE	Showed potential for green jobs, skills . . . identified need for reskilling and vocational training.
OECD [53]	OECD/EU	Institutional analysis	CE and resource productivity	Compared countries; emphasized monitoring frameworks and productivity indicators.

4. Results

4.1. Monitoring Frameworks and Slovenia's Indicator Performance

This section synthesizes insights from the literature and policy documents identified in the review and organizes them around the EU monitoring framework for the CE. The aim is to link the general EU-level indicators with national implementation in Slovenia, highlighting convergences and divergences.

In 2018, the EC published two documents outlining a monitoring framework for the CE, which included the EU's policy on the CE [54]. The documents align with the EU's industrial strategy and SDGs. To measure progress on the CE, the EC, backed by the EU Council and Parliament, proposed and created a monitoring framework to track resource efficiency. The CE monitoring framework builds upon and complements the recently developed Resource Efficiency Scoreboard and Raw Materials Scoreboard by the Commission. In the document Monitoring Framework for the CE [54], the EC set the table of ten indicators grouped into four aspects of the CE. The table includes all set indicators and explains them in relation to the EU levers. However, the document does not list key performance indicators for each of the indicators. The list of indicators is presented in Table 2. In the second document, the EC sets the methodology for selecting the indicators and includes an analytical description for each. The document provides the critical metadata for each indicator [54].

Table 2. Indicators for achieving a low-carbon CE (SDG 8) are set in the Slovenian development strategy 2030.

Indicator	Set 2030 Value	Latest Data for 2023	Source
Material productivity	3.5 kg PPP/kg	3.2 PPP/kg (EU 3.9 PPP/kg)	[53,55]
Share of Renewable Energy in Gross Final Energy Consumption	27%	25.1% (EU 24.6%)	[44,45]
Emissions productivity (GDP per Total GHG emissions)	EU average in 2030	3.81 (EU 4.11) EURO2010 PPS/kg CO_2 latest data for 2021	[44,56]

Although this document precisely defines the indicators set at that moment, it still does not define key performance indicators to determine the value that the EC is looking for with each indicator separately. This means that we do not know what we want to achieve, by what year we want to achieve specific values, and compared to what year we are interested in the growth/decline of the indicator.

The EC and Eurostat disseminate all the indicators on a dedicated site for the CE. This website also provides a brief introduction to the monitoring framework, background information, and a list of relevant links [54]. The website will also give updates on changes regarding the indicators, tools to monitor progress, and document the methodologies for the indicators, data sources, definitions, and publishing standards. The Commission will continue to elaborate on the indicators that require further development, particularly those related to food waste and green public procurement [31].

In May 2023, two news documents were published to update the Monitoring framework from 2018: Revised Monitoring Framework for the CE and Measuring Progress Towards CE in the European Union—Key Indicators for a Revised Monitoring Framework [57,58]. The revised documents introduce a new component of global sustainability and resilience. New indicators, such as the material footprint, resource productivity, consumer footprint, greenhouse gas emissions from manufacturing operations, and material dependency, are part of the new monitoring framework. KPIs are also set for the respective indicators [58].

4.2. Waste Consideration

The indicators for waste are gathered in two different aspects of the CE: "Production and consumption" and "Waste management".

Waste generation is set as an indicator under "Production and consumption". Its relevance lies in the fact that in a CE, waste generation is minimized. The levers of these indicators are the Waste Framework Directive, directives on specific waste streams, and the Strategy for Plastics. The indicator included three statistics in 2018: "Generation of municipal waste (per capita)", "Generation of waste excluding major mineral wastes per GDP unit", and "Generation of waste excluding major mineral wastes per domestic material consumption" [58].

In 2023, the scope of statistics was broadened with the addition of two new statistics: "Generation of packaging waste per capita" and "Generation of plastic packaging waste per capita" [59]. The second indicator is "Food waste," with the reasoning that discarding food has negative environmental, climate, and economic impacts. The levers include the General Food Law Regulation, the Waste Framework Directive, and various initiatives (e.g., the Platform on Food Losses and Food Waste) [54]. The statistics for food waste were included in the aspect of "Waste generation." [57].

In 2023, the 2030 targets and directions for improvement were set. Out of six statistics, only one has a target set to concrete numbers. The other five are to be significantly reduced, with no other explanation of the term's meaning. In the General Union Environment Action Program to 2030, the reason is as follows: significantly decreasing the Union's material and consumption footprints to bring them into planetary boundaries as soon as possible, including by introducing Union 2030 reduction targets, as appropriate [59].

As part of the "Waste Management" initiative, "Overall recycling rates" and "Recycling rates for specific waste streams" are established as indicators [60].

The relevance of the "Overall recycling rates" is that increasing recycling is part of the transition to a CE, with the lever of the Waste Framework Directive. Two statistics cover this indicator: "The recycling rate of municipal waste" and the "Recycling rate of all waste [61], excluding major mineral waste [54]. The same statistics were set in the 2023 document. In the 2023 document, the target for improvement of "Overall recycling rates" was set at 60% by 2030 [57].

The relevance of the "Recycling rates for specific waste streams" is that they reflect the progress in recycling key waste streams. The levers are the Waste Framework Directive, Landfill Directive, and directives on specific waste streams [62]. In 2018 documents, six statistics set the indicator: "Recycling rate for overall packaging", "Recycling rate of plastic packaging", "Recycling rate of wooden packaging", "Recycling rate of e-waste", "Recycling of bio-waste", and" Recovery rate of construction and demolition waste" [54]. Based on the 2023 documents, only three of the first set of statistics are being monitored: "Recycling rate for overall packaging waste", "Recycling rate for plastic packaging waste", and "Recycling rate for electrical and electronic equipment waste that is separately collected" [57].

In the 2023 EC documents, 2030, the target or direction for improvement of the "Recycling rate for overall packaging waste" is set at 70% and the "recycling rate for plastic packaging waste" at 55%. The target for "Recycling rate for electrical and electronic equipment waste that is separately collected" is not set. The set recycling rates are ambitious, as plastic waste often contains contaminants and chemical additives, posing challenges for recycling facilities. Designing products with their entire life cycle in mind, including recycling and disposal, is crucial for a sustainable and environmentally responsible approach to plastic use. Multilayered plastic products and additives, such as colorants, labels, pigments, and volatile organic compounds, complicate the recycling process by hindering the production of new feedstocks, including monomers and chemical reagents. Manufacturers should treat plastic waste as a resource, utilizing pretreatment and recycling processes to improve recycling efficiency. Ensuring transparency in the composition of plastic products at the end of their life can greatly aid reprocessing. Redesigning plastic products and improving

recycling processes are critical for transitioning to a CE, but reducing plastic usage and ensuring proper sorting are also crucial [9,63].

According to the EC's Proposal on Packaging and Packaging Waste, the headline target is to reduce packaging waste by 15% per capita per Member State by 2040, compared to 2018 [64]. The aim is to achieve this goal by reusing and recycling. The EC has intended to set a number of measures, such as: a certain percentage of products will have to be reusable or refillable packaging, standardization of packaging formats, banning of certain forms of packaging, creating a mandatory deposit return system for plastic bottles and aluminum cans, and mandatory recycled content rates that producers must include in new plastic packaging [64]. The EU's targets for packaging waste recycling (70% overall and 55% for plastics by 2030) are highly ambitious. Most current plastic packaging consists of multi-layered or composite materials, which are technically challenging to recycle, resulting in significant downcycling rather than closed-loop recovery. Achieving these targets will require not only improved recycling technologies but also eco-design, material substitution, and stronger market incentives [65].

4.3. CE Indicators on Waste: A Slovenian Case

4.3.1. Institutional Framework and Policy Alignment

This dedicated subsection presents Slovenia's performance on waste-related indicators. This subsection allows a focused discussion of national data in relation to EU benchmarks.

Slovenia's institutional framework for CE is primarily governed by the Ministry of the Environment, Climate, and Energy, in coordination with the Ministry of Economy, Tourism, and Sport. The 2018 Roadmap Towards the CE was spearheaded by the Partnership for Green Economy, which includes stakeholders from business, civil society, academia, and regional development agencies. However, the absence of a central CE coordination unit or inter-ministerial platform hinders systematic implementation. Municipalities, which are responsible for waste and land use management, often lack resources and guidance to translate CE principles into local planning and procurement [66].

Progress towards CE is limited [67] due to various barriers, including cultural, regulatory, market, and technological factors [67]. The Slovenian government published the Roadmap towards the CE in Slovenia in 2018 [42], identifying four priority areas: food system, forest-based value chains, manufacturing, and mobility. The manufacturing industry is one of the country's main and most export-oriented sectors, and compliance with circular principles is becoming necessary to maintain international competitiveness. The promising prospect of introducing CE principles includes (1) ecological design, (2) industrial symbiosis, (3) the use of secondary sources, (4) the transition to renewable energy sources, (5) innovative materials, (6) limiting the use of rare materials, (7) fair sourcing in supply chains, and (8) reducing the use of plastics and reducing the use of hazardous chemicals.

The document is closely linked with the SDGs goals set in the Slovenian development strategy 2030, where the transition to a low-carbon CE is to be achieved by [44]:

- Education and inclusion of various stakeholders in the transition to CE to break the link between economic growth and growth in consumption of resources and GHG emissions.
- Promotion of innovation, the use of design and information, and communication technologies to develop new business models and products that use raw materials and energy more efficiently [68];
- Replacement of fossil fuels with the promotion of EE and the use of RES in all areas of energy use.

- Ensuring that infrastructure and energy use in transport support the transition to low-carbon CE
- Using spatial planning to design nodes for the low-carbon CE [44].

The non-binding performance indicators set in the Slovenian development strategy 2030 are [44]:

- Material productivity, i.e., the ratio between GDP and total domestic material consumption
- Share of Renewable Energy in Gross Final Energy Consumption
- GDP per Total GHG emissions: set the goal to be the EU average in 2030

The strategy has two primary objectives, both of which are environmentally focused. Low-carbon circular development emphasizes the need to decouple GDP growth from resource consumption and to manage resources effectively. Additionally, it emphasizes the need to alter consumption and production habits, minimize waste generation, and increase the use of secondary raw materials, which aligns with CE principles. The second objective is related to sustainable management of natural resources, focusing on an ecosystem-based approach to managing natural resources [55].

The latest data on material productivity [53,55], presented in Table 2, show that Slovenia is behind EU values and has not met its 2030 goals. The latest OECD data for 2023 shows Slovenia is still 8.9% behind the 2030 target. Compared to EU data, Slovenia is 19.7% behind in terms of material productivity. During the 2017–2021 period, an above-average increase in material productivity was observed compared to the EU. This was associated with lower building activity, resulting in reduced use of non-metallic minerals. In 2015, material productivity reached 85% of the EU average [45,53,56].

The latest data on resource productivity from 2024 shows that Slovenia is below the EU average with 2.3 EUR/kg, although the gap is higher with 27.4% [46]. Among the EU countries, the Netherlands is the leading country with the highest resource productivity share, which was 8.2 EUR/kg, a 113.3% difference compared to Slovenia [46]. On the other hand, the share of RES [44,45] is higher compared to the EU, with a 2.0% difference in the values for 2023. Nevertheless, the share is 9.3% below the set 2030 value. The data also shows that the percentage of RES share in Slovenia has been steady at 25% since 2020 and has not increased as steadily as in the EU, where it has risen from 22.0% in 2020 to 24.6% in 2023 [56]. The data on emissions productivity based on the purchasing power standard shows a steady increase since 2016, with a 39.6% increase compared to 2021. Similarly, the increase is also visible in the EU, although the increase from 2016 to 2021 was 28.8%. The values were lower in Slovenia, with a 7.6% difference in 2021 [56]. In 2016, Slovenia became a member of the Ellen MacArthur Foundation's international Circular Economy 100 (CE100) to accelerate resource productivity and the CE, which is a support scheme offering companies a supportive environment to learn and adopt circular practices [55,69].

Monitoring progress towards the CE is challenging, as the transformation process is not limited to certain raw materials or sectors. The EC monitors several CE indicators within the EU Monitoring Framework [70]. The CE monitoring framework data on waste is presented for Slovenia in this chapter. Within the Monitoring framework for CE, Eurostat developed a new tool to visualize material flow diagrams and related emissions (see Figure 3). The Sankey diagram illustrates how material enters, circulates within, and exits a national economy as waste or recycled material, presenting a single method for measuring the circularity rate at the macroeconomic level [67,71]. Figure 3 shows the material flow diagram for Slovenia for 2023. It can be seen that the material flow consumed in Slovenia remains largely linear, despite some modest feedback loops, which can be attributed mainly to recycling activities.

In 2023, the EU-27's circular material use rate was 11.8%, ranging from 1.3% to 30.6%, with the Netherlands having the highest rate and Romania the lowest [31]. These materials

were either captured as stock (e.g., capital equipment, buildings, or fuel depositories), dissipated (materials dispersed through erosion or emissions released into the air), or lost (e.g., landfilled or incinerated waste) [67]. Slovenia recorded a circular material use rate of 8.8%, meaning that more than 90% of materials were not recycled back into the national economy. Although the CE recycled use rate is higher compared to 2022, it was still below the highest reported rate of 10.2% in 2019. Slovenia has reported only 3383 thousand tons of flows going into recycling, which is among the lowest amounts in the world. The countries with the highest reported amounts are France, Germany, and Italy, with 152,015, 147,297, and 130,766 thousand tons, respectively [47]. Slovenia should increase its circular material use rate, as this would also provide an additional incentive to improve the recycling rate and the utilization of recycled materials, thereby reducing its dependence on material imports [55]. Significant progress is still needed. The rate of preparing mineral construction and demolition waste for reuse and recycling in Slovenia in 2022 was 70.6%, compared with the EU average of 79.8%. Several measures that could potentially increase the rate were identified. They include separate collections at the source, which can be achieved through digital pre-demolition audits, as well as extended producer responsibility and other economic instruments. The increase in rate is connected with upstream measures regarding circularity, including the increasing recycling content in construction products and the circular design of construction works. Another important area that needs to be addressed is the critical raw materials (CRMs), as Slovenia currently lacks a national framework that focuses on the comprehensive management of CRMs and their circularity. CRM-relevant aspects are partly covered by the management of batteries and accumulators, as well as waste batteries and accumulators, with the aim of also improving the circularity of CRMs. However, Slovenia lacks measures to promote the substitution of CRMs and their more efficient use in products. Furthermore, no measures are available that require reductions in the use of CRMs. However, with the reliance on imports of materials, these challenges should be adequately addressed [72].

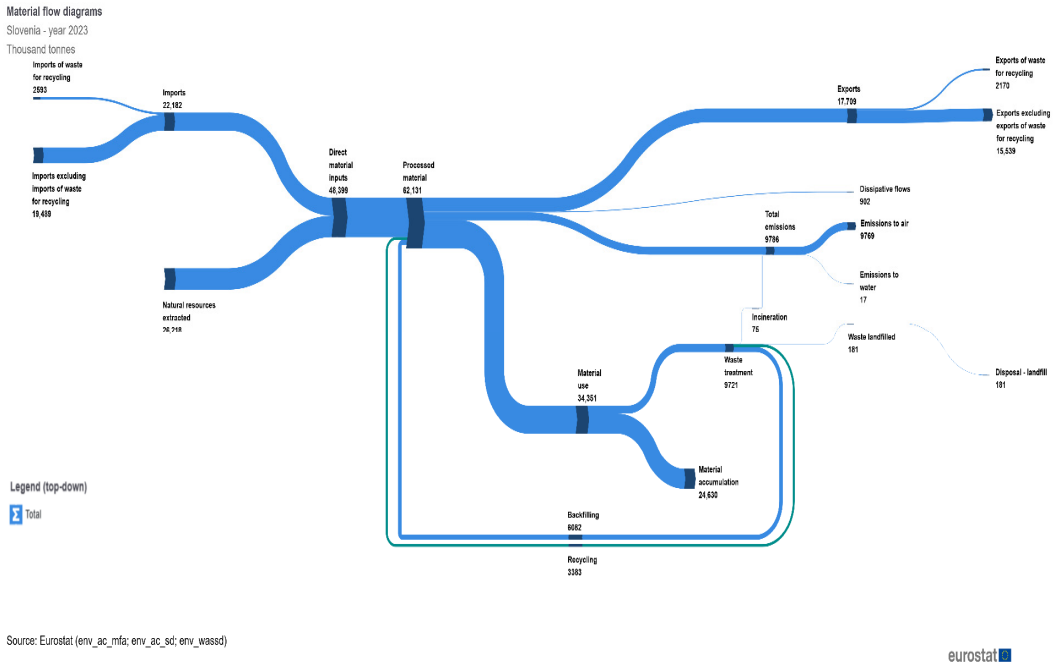


Figure 3. The material flow (Sankey) diagram produced by Eurostat represents the material flows in Slovenia in 2023 (in thousand tons). (Source: [73]).

4.3.2. Quantitative Indicators and Performance Data

In Table 3, waste CE framework indicators are presented. It can be observed that values for material footprint are slightly above the EU average. Slovenia ranked 10th among EU countries with the lowest material footprint. For Slovenia, a yearly decrease in the material footprint was observed in recent years, with a 12.7% decrease from 2023. On the other hand, an increase in resource productivity was observed. Slovenia is among the countries with the highest resource productivity index score. The resource productivity index has been steadily increasing. Although the COVID-19 recession caused a moderate decrease between 2019 and 2020, the trend towards higher resource productivity has continued [48]. Faster improvement in resource productivity will be hindered by higher energy use in transport, which generates more emissions per unit of GDP than the EU average [53].

Table 3. Waste CE Framework Indicators for Slovenia. (Source: [49]).

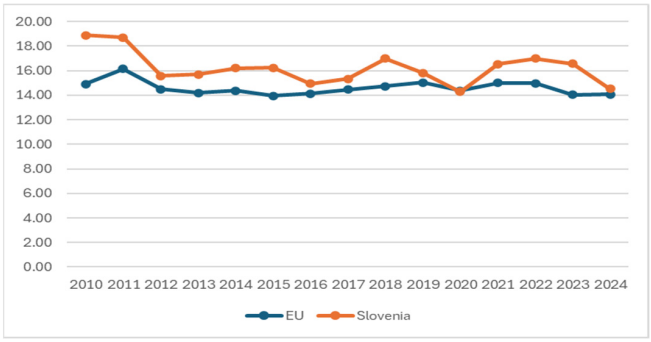
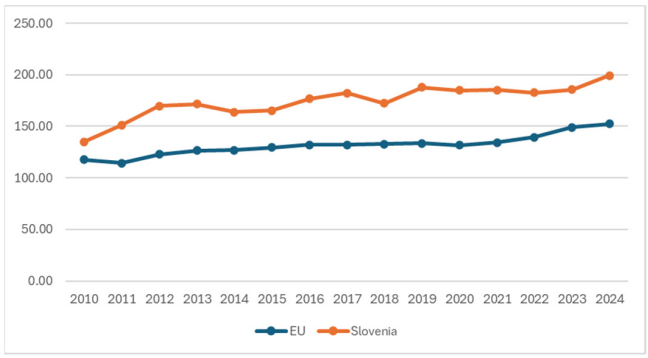
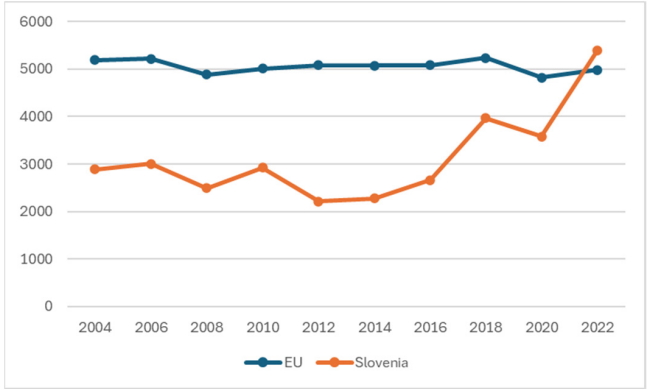
Monitoring Framework CE Waste Indicators	SI (EU Average)	Year	Trend in the Years 2014 to the Latest Data (See Column Year)
Material consumption			
Material Footprint (tons per capita)	14.5 (14.1)	2024	
Resource productivity (index 2000 = 100)	199.4 (152.2)	2024	
Waste generation			
Total waste generation per capita (kg per capita)	5398 (4984)	2022	

Table 3. *Cont.*

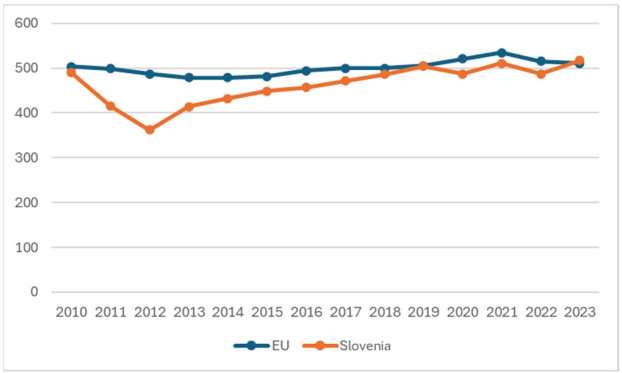
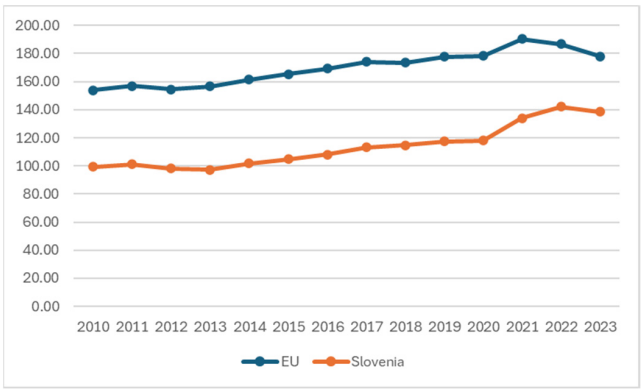
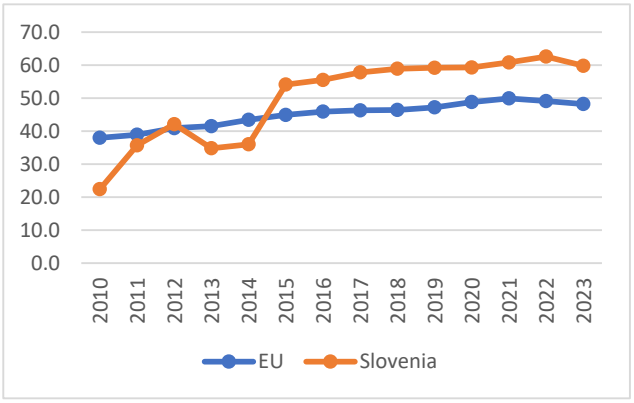
Monitoring Framework CE Waste Indicators	SI (EU Average)	Year	Trend in the Years 2014 to the Latest Data (See Column Year)
Generation of municipal waste per capita (kg per capita)	517 (511)	2023	
Generation of packaging waste per capita (kg per capita)	138.5 (178.1)	2023	
Overall recycling rate			
Recycling rate of municipal waste [%]	59.8 (48.2)	2021	
Recycling rate for specific waste streams			

Table 3. *Cont.*

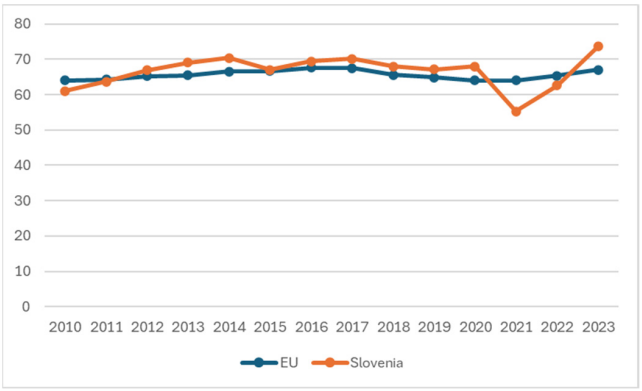
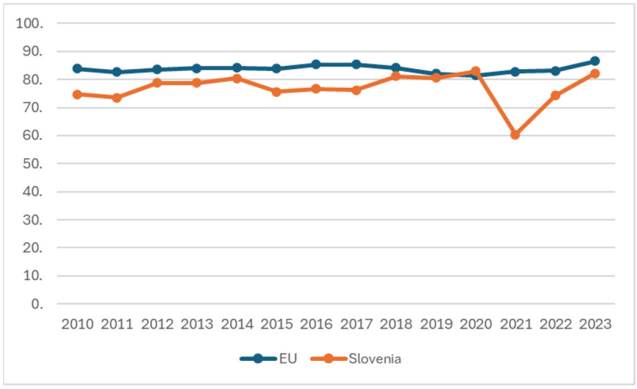
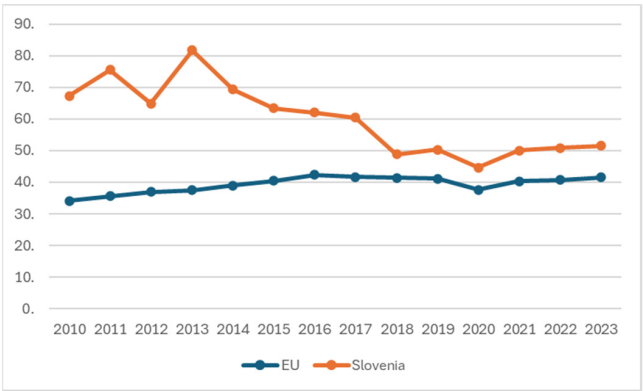
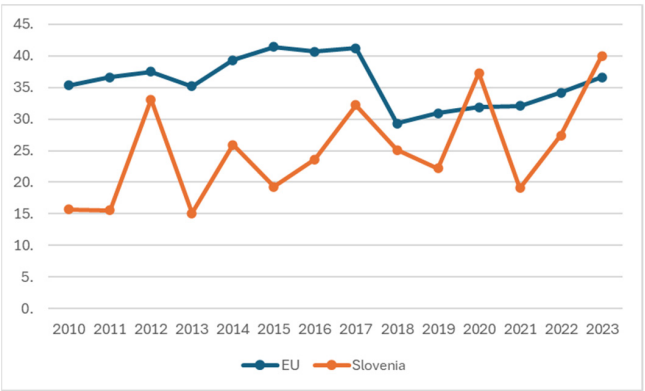
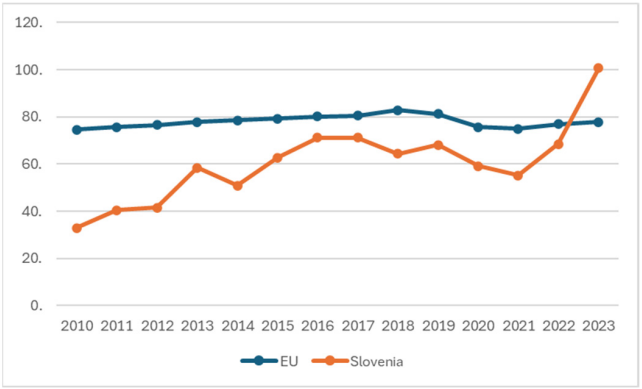
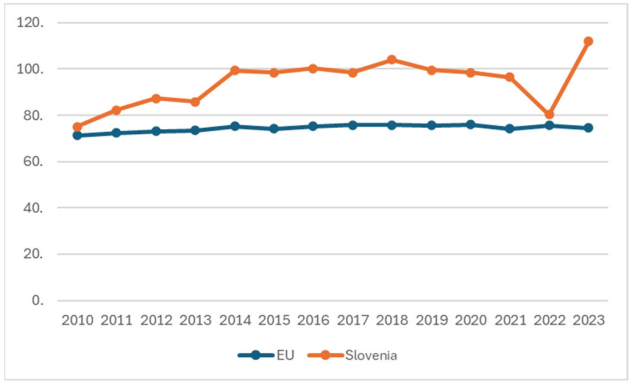
Monitoring Framework CE Waste Indicators	SI (EU Average)	Year	Trend in the Years 2014 to the Latest Data (See Column Year)
Recycling rate of overall packaging [%]	73.6 (67)	2023	
Recycling rate of paper and cardboard packaging [%]	86.6 (82.2)	2023	
Recycling rate of plastic packaging [%]	51.5 (41.5)	2023	
Recycling rate of wooden packaging [%]	40.0 (36.6)	2021	

Table 3. *Cont.*

Monitoring Framework CE Waste Indicators	SI (EU Average)	Year	Trend in the Years 2014 to the Latest Data (See Column Year)
Recycling rate of metallic packaging [%]	77.9 (100.7)	2023	
Recycling rate of glass packaging [%]	112.0 (74.5)	2023	

4.3.3. Emerging Challenges and Sectoral Insights

To complement the data presented in Table 3, the following debate interprets the observed trends and situates them within the broader EU context. The analysis of CE indicators for Slovenia between 2010 and 2023 reveals several important trends when compared with EU averages. Recycling rates showed a steady increase, particularly after 2014, reflecting Slovenia's alignment with EU waste legislation, including the Waste Framework Directive, and supported by extended producer responsibility schemes and public awareness campaigns. At the same time, landfilling rates declined sharply after 2010, largely due to national restrictions and EU landfill directives, and by 2018, Slovenia reported rates below the EU average, indicating effective policy enforcement. Waste generation per capita remained relatively stable, with slight increases during 2015–2017 coinciding with economic growth, underscoring the persistent link between consumption and waste generation despite CE measures. Resource productivity also improved gradually, driven by efficiency gains in key industries, though progress slowed during the 2012–2014 financial recovery period, leaving Slovenia close to but not exceeding EU averages. Finally, the rate of secondary material use increased modestly, broadly following EU trends, but post-2016 fluctuations point to market and structural challenges in scaling up secondary raw materials within Slovenia's industrial base. If we explain in more detail, the total amount of waste generated in Slovenia is primarily driven by the largest waste categories, namely soils and waste from construction and demolition (major mineral waste [74]).

Construction and demolition waste is seen as a source for the recovery of materials, and the available data on the recovery and construction and demolition waste recovery rates show that Slovenia has exceeded the 70% EU recovery target since 2014 [75]. Total

waste generation data indicate that Slovenia, on average, produced less waste compared to the EU average. However, a shift in the trend was observed, as the amount of waste produced in Slovenia was 8% higher than the EU average. The trend indicates that the amount of waste generated per capita has been increasing annually since 2012. A 144.3% increase has been observed when comparing 2012 and 2022 data, with 2210 and 5398 kg per capita of total waste generation, respectively.

The generation of municipal waste per capita is slightly below the EU average. Slovenia has made significant progress in managing municipal waste. Currently, municipal waste accounts for approximately 10% of the waste generated in Europe. By reducing municipal waste and increasing recycling rates, the negative environmental impact can be decreased [76]. Slovenia has made significant improvements in reducing municipal waste disposal in landfills, which is also reflected in an increase in recycling rates. Slovenia has implemented a separate waste collection system, awareness-raising campaigns, and a landfill tax. This resulted in an increase in the material recycling, composting, and partly incineration, while landfilling decreased [55]. Municipal waste from households is collected by waste management centers. Slovenia has achieved a significant reduction in landfilling biodegradable waste through the separate collection of biowaste and the mechanical-biological treatment of mixed municipal waste, resulting in a substantial decrease in landfilled waste [55].

Data on food waste generation indicate that Slovenia generates almost twice as much food waste per capita as the EU average and is ranked second best in the EU, based on available data [77]. Between 2021 and 2023, for which data on food waste have been available in the Eurostat database, Slovenia generated an average of 72.7 kg of food waste per capita, compared to 128.7 kg for the EU, representing a 55.6% difference. 44% of food waste was generated in households. In the food service sector, the share was 34%, followed by 9% in food production and 9% in food stores. Food waste was primarily treated anaerobically in biogas plants (41%), followed by aerobic treatment in composting plants (34%). Stabilization of food waste before disposal in plants for municipal waste's mechanical and biological treatment accounted for 22%. Less than 3% was processed with other methods [78]. A 9% increase in food waste generation was observed in 2023 compared to 2022, indicating that Slovenia is moving away from reaching SDGs. Approximately 37% of the generated food waste was estimated to be edible and preventable, resulting in approximately 61,000 tons of unnecessary waste. Key regulatory challenges in successfully tackling this issue include policy fragmentation, as responsibility is spread across several ministries with insufficient coordination. Furthermore, although recent amendments to the Environmental Protection Act (2004) and the Food Safety Act (2006) introduced tax incentives for food donations, liability concerns exist. Some businesses are reluctant to donate food, despite the introduction of the 2023 Good Samaritan protections [79].

In 2021, the Slovenian National Strategy for Less Food Losses and Food Waste in the Food Supply Chain was adopted. Three strategic goals were identified: (1) prevention of food losses, food surplus, and food waste, (2) reduction in food waste through food donations of edible food surplus and processing into new products, and (3) appropriate food waste management. According to a survey by the Ministry of Agriculture, Forestry, and Food (MKGP), as well as data from Slovenian Caritas, Lions Clubs International District 129 Slovenia, the Red Cross of Slovenia, and Slovenian Philanthropy, approximately 1400 tons of surplus food are distributed annually in the Republic of Slovenia. This food reaches more than 11,500 people [80]. Torrefaction of food waste is considered a promising food processing technology that can convert food waste into a high-calorific-value solid fuel. For cities, biogas is seen as a superior solution to composting waste due to potential odor issues associated with landfilling [81]. The national waste management plan of Slovenia

was adopted in 2022. The primary objectives are reducing material consumption, creating closed material loops, supporting the usage of fewer resources, and reusing materials and products [79,80].

Packaging waste represents a significant growing problem, as the average EU member generates almost 180 kg of packaging waste per year [82]. Packaging waste is mainly collected through door-to-door collection or through collection of low-density bring points in less populated areas. Waste separation at the source in Slovenia is implemented through a universal pay-as-you-throw scheme, based on container volume and collection frequency, which covers the entire population. The extended producer responsibility system applies to packaging waste from both household and non-household sources across all material types, though it lacks advanced fee modulation, such as higher charges for hard-to-recycle plastics or composite materials. A packaging tax is levied according to environmental burden units, as defined in the regulation on environmental pollution from packaging waste. Additionally, a voluntary deposit-return scheme is in place, but it is currently limited to reusable packaging. Introducing a mandatory system could strengthen reuse and enhance recycling rates [74,79].

As packaging waste presents a significant challenge, the goal is to enhance the design to ensure the product's reliability, allowing it to be reused, upgraded, and repaired. The goal is to reduce the amount of packaging waste [82]. The amount of packaging waste generated per capita in the EU reached 178 kg in 2023. The data showed a 6.4% decrease from the 2021 value and a 4.7% decrease from the 2022 value, respectively. Slovenia generated 25.0% less packaging waste in 2023 compared to the EU; however, the overall trend in Slovenia shows that the amount of waste has been increasing compared to the 2017–2020 values, when the average waste generated was 115.9 kg of packaging waste per capita. The EU has changed the rules for calculating recycled packaging waste, which Slovenia has implemented in the reporting rules since the reference year 2021. The overall recycling rate is primarily driven by the recycling of paper and cardboard packaging waste. The overall recycling rate has been above 60% since 2022, which can be attributed to a switch in the data collection methodology. The switch was towards using the reports of waste treatment operators as the primary data source. Furthermore, improvements in ensuring data quality, correctness, and accuracy have been made by introducing controls in the application for reporting.

The overall recycling rate for packaging waste is primarily driven by paper and cardboard, which represent the largest share of packaging waste generated [74]. The data shows that the recycling rate of paper and cardboard packaging showed a decrease in 2021 due to a change in reporting rules. The latest data show that in 2023, the recycling rate reached 40%, surpassing the EU average of 36.6%. The steel and glass recycling rate data indicate that Slovenia exceeds the EU average. The primary objectives of the Slovenian Waste Prevention Program (NWPP) are focused on waste prevention, encompassing reducing material consumption, establishing closed material loops, promoting the use of fewer resources, and reusing materials and products.

The primary policies behind waste recycling are the collection services for paper and cardboard, metals, plastics, glass, and biowaste. The predominant system is door-to-door, complemented by low-density bring points. Based on the EEA's early warning assessment profile for Slovenia [83]. Slovenia is on track to achieve the 2025 targets for the preparation for reuse and recycling of municipal waste, as well as for the recycling of packaging waste [83]. Scriosteanu and Criveanu (2023) [82] identified that Slovenia is one of the countries with a recycling rate significantly higher than the average EU rate. The modeled data up to 2030 showed that Slovenia belongs to a cluster of countries that register exceptionally high values of recycling rates, alongside Denmark, Finland, Germany, and the Netherlands [82]. The challenges persist regarding multi-material, multilayer plastic

packaging (MMPP), which is widely used in fast-moving consumer goods. Packaging for fresh food products may consist of four to seven layers of different components, such as polyolefins PE and PP and chemical variants (HDPE, LDPE, LLDPE, OPP), or polyesters such as PET and PLA. These packaging structures pose a significant challenge for existing recycling systems, confronting CE. MMPP recycling is generally challenging, as current industrial technologies are unable to effectively identify, sort, or separate its multilayer structures. Consequently, MMPP is typically classified as mixed plastic waste in post-consumer streams and is often incinerated with energy recovery in European countries—a practice that limits its contribution to CE objectives. Further technological developments are needed to recycle multi-material, multilayer plastic packaging waste, primarily in high-income countries. To enhance recyclability, there is a recognized need for greater integration and transparency across all actors in the packaging value chain. This requires collaborative efforts from waste management entities, governments, the packaging industry, research institutions, brand owners, and consumers to create a more cohesive system. However, challenges such as the heterogeneity of local waste management systems, the diverse composition of MMPP materials, and regulatory differences complicate the achievement of a transparent CE in this sector. A significant portion of the world still lacks basic waste management and recycling systems. As a result, despite Europe and a few developed countries having advanced technologies for recycling multilayer plastics, global challenges such as ocean plastic pollution, carbon emissions from plastic production, and the depletion of fossil resources will persist. To mitigate these issues, increasing the use of bio-based materials in MMPP and plastic packaging offers a short-term solution to reduce carbon emissions and move away from fossil-based economies. Therefore, renewable materials in packaging can enhance sustainability, particularly where recycling of MMPP is not yet feasible [84].

5. Discussion

Our findings align with earlier studies that emphasize the role of EU legislation in driving recycling and landfill reduction across member states [50,58,67]. Slovenia's sharp decline in landfilling and steady growth in recycling confirm these broader European trends while also reflecting successful national transposition of directives. At the same time, slower progress in resource productivity and secondary material use resonates with previous analyses highlighting structural challenges in smaller economies with limited industrial capacity [85]. Compared to EU-wide assessments of monitoring frameworks, Slovenia demonstrates both convergence—particularly in waste indicators—and divergence, especially regarding the integration of secondary raw materials into production processes. These comparisons suggest that Slovenia is broadly on track with EU CE objectives, though gaps persist in areas requiring systemic industrial transformation [51].

This article set out to examine the extent to which Slovenia's CE policy, legislative framework, and performance in monitoring indicators align with the broader objectives set by the European Union. Certainty is moderate, as the analysis relies on official indicators but suffers from limited sectoral disaggregation. The research question highlights that while Slovenia demonstrates strong strategic ambition and formal legislative alignment with EU CE priorities, several gaps persist in implementation, monitoring, and cross-sectoral integration. Evidence is further constrained by gaps in sectoral data and the absence of longitudinal national monitoring. Additionally, the review process did not include formal intercoder reliability testing, which may impact reproducibility.

Despite this formal alignment, the practical implementation of CE policies reveals a more complex reality. The governance structure remains fragmented, with limited vertical coordination between national and municipal authorities and inconsistent horizontal in-

tegration across sectors, including transport, manufacturing, and agriculture. This limits the systemic uptake of CE practices and results in disjointed application of CE principles. Although individual municipalities and enterprises have launched local CE initiatives, the absence of a coherent national implementation framework has hindered cumulative and scalable impact. From the perspective of EU monitoring indicators, Slovenia's performance is mixed. The country has achieved commendable results in municipal waste recycling, consistently surpassing the EU average. However, critical indicators such as the circular material use rate (CMU) and domestic material consumption (DMC) reveal structural weaknesses. Slovenia's CMU remains among the lowest in the EU, indicating that the share of secondary materials re-entering the economy is minimal. Similarly, the upward trend in DMC suggests that the country's resource intensity is increasing rather than decreasing—a direct contradiction to CE objectives focused on decoupling economic growth from material use.

The results suggest that Slovenia's CE transition is uneven and sectorally imbalanced. While progress has been made in consumer-facing domains (e.g., waste collection and recycling), industrial and upstream sectors lag behind. Structural barriers, including capital lock-in in traditional production systems, limited market incentives for industrial symbiosis, and a lack of harmonized standards for secondary materials, contribute to this stagnation. Moreover, SMEs, which make up the bulk of Slovenia's economy, face disproportionate challenges in accessing financing and expertise for circular innovations.

The governance and institutional dimensions further compound these issues. Slovenia lacks a dedicated national CE monitoring dashboard that could allow policymakers to track performance, identify lagging sectors, and tailor policy responses. Existing indicators are scattered across institutions and often lack methodological harmonization, making intersectoral comparisons and regional benchmarking difficult.

While the EU's CE Monitoring Framework provides a robust template, its translation into national contexts remains incomplete. Additionally, stakeholder engagement, particularly from the private sector, is inconsistent. Although strong collaboration exists in domains like municipal waste, participation from industry, academia, and civil society is fragmented across CE implementation processes. The fragmented nature of CE governance in Slovenia also undermines policy coherence. While CE goals appear in multiple national strategies (e.g., the Roadmap, NECP, and RRP), there is limited integration across ministries and little coordination with (smaller) municipal-level actors [43,86,87]. This hinders the development of circular industrial ecosystems and slows the adoption of horizontal measures, such as extended producer responsibility, secondary materials markets, and cross-sectoral resource exchanges.

Nevertheless, Slovenia possesses several structural strengths that could be leveraged to accelerate CE implementation. The country has a vibrant research and innovation ecosystem, with institutions actively participating in EU-funded CE projects under Horizon Europe and Interreg. Its high level of digitalization and compact geographic scale also create favorable conditions for piloting circular solutions, including smart waste systems, digital product passports, and regional resource exchanges. Financial instruments such as the Recovery and Resilience facilities, cohesion funds, and the LIFE program offer substantial support opportunities, provided they are strategically aligned with national CE goals. Notably, Slovenia has begun to mobilize funding from the Recovery and Resilience Facility and other EU instruments to support its green transformation, but the long-term impact of these investments will depend on their ability to support systemic CE infrastructure rather than isolated projects. For instance, lessons from Estonia's digital circular tracking systems and Croatia's circular tourism pilots illustrate the importance of pairing CE investments with institutional innovation and stakeholder engagement [86,88,89].

Several governance and structural constraints help explain these gaps. First, policy implementation across Slovenia remains fragmented across institutions and sectors, with limited cross-ministerial integration or vertical coordination between national and municipal actors [90,91]. Second, although Slovenia performs relatively well in recycling metrics, low performance in Circular Material Use rates (CMU) and high Domestic Material Consumption (DMC) indicate that much of the economy remains linear in practice, especially in upstream and industrial segments. Ultimately, a lack of coherent and disaggregated CE monitoring systems hinders both evidence-based policymaking and accountability.

To capitalize on these challenges and accelerate Slovenia's circular transition in line with EU goals, several future propositions should be considered, as we found; first, it is necessary to establish a dedicated governance structure to centralize CE oversight and strategic coordination. A national-level CE Council or a similar inter-ministerial platform could harmonize activities, integrate CE across sectoral policies, and engage with regional and local stakeholders [59,87]. Second, targeted sectoral strategies are crucial for operationalizing CE in practice. Sector-specific roadmaps—particularly in construction, agri-food systems, electronics, and textiles—would allow for material flow baselining, targeted innovation support, and industry-led transition pathways aligned with both national priorities and EU taxonomy requirements. Third, monitoring should be institutionalized via a national CE indicator platform, aligned with the EU's CE Monitoring Framework but extended to enable sectoral and regional analysis. Real-time, disaggregated data would help identify implementation gaps, support benchmarking, and inform corrective measures. Furthermore, Slovenia should foster industrial symbiosis and resource exchange by developing regional CE hubs or clusters. These could be anchored in existing regional development agencies and supported by EU structural funds to foster business-to-business cooperation, innovation ecosystems, and infrastructure for reuse, repair, and remanufacturing [52,92]. Additionally, public procurement policies offer an immediate lever for change. Institutionalizing circular criteria across national and municipal procurement frameworks could create reliable demand for CE products and services. Fiscal measures such as green tax incentives or landfill levies may further reinforce behavioral shifts toward more sustainable practices [51]. Last but not least, speaking as Slovenian researchers, the success of these interventions will mostly depend on public engagement and human capital. Integrating CE into school curricula, vocational training, and university programs, while also supporting awareness campaigns and consumer engagement initiatives, would enhance societal readiness and resilience in the face of transition [92,93].

Further longitudinal and sector-specific research is needed to assess how Slovenian CE policies evolve in response to EU legislative tightening and whether they lead to durable structural changes [55,86,88]. Key areas for future investigation include the role of public procurement in driving demand for circular products, the integration of CE into vocational and higher education, and the effects of green fiscal incentives on industrial behavior. Without continued empirical monitoring and stakeholder-based evaluations, Slovenia risks stagnation at the level of compliance, rather than progression toward a regenerative, innovation-driven CE model [55,86]. While the European Green Deal sets ambitious objectives for climate neutrality and recycling rates, we note that implementation timelines may be overly optimistic given current technological and market barriers. For instance, plastic packaging recycling remains limited, with the majority of polymers such as LDPE and polystyrene either incinerated or landfilled, and PET is often downcycled. Similarly, wood is typically reused rather than recycled in a closed loop. These realities raise questions about the feasibility of achieving a 55% recycling target for plastic packaging by 2030. Therefore, while Slovenia and the EU demonstrate strong strategic ambition, progress

will depend on scaling up innovation, standardization, and economic incentives to ensure that recycling efforts move beyond small-scale or downcycling practices.

This study has certain limitations that should be acknowledged. Despite using four major databases (Scopus, Web of Science, ScienceDirect, and Google Scholar), publication coverage may not be exhaustive. Some relevant studies might be absent because they were not indexed in these databases or lacked the selected keywords in titles and abstracts. Similar sampling constraints have been noted in other bibliometric or systematic reviews using comparable protocols [52,85]. Additionally, the exclusion of non-English publications and purely technical studies may have limited the representativeness of sector-specific CE research. Future reviews could integrate bibliometric or network-based analyses to mitigate these biases and ensure greater inclusiveness.

The application of the PRISMA protocol was adapted to the specific scope of our research, which may blur the line at times between the findings of this review and the broader consolidated evidence in the literature. Although four major databases (Scopus, Web of Science, ScienceDirect, and Google Scholar) and additional sources were consulted, it is possible that some relevant publications were not captured. As with any systematic review, methodological constraints such as potential exclusion bias and differences in database indexing remain inherent challenges. To strengthen future work, researchers could extend database coverage, complement systematic reviews with bibliometric or meta-analytical approaches, and update the analysis as the body of CE literature continues to grow.

6. Conclusions, Implications and Future Work

To ensure Slovenia's transition toward a more circular model, several measures are needed. First, the establishment of a central CE coordination body—mandated to oversee implementation, monitor progress, and coordinate inter-ministerial and regional activities—would address the governance fragmentation currently observed. Second, Slovenia should prioritize the development of sector-specific CE roadmaps, particularly for high-impact sectors such as construction, textiles, food, and information technology. These roadmaps would enable more targeted interventions, ensure compatibility with EU taxonomy regulations, and guide investment priorities. Third, greater emphasis should be placed on monitoring and evaluation. The adoption of a unified national CE indicator framework, adapted from the EU model but disaggregated by sector and region, would support evidence-based policy and enhance transparency and accountability.

Taken together, the findings provide an answer to our research question. Slovenia's CE policy framework is formally aligned with EU objectives, but persistent governance fragmentation, weak monitoring, and sectoral imbalances continue to hinder progress. Future research should therefore move beyond indicator-based assessments to include longitudinal sectoral case studies, comparative analyses with other small EU Member States, and participatory approaches with businesses, policymakers, and citizens in order to capture the dynamics of CE implementation more comprehensively.

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Abbreviations

The following abbreviations are used in this manuscript:

EE	Energy Efficiency (appears in the Slovenian Development Strategy section)
EC	European Commission
COM	Commission document (e.g., COM(2018) 29)
ARSO	Agencija Republike Slovenije za okolje (Slovenian Environment Agency)
CE	Circular Economy
CMU	Circular Material Use (rate)
DMC	Domestic Material Consumption
EEA	European Environment Agency
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HEIs	Higher Education Institutions
IRB	Institutional Review Board
NECP	National Energy and Climate Plan
NGO	Non-Governmental Organization
NWPP	National Waste Prevention Program
OECD	Organization for Economic Co-operation and Development
PPP	Purchasing Power Parity
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RES	Renewable Energy Sources
RRP	Recovery and Resilience Plan
SDGs	Sustainable Development Goals
SME(s)	Small and Medium-Sized Enterprise(s)
WFD	Waste Framework Directive (Directive (EU) 2018/851 amending Directive 2008/98/EC)
PPWD	Packaging and Packaging Waste Directive (Directive (EU) 2018/852 amending Directive 94/62/EC)
MWR	Municipal Waste Recycling rate (indicator, %)
MWG	Municipal Waste Generation (indicator, kg per capita)
PWR	Packaging Waste Recycling rate (indicator, %)
PPR	Plastic Packaging Recycling rate (indicator, %)
LFR	Landfilling Rate of municipal waste (indicator, %)
SRT	Secondary Raw Material Trade (indicator, tons, €)
RP	Resource Productivity (GDP/DMC; indicator, EUR/kg)

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