

SUSTAINABLE DEVELOPMENT CULTURE TRADITIONS JOURNAL

Volume 16a / 2025

**Special Issue
Cost Action CA22124
ECO4ALL**

**EU Circular Economy
Network for All:
Consumer Protection
through reducing,
reusing, repairing
(ECO4ALL)**



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This Special issue COST Action ECO4ALL is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

COST Action CA22124

EU Circular Economy Network for All: Consumer Protection through reducing, reusing, repairing (ECO4ALL)



**Special issue ECO4ALL as the result of Special session COST ACTION 22124 ECO4ALL
within 2nd OPEN-AIR CITIES International Conference
“Local and Regional Sustainable Development and Urban Reconstruction”
Athens, February 14-16, 2025**

Carrying out sustainable development goals by 2030, especially focusing on sustainable consumption, represents a collective priority in today's society, but significant regional differences within the EU and globally. In this context, the transition to the circular economy (CE) brings a significant paradigm shift in modern sustainability strategies, especially in the area of consumer protection and the development of sustainable practices. ECO4ALL action responds to these challenges by encouraging regional and international cooperation to improve sustainable consumption and consumer protection, thereby contributing to the achievement of sustainable development goals and creating a circular economy that serves the interests of all participants in society. ECO4ALL particularly emphasizes producer responsibility in the product design and marketing stages, thereby encouraging consumer protection through the strategies of reducing, reusing, and repairing products.

The special session is focus on circular economy (CE) strategies that can improve consumer protection, reduce environmental risks, promote resource efficiency, and alleviate inefficient use. One of the key aspects of this session is the discussion on how the proactive role of consumers can contribute to the full circularity of the process, through inclusive participation in every step of sustainable development, and advocating for stronger regulatory frameworks that encourage circular practices. ECO4ALL thereby complements existing EU policies, which are focused on the ecological and productive aspects of the circular economy, expanding the focus on social and consumer dimensions.

The key topics of the present Session are the following:

- The Role of Circular Economy in Achieving the 2030 Sustainable Development Goals
- Circular Economy Strategies for Sustainable Resource Management
- Consumer Protection through Product Lifecycle Extension through Reducing, Reusing, and Repairing
- Circular Economy as a Tool for Sustainable Consumption
- Enhancing Cross-border Cooperation for Circular Economy Success
- Policy Frameworks for Regional Development and Their Impact on Circular Economy Adoption
- The Socio-Economic Impacts of Circular Economy Practices on Consumer Rights
- Overcoming Barriers to Circular Economy Implementation in Different Regions
- Cross-sector Collaboration for Promoting Circular Economy in Consumer Markets
- Education and Awareness for Sustainable Consumption

The Special issue COST Action CA22124 ECO4ALL is the result of Special session of the 2nd OPEN-AIR CITIES International Conference “Local and Regional Sustainable Development and Urban Reconstruction” Athens, February 14-16, 2025 and is based upon work from COST Action CA22124 - ECO4ALL “EU Circular Economy Network for All: Consumer Protection through reducing, reusing, repairing”, supported by COST (European Cooperation in Science and Technology - www.cost.eu).

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CIRCULAR ECONOMY AS A STRATEGIC IMPERATIVE FOR FOSTERING SUSTAINABILITY AND CONSUMER ENGAGEMENT

DOI: 10.26341/issn.2241-4010-2025-16a-1-K02140

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Abstract

In contemporary society, the idea of a circular economy plays a crucial role in achieving sustainable development goals. It promotes efficient resource use, enabling reuse and recycling instead of single-use. It is based on economic systems and business models that replace the linear model with alternative approaches such as reducing, reusing, and repairing. As consumer needs become more complex and technologies advance, it is necessary to focus on circular strategies that enable responsible resource management and strengthen consumer awareness. This paper aims to identify barriers to implementing circular strategies by analyzing consumer education and the relationship between systems, needs, and opportunities, focusing on the local specificities of the countries involved in the COST Eco4All action. The research includes data from 30 countries collected through surveys. The results will be processed through statistical analyses to identify differences in barriers and opportunities between these countries, providing insights for creating more effective circular strategies at regional and national levels. The paper highlights the importance of consumers as catalysts for circular transformation, whose protection and engagement have a fundamental impact on the success of this concept.

Keywords: Circular economy, Customer, Strategies, Barriers, Sustainable development

Introduction

In today's world, the circular economy (CE) is recognized as a fundamental concept. Increasing concerns over rising resource consumption have prompted both governments and

companies to adopt circular models. These models not only help alleviate resource scarcity but also serve as a source of innovation and economic development (Alves et al., 2022). This concept has gained global significance as it addresses the issues of diminishing resources and the environmental challenges posed by the current linear economic model. It also encourages active consumer protection and education (WHO, 2018).

Therefore, to promote sustainability and effective resource management, the circular economy has emerged as an innovative approach that links industries, governments, and consumers (Brydges, 2021). It provides solutions for more efficient material use and recycling within industries while promoting policies encouraging sustainable economic growth at the government level (Alves et al., 2022). Additionally, it empowers consumers to adopt more responsible habits, engage in product reuse, and support circular business models (Jain et al., 2018; Geiger, 2018).

This concept encompasses various aspects, including adapting business models, redesigning products, and promoting responsible resource use. Of particular importance is the involvement of consumers in this process by raising awareness of the importance of circular models, educating them about sustainable practices such as recycling and reuse, and providing information about consumer rights in the context of the circular economy (Stumpf et al., 2021).

The circular economy provides numerous benefits but presents some challenges for consumers. This model operates on principles of "make-use-return" or "take-make-use" with the goal of reducing waste production. As a result, it has distinct implications for consumers (Schaik, & Klundert, 2001; Elisha, 2020). In this context, consumer protection involves ensuring that products are safe, durable, and designed for repair or reuse. To successfully implement this concept, companies need to undergo structural changes while also fostering informed consumers who comprehend the principles of circular business. This approach ultimately contributes to sustainable development as a whole (Lewandowski, 2016).

The concept of a circular economy has been extensively studied, particularly regarding general sustainable development and waste reduction strategies. However, significant research gaps exist in understanding the specific aspects of its implementation at the international level, especially when considering countries' local specificities. Most existing research focuses on macroeconomic policies, technological innovations, and industrial models, while there is relatively little emphasis on the interaction between consumer education and their specific needs. Further analysis is needed to understand how education and environmental awareness can overcome barriers to implementing a circular economy and adapt circular strategies to various socio-economic and cultural contexts. In this sense, this paper seeks to fill existing gaps through the analysis of three key research questions:

RQ1: How does work experience influence the perception of personnel, organizational, and financial barriers in managing a circular value chain?

RQ2: How does work experience influence the perception of institutional and infrastructural barriers to implementing the circular economy?

RQ3: How does the country of origin influence the perception of institutional barriers, such as the absence or low level of financial incentives and the effectiveness of recycling laws?

Hence, this research aims to examine how strategic planning and management can contribute to a more efficient application of circular economy principles, emphasizing overcoming key barriers, such as personnel, organizational and financial obstacles, and institutional, infrastructural, and legal challenges. The research will also analyze how these barriers affect the strengthening of environmental awareness and active engagement of consumers, as well as the challenges associated with implementing circular strategies that must be adapted to local socio-economic and cultural specificities in the countries involved in the COST action Eco4All.

Literature review

The circular economy is an alternative to the traditional linear economy, which relies on the "take-use-throw" model by promoting a pattern of reducing, reusing, and repairing (Özkan et al., 2020). In a circular economy, resources are kept in use for as long as possible to maximize their value. Once products and materials have served their purpose, they are returned and reused instead of being discarded (Morgan & Mitchell, 2015). According to Erkman (2001), when a product reaches the end of its life cycle, its materials tend to be retained within the economic system wherever feasible. In this way, materials can be reused, thereby continuously creating additional value.

The circular economy, as a sustainable approach, aims to reduce the negative effects of the linear economy by building long-term resilience in business and economic circumstances while providing significant environmental and social benefits (Alves et al., 2022). This model is gaining importance in developing countries and developed economies, supporting various sectors such as industry, tourism, and services. The focus is on reducing waste at all stages of the production process, from design to disposal, which not only improves sustainability but also contributes to closing the supply chain loop (Hartley et al., 2020).

According to Bocken et al. (2016), strategies play a key role in implementing circular approaches, enabling organizations to extend the life of products, reduce waste, and use resources efficiently. Well-designed strategies promote economic and environmental benefits and raise awareness of circular practices through the engagement of consumers and other relevant stakeholders. Hence, strategic management in the circular economy is a key factor for achieving sustainability and encouraging consumers' active participation.

Innovative models, driven by digital technologies, rely on close cooperation with customers, mass personalization, and sharing and collaborative economy principles. They accelerate the transition to a circular economy and encourage resource optimization, making the European economy less dependent on primary raw materials (European Commission, 2020).

The European Commission (2020) proposes changes to the law on consumer protection in the EU to encourage greater consumer participation in the circular economy. These changes aim to provide consumers at the point of sale with reliable and relevant information about products, including their lifespan, as well as the availability of repair services, spare parts, and repair manuals. Also, companies and consumers can jointly analyze the end of product life, focusing on recycling, repairing, and reusing options (Islam et al., 2021).

Consumer behaviour plays a significant role in the success of companies that apply circular principles in their business (Parajuly et al., 2020). According to Islam et al. (2021), consumer behaviour research can help companies find appropriate methods to improve aspects of the circular economy that will serve consumers through their consumption and raise awareness about disposal, recycling, and repair. Active participation of end consumers is a key factor in the transition to a circular economy, as it influences the demand for products that support this model. This includes durable, high-quality, and repairable products, as well as those that can be reused, recycled, remanufactured, repaired, or resold, and products that can be shared (Shevchenko et al., 2023).

Methodology

This paper presents the results of a survey conducted within the COST Action CA22124 - ECO4ALL framework, in which representatives from 30 countries participated. A total of 165 respondents were surveyed, which provides a significant basis for analysis. The survey aimed to collect data on the role of consumers in circular practices, with a particular focus on

activities such as waste reduction, reuse, and product repair. Conducted through a structured online questionnaire, the survey highlighted the importance of empowering consumers by informing them about their rights, obligations, and opportunities in the context of a circular economy. In addition, their impact on creating business policies and strategies was analyzed. The data obtained serve as a basis for quantitative analysis and formulating recommendations for improving public policies at the national and European levels.

Before proceeding to a detailed demographic analysis of the respondents, the measuring instrument's reliability was checked. The calculated value of Cronbach's α coefficient for the entire data set was 0.978, indicating an extremely high level of reliability of the instrument. These results confirm that the measuring instrument is adequate for assessing the selected parameters and provides justification for continuing the research with a more detailed analysis of the data. This provided a stable basis for interpreting demographics and other relevant aspects, further contributing to the conclusions' relevance and significance.

Data Analysis and Results

After data collection and initial analysis were completed, incomplete responses were eliminated from the sample, resulting in a final set of 165 valid questionnaires. Table 1 shows the demographic characteristics of the respondents.

Table 1: Demographics profile of respondents

Measure	Item	%
Gender	Male	34.5
	Female	65.5
Age	18 - 30	25.5
	31 - 40	24.8
	41 - 50	30.3
	51 - 60	14.5
	61 - 65	0.6
	65+	4.2
The level of education	High school diploma or less	6.1
	Higher school	7.9
	Basic academic studies	9.1
	Master studies	16.4
	Doctoral studies	60.6
Years of working experience	none	3.6
	up to a year	6.7
	from 1 to 5 years	17.6
	from 6 to 10 years	8.5
	from 11 to 20 years	30.3
	from 21 to 30 years	18.8
	from 31 to 40 years	11.5
	40+ years	3.0
Country	Albania	7.3
	Algeria	0.6
	Bosna and Herzegovina	4.8
	Bulgaria	1.2
	Croatia	1.2
	Cyprus	1.2
	Czech Republic	9.7

Denmark	0.6
Estonia	0.6
Georgia	0.6
Greece	1.2
Hungary	3.6
Indonesia	0.6
Ireland	0.6
Israel	6.1
Italy	0.6
Latvia	0.6
Montenegro	0.6
Munich	0.6
North Macedonia	1.8
Portugal	3.6
Republic of Moldova	16.4
Romania	0.6
Serbia	12.7
Slovakia	0.6
Spain	1.8
Sweden	0.6
Taiwan R.O.C.	0.6
Turkey	17.0
United Kingdom	1.8

Table 1 shows the demographic profile of the respondents, including gender, age, education level, work experience, and countries of origin. Most respondents are women (65.5%), while men comprise 34.5%. The age groups are diverse, with the most represented respondents aged 41 to 50 (30.3%), followed by those between 18 and 30 (25.5%) and 31 to 40 (24.8%). The age group from 51 to 60 is less represented (14.5%), while respondents over 60 are rare (4.8%).

In terms of education, the majority of respondents have a doctorate (60.6%), while a smaller percentage have a master's degree (16.4%), basic academic studies (9.1%), college (7.9%) or high school or lower education (6.1%). Work experience varies, with the largest number of respondents reporting between 11 and 20 years of experience (30.3%), while groups with less than five years (21.2%) and over 30 years (14.5%) are less represented.

Respondents come from 30 different countries involved in the COST action. The most represented participants are from Turkey (17.0%), the Republic of Moldova (16.4%), Serbia (12.7%) and the Czech Republic (9.7%). A smaller percentage comes from other countries, such as Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Greece, Hungary, Italy, Portugal and Spain, with less than 8% shares. This diversity, which includes participants from a broader pan-European context, provides a solid basis for analysis within the framework of international cooperation and research within the ECO4ALL action.

Further data analysis examined the relationship between demographic characteristics, such as work experience and country of origin, and barriers that limit circularly responsible consumer behavior. This approach allowed for a deeper understanding of the interrelationships between these variables, providing a basis for formulating conclusions and identifying factors that influence consumer behavior in the circular economy context.

Discussion of the results

This research analyzes the relationship between demographic characteristics, such as work experience and country of origin, and key barriers that hinder effective circular value chain management. These barriers include personnel, organizational, and financial obstacles, as well as institutional, infrastructural, and legal challenges that can hinder the implementation of circular practices.

The relationship between customers' work experience and perceptions of personnel, organizational, and financial barriers was examined: high initial investment (Barr_hii) and short-term interests of stakeholders (Barr_stis). The research question RQ1 was confirmed based on the obtained results. The results show significant differences in responses depending on the length of work experience. For the high initial investment barrier, participants with work experience of 1 to 5 years and 11 to 20 years more often perceive this barrier as extreme. For the short-term interests' barrier, participants with work experience of 11 to 20 years express the most concern. Statistically significant results ($p = 0.024$ for Barr_hii and $p = 0.000$ for Barr_stis) indicate that work experience influences the perception of these barriers, which are classified as personnel, organizational, and financial barriers, with those with more work experience more often recognizing these challenges as significant obstacles.

Within institutional and infrastructural barriers, statistically significant differences in responses related to consumers' work experience were observed for four key items. The first item, Absence or low level of financial incentives (IIB_fi), showed a significant difference in responses, with consumers with more work experience more often perceiving this barrier as significant ($p = 0.001$). The second item, Antitrust laws that prevent cooperation in the circular economy (IIB_al), also showed a statistically significant difference ($p = 0.038$), with consumers with 11 to 20 years of work experience expressing agreement with this barrier more often. The third item, Problems with responsibility, obligations and ownership of the circular economy implementation process (IIB_roo), also showed a significant difference ($p = 0.015$), with the highest percentage of responses as a significant barrier being given by consumers with work experience between 11 and 20 years. Finally, Limited reverse logistics capacities (IIB_lc) showed the highest statistical significance ($p = 0.000$), indicating that consumers with more work experience often see this barrier as an important challenge in implementing the circular economy. These differences show that work experience plays a significant role in the perception of various institutional and infrastructural barriers in the process of transition to a circular economy. Based on these findings, the research question RQ2 is confirmed. The results demonstrate that work experience significantly influences the perception of institutional and infrastructural barriers, as evidenced by statistically significant differences in responses for key items such as financial incentives, antitrust laws, responsibilities in the circular economy process, and reverse logistics capacities.

When it comes to analyzing the relationship between countries of origin and barriers within institutional and infrastructural barriers, two items showed a statistically significant difference: Absence or low level of financial incentives (IIB_fi) and Recycling laws are ineffective in achieving (IIB_r) high-quality recycling. According to the results of the Chi-Square test, IIB_fi showed a statistically significant difference (Pearson Chi-Square = 154.141, $df = 116$, $p = 0.010$), with countries such as Serbia, Albania and Turkey marking this item as an "Extreme barrier" more, while other countries, such as Hungary and Portugal, had a lower number of such responses. Similarly, for IIB_r (Pearson Chi-Square = 151.711, $df = 116$, $p = 0.015$), countries such as Turkey and the Republic of Moldova also perceived recycling laws as a significant barrier. In contrast, other countries, such as Slovakia and Portugal, were less concerned about these laws' effectiveness. These differences point to the different attitudes and challenges that countries face about recycling financing initiatives and

legislation. Based on these claims and statistically significant differences, the research question RQ3 is confirmed, indicating that countries of origin significantly influence the perception of institutional and infrastructural barriers.

Conclusion

The transition from a linear to a circular economy model is a continuous process that changes traditional production and consumption paradigms. This research examines how strategic planning and management can contribute to a more successful implementation of the circular economy principles by overcoming key barriers, including human resources, organizational, financial, institutional, infrastructural, and legal challenges. In addition, the analysis focuses on the impact of these barriers on increasing environmental awareness and active consumer involvement, with a particular emphasis on adapting circular strategies to the specificities of the countries covered by this research, which are involved in the COST action ECO4All. Given the importance of consumers in this transition, their behavior is recognized as a key factor in achieving sustainable change.

This research contributes significantly to understanding how work experience and country of origin influence the perception of key barriers to implementing a circular economy. The results highlight that work experience shapes consumer attitudes towards barriers such as high initial investments and short-term stakeholder interests, while institutional and infrastructural barriers, such as lack of financial incentives and limited reverse logistics capacities, further complicate the transition process. In addition, significant differences between countries indicate the need for a localized approach that considers specific socio-economic and cultural characteristics.

This paper's theoretical contribution lies in filling the gaps in the literature on consumer interaction with circular economy principles. The research expands the existing understanding of barriers with a focus on their perception from the consumer's perspective, which contributes to the development of more effective strategies for education and awareness raising. Analyzing work experience and origin as key determinants enables more precise modeling of obstacles and solutions in the circular economy.

The practical implications are manifold. For companies and policymakers, the findings suggest adapting strategies and communication campaigns to overcome the barriers perceived as key by different consumer groups. Educating consumers about the principles of the circular economy and providing financial incentives can significantly improve their involvement and acceptance of this model. Also, the identification of differences between countries provides a basis for developing localized policies that respond to the specific challenges of each country, thereby contributing to the global goal of sustainable development.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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THE ROLE OF CIRCULAR ECONOMY IN SUSTAINABLE DEVELOPMENTS GOALS IN ALBANIA

DOI: 10.26341/issn.2241-4010-2025-16a-2-K02215

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Abstract

This article aims to explore the role of the circular economy towards the accomplishment of Albania's Sustainable Development Goals by emphasizing the developments of sustainable practices in areas such waste management, resource efficiency, and environmental conservation. Aiming to align the country's practices with EU standards, Albania has integrated the circular economy practices into several national policy frameworks and recently approved or reviewed environmental laws. Through collaboration with several international organizations, and the implementation of international projects, Albania has developed a Circular Economy Roadmap, focused on green procurement, producer responsibility and public engagement.

Even though there are significant developments especially in the alignment with EU standards, limited recycling infrastructure, low waste separation rates, low public awareness, and inadequate regulatory implementation are considered significant obstacles in the process of transition from linear to circular economy. Enhancing the regulatory framework, promoting the public awareness, investing in the improvement of infrastructure, financing SME-s and improved collaboration among the public and private sector, would support an easier transition to circular economy and contribute to the job creation, environmental protection, and sustainable growth in Albania.

Keywords: *Circular economy, sustainable development goals, Albania, EU integration.*

Introduction

The Sustainable Development Goals are made of seventeen objectives aimed at achieving sustainable development, with a strong emphasis on solving several social, economic, and environmental concerns. The SDGs are published in 2015 by the UN General Assembly. Aimed to be accomplished by 2030, SDGs follow the Millennium Development Goals and shifts the global development direction toward sustainability. For developing nations like Albania, the Sustainable Development Goals are particularly significant because their achievement will indicate progress in fulfilling the prerequisites for EU membership. Albania has adopted the National Strategy for Development and European Integration 2015-2020 and integrated the Sustainable Development Goals since being granted EU candidate status in June 2014.

Several Sustainable Development Goals, especially goals associated with production and consumption, economic expansion, and environmental sustainability, are closely related to the circular economy principles. Recognizing the role of the circular economy practices in achieving several Sustainable Development goals especially those that are related to production and consumption, resource management, waste management, competitiveness and innovation, environment protection, clean energy, economic growth and so forth, has leveraged the interest of the researchers and the policymakers toward circular economy

implementation practices (Arruda et al., 2021; Moraga et al., 2019; Padilla-Rivera et al., 2020).

The circular economy has significant economic, environmental, and social impact. Ekins et al. (2019), Lewandowski (2016), and Rizos et al., (2017) show that switching from a linear to a circular economy seeks to decline environmental damage caused by non-reusable waste and so lessen reliance on non-renewable natural resources. A basic model of the circular economy is the pattern of utilizing the output of one product as the input for another, so generating a closed-loop system. McCarthy et al. (2018) also argue that optimizing the use of natural resources can help achieve environmental objectives, lower reliance on imports by using domestic secondary resources, and promote economic growth and job creation by circular economy practices.

The distinction between a linear economy and a circular economy is substantial. In a linear economy, resources are extracted, processed into products, consumed, and ultimately removed as waste. On the other hand, the circular economy operates within a closed-loop framework, where waste is minimized, and resources are continuously cycled back into the system. After products are used, they undergo processes such as recycling, recovery, repair, retention, and return, ensuring their ongoing utility and reducing environmental impact.

Ellen MacArthur Foundation (2015) describes the concept of circular economy by using butterfly diagram. The diagram illustrates the circulation of materials through two circles. The first cycle includes the activities and processes such as sharing, maintaining or prolonging, reusing, remanufacturing and recycling of the finite sources and is called the technical cycle. The second cycle includes all the activities and processes that ensure the regeneration of nature and natural renewable resources, and the sustainability of their utilization is called the biological cycle.

The implementation of circular economy is in the early development stages in Albania. However, a report of OECD (2024) highlights three critical focus areas where circular economy reforms could significantly benefit Albania. These include: (1) utilizing economic tools to promote sustainable production and consumption practices, (2) fostering the development of circular business models, especially among small and medium-sized enterprises (SMEs), and (3) tackling challenges within the plastics value chain, having a particular focus on combating marine pollution. Sustainable production and consumption can be achieved by increasing the recycling rate, extending the life of production and increasing the waste management. Business models play a crucial role in the implementation of circular economy.

The aim of this paper is to investigate the role of circular economy in the Sustainable Development Goals in Albania emphasizing the main obstacles and opportunities in the process of transition towards more sustainable practices in waste management, resource efficiency, and environmental conservation. Since receiving its candidacy for the European Union integration, Albania has undertaken several reforms focusing on the sustainable growth and development, with a special focus on green reforms, waste management, and increasing the infrastructure supporting the circular economy.

Albania is in the earliest steps of implementation of circular economy. Based on the statistics of the Albanian Institute of Statistics (2022), the recycling rate of municipal solid waste in Albania is only 17%, which is significantly lower compared to the EU average of 49% (Eurostat, 2022). Based on the report of Lloyd's Register Foundation (2024) entitled World Risk Poll 2024 Report, 78% of the household in Albania has responded not to practice any waste separation at the source, which is a very high percentage compared to the 63% which is the average for the low-income countries, emphasizing the low public awareness and the need for increased public participation and improved waste management infrastructure.

Literature Review

Several research papers have examined the connection between the circular economy implementation indicators and the compliance with SDGs and have achieved significant results. Rodriguez-Anton et al., (2019) investigate the correlation between nine indicators of circular economy and SDGs, in 156 countries with data as of 2017. The chosen indicators are organized in four groups, such as production and consumption indicator, waste management indicator, secondary raw materials indicator and competitiveness and innovation indicator. The authors investigate the correlation between the chosen indicators and SDG 6, 8, 9, 11, 12, 13, 14, and 15. The findings of the study suggests that there is found a relationship of all CE indicators with SDG 8, 9, 11, 12 and there is found a relationship of at least one of CE indicators with SDG 13 and SDG 14.

Fatimah et al., (2020) give a valuable contribution by developing and designing the smart systems and business processes for the waste management in Indonesia. They use internet of things to integrate the application of the circular economy processes. The authors conclude that the system they have designed to implement the circular economy will have a significant influence on the Sustainable Development Goals such as SDG 3, 6, 8, 12 and 13. Their system is designed to have vital economic, social and environmental impact. Another study by Dantas, et al., (2021) aims to investigate the impact of both circular economy and Industry 4.0 on the Sustainable Development Goals. By conducting a systematic literature review, the authors find that the incorporation of Circular Economy and Industry 4.0 has a pivotal impact on the SDGs as it ensures the incorporation of innovative technology, circular production practices and business models. The impact is particularly significant in SDG 7, 8, 9, 11, 12, and 13.

Ronzon and Sanjuan (2020) examine the relationship between EU bioeconomy strategy and sustainable Development Goals in 28 EU countries for the period from 1990 until 2018 by using a bivariate correlation and mapping the 2018 EU bioeconomy strategy with SDGs. The results of their study suggests a positive relationship among bioeconomic strategy and SDG 7, 11, and 15. However, there is a negative correlation between agrobiodiversity strategies and SDG 2, SDG 8, SDG 9, and SDG13. Schroeder, Anggraeni, & Weber (2018) use a narrative literature review to analyse the relation between circular economy and sustainable development goals. The findings suggest that the practices of circular economy have a positive direct strong contribution to SDG 6, 7, 8, 12, 15. Furthermore, Circular Economy may give a significant contribution on potential synergy among several SDGs such as SDG 8, 1, 2, 14, and 15.

Also, Ferraz & Pyka (2023) conduct a bibliometric analysis 649 research papers for the period 2007-2022, and systematic literature review of 81 articles to investigate the impact of circular economy and bioeconomy on sustainable development goals. The authors conclude that the circular economy primary impacts SDG12, continuing SDG7, 6. Furthermore, bioeconomy impacts SDG 7, 9, and 12.

Table 1. Literature Review Summary

Study	Focus Area	Methodology	Key Indicators/Systems	Relevant SDGs	Key Findings
Rodriguez-Anton et al. (2019)	Correlation between CE indicators and SDGs	Correlation analysis using data from 156 countries (2017)	Production & consumption, waste management, secondary raw materials, competitiveness & innovation indicators	SDG 6, 8, 9, 11, 12, 13, 14, 15	Strong correlation of all CE indicators with SDG 8, 9, 11, 12; at least one CE indicator linked to SDG 13 and 14.

Fatimah et al. (2020)	Smart systems & business processes for waste management in Indonesia	Development of IoT-based systems	Internet of Things (IoT) for CE process integration	SDG 3, 6, 8, 12, 13	CE system design has significant economic, social, and environmental impacts, enhancing SDG implementation.
Dantas et al. (2021)	Joint impact of CE and Industry 4.0 on SDGs	Systematic literature review	Integration of innovative tech, circular production practices, and business models	SDG 7, 8, 9, 11, 12, 13	CE and Industry 4.0 combination plays a pivotal role in driving SDGs through technology and business model innovation.
Ronzon & Sanjuan (2020)	Relationship between EU bioeconomy strategy and SDGs	Bivariate correlation and strategy mapping (1990–2018)	EU bioeconomy strategy and agrobiodiversity strategies	Positive: SDG 7, 11, 15; Negative: SDG 2, 8, 9, 13	Positive correlation with SDG 7, 11, 15; negative correlation found between agrobiodiversity strategies and SDG 2, 8, 9, 13.
Schroeder et al. (2018)	Narrative literature review	CE practices and SDG synergy analysis	Strong contribution to SDG 6, SDG 7, SDG 8, SDG 12, SDG 15; Potential synergy with SDG 8, SDG 1, SDG 2, SDG 14, SDG 15	Schroeder et al. (2018)	Narrative literature review
Ferraz & Pyka (2023)	Bibliometric analysis (649 papers, 2007-2022) & systematic literature review (81 articles)	Impact of CE and bioeconomy on SDGs	CE primary impact on SDG 12; also impacts SDG 7, SDG 6; Bioeconomy impacts SDG 7, SDG 9, SDG 12	Ferraz & Pyka (2023)	Bibliometric analysis (649 papers, 2007-2022) & systematic literature review (81 articles)

Methodology

As Albania is still in its early phases of implemented circular economy, this study employs a desk research approach to analyse the role of the circular economy in achieving Albania's Sustainable Development Goals. The research methodology of this study consists of using available data, articles, reports to have a descriptive analysis of the topic of study. The key concepts of conducting the research are circular economy and sustainable development goals in the context of Albania. To look for those concepts are used scientific research search engines such as Science Direct, Google Scholar, Semantic Sholar, RePEc and SSRN. For reports and data mostly are used the websites of OECD, United Nations, The World Bank, Eurostat, European Commission, the Albanian Institute of Statistics, and so forth. One of the

most important limitations of this methods stands in the fact that the analyse may not go into deep details.

Findings and Discussions

Albania's shift to a circular economy is in its nascent stages, characterized by both emerging opportunities and persistent challenges. The integration of circular economy practices into Albania's policy framework has been primarily driven by the National Waste Management Strategy (2018-2033) and various environmental protection laws designed to align with EU standards. The implementation of several national strategies and the improvement of the regulatory framework emphasize Albania's commitment to aligning with sustainable development goals, particularly within the context of its EU integration aspirations.

In the framework of application of the circular economy, Albania has development the Circular Economy Roadmap, which relies on three main pillars: green public procurement, extended producer responsibility, and public awareness campaigns. The Circular Economy Roadmap serves as a guideline to the Albanian government by providing several policy recommendations and monitoring frameworks to facilitate and track the transition to circular economy. Albania's transition to circular economy is also supported by the European Union institutions and the UNDP which have continuously offered technical assistance and funded several projects, contributing to the facilitation of the capacity-building and the adoption of best practices from other European countries.

The implementation of the circular economy in Albania is supported by business models in several areas, such as waste management, agriculture, textiles, tourism, and renewable energy, which are crucial to achieving sustainable development Goals (Hysaj, 2024) . Sustainable Goal 12, related to Responsible Consumption and Production, is the focus of the main pillars of circular economy, such as sustainable resource use, waste generation reduction, and recycling practices (Schroeder, Anggraeni, & Weber, 2018). Moreover, Sustainable Development Goal 8, related to Decent Work and Economic Growth, and Sustainable Development Goal 9, related to industry, innovation, and infrastructure, is supported by the promotion of recycling, waste management, and eco-innovation sectors (McCarthy et al., 2018; Ferraz & Pyka, 2023). Sustainable Development Goal 6, Climate Action, is promoted by the policies and laws aiming to lower the greenhouse gas emissions through waste management and energy efficiency. Moreover, the promotion of renewable energy supports the achievement of Sustainable Development Goal 7, Affordable and Clean energy (Ferraz & Pyka, 2023; Schroeder et al., 2018).

Regardless of the significant developments that enable the application of circular economy practices, this process faces considerable barriers. These barriers are related to the limited and inadequate recycling infrastructure, low levels of waste separation at the source from the households, and gaps in regulatory enforcement. Even though several EU projects are supporting the country's advancement toward this direction, the limited financial incentives and low awareness among businesses and consumers makes the transition difficult and slow. Moreover, small and medium-sized enterprises, which represent over 99% of Albania's businesses, often lack the technical expertise and resources needed to adopt circular business models (OECD, 2019).

Regardless of the barriers and challenges faced there are numerous local initiatives aiming to ease the application of circular economy. Municipalities of Tirana and Durrës have launched several projects aiming to improve the waste management systems, to encourage recycling, and to promote the usage of clean energy, furthermore, directly contributing to SDG 11, associated with Sustainable Cities and Communities, SDG 12 associated with Responsible Consumption and Production, and SDG 7, associated with Affordable and Clean

Energy. Furthermore, the encouragement of public-private partnerships, educational initiatives, integration of the circular economy concept into university curricula, and collaboration with academia are widely used practices used to promote community involvement in sustainable practices and increase awareness especially among young generations.

Conclusions

This study analyses the contribution of circular economy in the fulfilment of Albania's Sustainable Development Goals (SDGs), focusing on the goals associated with responsible consumption and production, economic growth, sustainable cities and communities and environmental sustainability. Albania has made significant efforts to incorporate circular economy principles within its national policies, aligning with EU environmental standards and fostering international cooperation.

On the other hand, the transition to a fully functional circular economy in Albania is still a work in progress. The primary obstacles include infrastructural deficiencies, weak regulatory enforcement, limited financial incentives, and insufficient public awareness. To overcome these challenges, it is crucial to strengthen institutional capacities, enhance stakeholder engagement, and promote innovative business models that support circular practices.

Key policy recommendations derived from this study include:

- **Enhancing Regulatory Frameworks:** Strengthening the enforcement of existing environmental regulations and introducing new policies that incentivize circular economy practices.
- **Promoting Public Awareness:** Implementing nationwide educational campaigns to encourage a culture of sustainability among citizens and businesses. Integrating the circular economy concepts into university curriculum.
- **Supporting SMEs:** Providing technical assistance, financial incentives, and capacity-building programs to help SMEs adopt circular business models as the SMEs make 99% of businesses in Albania and they have limited financial sources.
- **Encouraging Public-Private Partnerships:** Leveraging partnerships between government entities, businesses, and civil society to induce innovation and investment in circular economy initiatives.
- **Improving Infrastructure:** Investing in modern waste management and recycling facilities to support efficient resource recovery and reduce environmental impact. Moreover, financing the infrastructure to facilitate clean energy

In conclusion, although Albania faces considerable challenges in its circular economy transition, the opportunities for sustainable growth, environmental protection, and economic resilience are significant. By addressing the existing the internal barriers and benefiting from its international strategic partnerships, Albania has the opportunity to move forward with a more sustainable growth and development.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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LEGAL ANALYSIS OF CONSUMER RIGHTS TO PRODUCT REPAIR UNDER THE EU DIRECTIVE ON REDUCING, REUSING AND REPAIRING

DOI: 10.26341/issn.2241-4010-2025-16a-3-K02224

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Abstract

This paper provides a comprehensive legal analysis of the time limits governing consumers' rights to claim and request product repairs. It focuses on the new EU Directive promoting product lifecycle extension through reducing, reusing, and repairing. The Directive mandates that manufacturers and sellers enable product repairs up to ten years from the date of manufacture, marking a significant advance towards sustainable consumption and enhanced consumer protection, but only for certain kinds of goods.

Scientific contribution lies in the author's critical examination of the intersection between the newly introduced obligations under the Directive and existing consumer rights under warranties and guarantees. By analysing potential overlaps and conflicts, the paper sheds light on the legal implications and challenges of harmonising these rights within current legal frameworks in selected member states.

The critical legal questions to be addressed will include alignment with existing laws and determining how the directive's mandate for repair for up to ten years aligns with existing national laws on warranties and guarantees. Additionally, stakeholders' responsibilities will be examined in relation to the analysis of the legal obligations of manufacturers and sellers under the Directive, as well as their interactions with consumers' rights to claim defects. In conclusion, the implementation challenges will be addressed to ensure the effective implementation of the Directive into national legislation.

By addressing these questions, the paper aims to provide actionable recommendations to facilitate the effective implementation of the Directive. The findings contribute to the broader discourse on consumer law reform, environmental sustainability, and the integration of circular economy principles into legal systems.

Keywords: *Consumer rights, R2R Directive, guarantee, sustainability, legal analysis.*

1. Introduction

The intensifying global awareness of environmental degradation and the imperative for sustainability have spurred unprecedented legislative action worldwide. The European Union is at the forefront of enacting comprehensive policies to mitigate the adverse consequences of unsustainable production and consumption patterns ([Luzak, 2020](#)).

The European Union has been progressively advancing a comprehensive framework to foster a circular economy, with a significant emphasis on enhancing product durability, repairability, and reusability ([Boniface et al., 2024](#)). This commitment is reflected in various policy initiatives and legislative measures designed to encourage sustainable production and consumption patterns across member states ([Camilleri, 2020](#)). The ambitious goals of the circular economy include minimizing waste, reducing material demand, and promoting the efficient use of resources throughout the product lifecycle ([Mikula et al., 2020](#)). Among the

key instruments driving this transition is the EU Directive on Reducing, Reusing, and Repairing (Directive (EU) 2024/1799 of the European Parliament and of the Council of 13 June 2024 on common rules promoting the repair of goods and amending Regulation (EU) 2017/2394 and Directives (EU) 2019/771 and (EU) 2020/1828; further in text: Directive on Reducing, Reusing and Repairing or Right to Repair Directive (R2R Directive) which seeks to empower consumers with enhanced rights related to product repair, thereby promoting a culture of repair over replacement and contributing to a more sustainable and resource-efficient economy ([Hernández et al., 2020](#)). This directive is strategically designed to tackle premature obsolescence and encourage manufacturers to create more durable, repairable, and easily disassembled products. By establishing a legal framework that supports and protects consumer rights to repair, the EU aims to incentivize manufacturers to prioritize product longevity and facilitate access to repair services and spare parts ([Hernández et al., 2020](#)). The directive's provisions aim to create a level playing field, ensuring that consumers are not unduly pressured into purchasing new products when their existing ones can be repaired, thereby extending product lifecycles and reducing environmental impact.

The R2R Directive represents a pivotal step towards a more sustainable and circular economy within the European Union, addressing critical aspects of product design, consumer rights, and waste reduction ([Pangburn & Stavroulaki, 2022](#)). It aims to establish a robust legal framework that empowers consumers to opt for repair over replacement, thereby extending the lifespan of products and reducing environmental impact.

This paper examines the EU legal framework on promoting repair as a pivotal step towards sustainable consumption and waste reduction within the European Union. A central problem it addresses is the prevailing "throwaway culture," which is incentivized by manufacturers designing products for obsolescence rather than durability and repairability. This problem will be tackled through a detailed legal analysis based on the European consumer protection legal framework.

This research explores the scope of consumer rights, the obligations imposed on manufacturers and sellers, and the mechanisms for enforcement, including the role of Member States with varying consumer protection standards. The Directive's legal, economic and environmental impacts will be analysed, considering its potential effects on businesses, consumers, and the environment. Furthermore, by examining the Directive's interaction with existing EU legislation, such as the Eco-design Directive, this article aims to provide a comprehensive understanding of its potential and challenges in promoting a more sustainable and circular economy ([Boniface et al., 2024](#)).

2. Objectives of the EU Directive on Reducing, Reusing and Repairing

The Directive on Reducing, Reusing, and Repairing addresses the unsustainable consumption patterns that have become a hallmark of modern economies. The core objective is to create a harmonised set of rules across member states that promote the repairability of goods, ensuring that consumers have access to the necessary information, spare parts, and repair services. Furthermore, it aims to incentivise manufacturers to design more durable, easily repairable products that are less prone to premature obsolescence, fostering a culture of sustainability and resource efficiency.

By establishing a legal framework that supports and protects consumer rights to repair, the EU aims to incentivise manufacturers to prioritise product longevity and facilitate access to repair services and spare parts ([Hernández et al., 2020](#)). This approach aims to promote sustainable consumption and minimise waste.

The directive acknowledges the significant role that consumer behaviour plays in the transition to a circular economy, recognising that informed purchasing decisions and a

willingness to repair products can drive demand for more sustainable goods and services. Ultimately, the EU Directive on Reducing, Reusing, and Repairing represents a multifaceted approach to promoting sustainable consumption and production patterns, aiming to create a more resilient and environmentally responsible economy that aligns with the principles of a circular economy. This Directive strengthens provisions related to the repair of goods, contributing to the proper functioning of the European Union's internal market and providing a high level of consumer and environmental protection([Directive, 2024](#)). The directive's provisions aim to create a level playing field, ensuring that consumers are not unduly pressured into purchasing new products when their existing ones can be repaired. Thus, the directive extends product lifecycles and reduces environmental impact.

The genesis of the EU Directive on Reducing, Reusing, and Repairing lies in the European Union's broader commitment to transitioning towards a circular economy, a model that emphasises resource efficiency, waste reduction, and sustainable consumption([Weale et al., 2002](#)). Recognising the limitations of the traditional linear "take-make-dispose" economic model, the EU has prioritised the development of policies and regulations that promote the reuse, repair, and recycling of products and materials ([Chiaraluce et al., 2021](#)). The Directive emerged as a direct response to growing concerns about premature obsolescence, the environmental impact of discarded products, and the need to empower consumers with greater control over the lifespan of their goods. It also aligns with the design for disassembly, remanufacturing, and recycling ([Hernández et al., 2020](#)). Academic research has highlighted the critical role of consumer behaviour in driving the transition to a circular economy, noting that consumers can either support or hinder this transition through their purchasing decisions([Jones & Comfort, 2021](#)).

The primary objective of the Directive is to establish a comprehensive legal framework that promotes the repairability and longevity of products, thereby reducing waste and conserving resources. This involves a multi-pronged approach that includes enhancing consumer rights, incentivising manufacturers to design more durable and repairable products, and facilitating access to repair services and spare parts. By empowering consumers to choose repair over replacement, the Directive aims to extend the lifespan of products, reduce the demand for new goods, and minimise the environmental footprint associated with manufacturing and disposal. The absence of incentives to design products and buildings for disassembly and reuse at the end of their life is a significant challenge ([Adams et al., 2017](#)).

The Directive aims to address several key challenges that hinder the widespread adoption of repair practices ([Mak & Lujinovic, 2019](#)). One such challenge is the limited access to repair information and spare parts, which often makes it difficult or impossible for consumers to repair their products. Another challenge is the perceived high cost of repair compared to the cost of replacing a product, which can discourage consumers from choosing repair even when it is technically feasible([Sevcenko et al., 2019](#)). The directive is designed to encourage a circular consumption pattern ([Rahla et al., 2021](#)). It aims to promote the development of a robust repair sector, creating new economic opportunities and supporting the growth of local repair businesses.

3. Core Provisions and Consumer Rights under the R2R Directive

The EU Directive on Reducing, Reusing, and Repairing introduces a range of provisions aimed at enhancing consumer rights and promoting the repairability of products. One of the most significant aspects of the Directive is the establishment of a "right to repair," which grants consumers the legal entitlement to have their products repaired by manufacturers or authorised repairers.

This right extends to a wide range of goods, including electronics, household appliances, and other consumer products, ensuring that consumers are not unduly pressured into purchasing new items when their existing ones can be repaired. The Directive requires manufacturers to provide access to repair information, diagnostic tools, and spare parts to both consumers and independent repairers, thereby facilitating the exercise of the right to repair ([Jin et al., 2022](#)).

This right extends beyond the warranty period, ensuring that consumers can access repair services throughout the reasonable lifespan of a product. The Directive requires manufacturers to provide consumers with clear and comprehensive information about the reparability of their products, including details on the availability of spare parts, repair manuals, and diagnostic tools. This information must be easily accessible and user-friendly, enabling consumers to make informed decisions about whether to repair or replace their products. Furthermore, the Directive requires manufacturers to design products that facilitate repair, using standardised components and avoiding the use of proprietary tools or techniques that could restrict access to repair.

The right to repair is a significant development that allows individuals to reclaim and tinker with old technologies ([Hatta, 2020](#)). To further incentivise repair, the Directive encourages member states to implement measures that reduce the cost of repair services, such as tax breaks, subsidies, or the establishment of repair vouchers. These measures aim to repair a more economically attractive option for consumers, encouraging them to choose repair over replacement. Additionally, the Directive encourages the development of repair networks and community repair initiatives, enabling consumers to access affordable and convenient repair services.

The Directive also addresses the issue of planned obsolescence, the practice of designing products with a limited lifespan to encourage repeat purchases. While explicitly prohibiting planned obsolescence is challenging due to difficulties in proving intent, the Directive takes steps to combat this practice by requiring manufacturers to ensure that spare parts are available for a reasonable period after a product is discontinued. This provision aims to prevent manufacturers from deliberately shortening the lifespan of products by limiting access to spare parts. The Directive introduces several key consumer rights related to product repair and maintenance.

First, consumers can request repair services from manufacturers or authorised repairers, regardless of whether the product is still under warranty. Second, consumers have the right to receive clear and transparent information about the cost of repair services before agreeing to proceed with the repair. The provisions of the directive are designed to keep repair costs minimal, making it a viable option for consumers. Third, consumers are entitled to a warranty extension for repaired products, ensuring that the repair is carried out to a satisfactory standard and that any subsequent defects are covered. Fourth, consumers can seek redress if a repair is not carried out correctly or if the product fails again after the repair.

These consumer rights are designed to empower consumers and provide them with the confidence to choose repair over replacement, contributing to a more sustainable and circular economy. The lack of consumer awareness regarding product care has also been identified as a reason why consumers either do or do not take care of their products ([Ackermann, 2018](#)).

4. Analysis of the Legal Framework and Scope of the Directive

The EU Directive on Reducing, Reusing, and Repairing is a complex legal instrument with a broad scope that encompasses various aspects of product design, manufacturing, and consumer rights. To fully understand its implications, it is essential to analyse the legal framework underpinning the Directive and clarify its scope of application.

The EU Directive places significant obligations on manufacturers to ensure the repairability and longevity of their products. Before the introduction of this Directive, consumer repair rights within the EU were mainly governed by Directive (EU) 2019/771 on the sale of goods. This directive provides for a minimum two-year legal guarantee period during which consumers can seek remedies, including repair, for defective goods. Nonetheless, implementation of these rights has varied across Member States, often resulting in disparate levels of consumer protection.

The Directive mandates that manufacturers design products with repairability in mind, using standardised components, avoiding proprietary tools, and providing clear disassembly instructions. The product should be designed to facilitate a seamless repair process. Furthermore, manufacturers must make spare parts, repair manuals, and diagnostic tools available to consumers and independent repairers for a reasonable period after discontinuing a product. Legal guarantees under Directive 2019/771 are supplemented by commercial guarantees voluntarily offered by sellers or manufacturers. These guarantees differ in duration, scope, and conditions and often do not align with the more extended repair obligation now mandated under the new Directive.

The new Directive extends beyond the scope of Directive 2019/771 by ensuring repairability throughout the product's lifespan, not just during the initial guarantee period. This is a significant shift towards promoting sustainable consumption patterns. The Directive also introduces the concept of "extended producer responsibility", requiring manufacturers to take greater responsibility for the end-of-life management of their products. ([Weale et al., 2002](#)) This includes incentivizing repair and reuse as well as ensuring the proper collection and recycling of products that cannot be repaired. The Directive aims to shift the focus from a linear "take-make-dispose" model to a circular economy model, where products are designed to last longer, be easily repaired, and ultimately recycled ([Chen, 2019](#)). Furthermore, the new Directive aims to overcome barriers to repair, such as limited access to spare parts and repair information, by requiring manufacturers to provide this information to consumers and independent repairers.

5. Interaction with the existing Consumer Rights

This Directive does not exist in a vacuum; it interacts with a well-established body of consumer rights legislation at both the EU and Member State levels. Understanding this interaction is crucial for effective implementation and to avoid unintended consequences.

As mentioned above, the Directive complements the existing EU directives, such as the Eco-design Directive and the Consumer Rights Directive. While the Eco-design Directive focuses on setting minimum standards for product durability and energy efficiency, this new Directive tackles the barriers to repair, ensuring that consumers can exercise their right to extend the lifespan of their products. It also reinforces aspects of the Consumer Rights Directive by clarifying the remedies available when goods are faulty and emphasising the importance of providing clear and accessible information to consumers (European Commission, 2023). Consumer protection law ensures the defence of the collective interests of consumers in the internal market([Chaudhary, 2005](#)). Member States are free to adopt measures that offer a higher level of consumer protection, as long as this is compatible with Union law ([Weale et al., 2002](#)).

The interplay between EU directives and national laws is equally important. Member States often have their specific regulations regarding consumer protection, product liability, and waste management. These national laws may impose additional or more stringent requirements than those outlined in EU directives. When implementing the new Directive, Member States must ensure that their national laws are aligned with the Directive's objectives

while preserving any existing national provisions that offer a higher level of consumer protection.

Regarding the relationship with national consumer protection laws, Member States have varying levels of consumer protection agencies and legal frameworks. Some, like Germany, France, and the Netherlands, boast strong consumer protection traditions, well-established consumer organisations, and proactive enforcement agencies ([Cuijpers, 2009; Giliker, 2016](#)).

Others, particularly in Southern and Eastern Europe, may have weaker systems due to limited resources or a less developed tradition of consumer activism. The Directive should be implemented to respect these existing national frameworks while ensuring a minimum level of consumer protection across the EU([Chaudhary, 2005](#)).

The Directive introduces the concept of "extended producer responsibility," which requires manufacturers to assume greater responsibility for the end-of-life management of their products. However, the specific details of these schemes are left to the discretion of each Member State, which may lead to inconsistencies in the application of the Directive and potentially undermine its effectiveness ([Kanamugire & Chimuka, 2014](#)). Clear guidelines from the Commission are needed to ensure a level playing field and prevent regulatory arbitrage.

Careful attention must be paid to potential conflicts with existing EU legislation, such as the Eco-design Directive. While both directives aim to promote sustainable products, their specific requirements may overlap or contradict each other. For example, stricter energy efficiency standards under the Eco-design Directive might inadvertently make products more difficult to repair. Policymakers need to ensure that the two directives are implemented in a coherent and mutually supportive manner ([Giliker, 2016](#)).

6. Legal Challenges and Implementation Issues

Prior to the introduction of the EU Directive, consumer repair rights within the EU were largely governed by Directive 2019/771 on the sale of goods. This directive provides a minimum two-year legal guarantee period during which consumers can seek remedies, including repair, for defective goods.

However, implementing these rights has varied across Member States, often resulting in disparate consumer protection. The new Directive strengthens consumer rights related to repair by working in conjunction with existing consumer protection laws, such as the Sale of Goods Directive (2019/771). While the Sale of Goods Directive provides a minimum two-year legal guarantee period during which consumers can seek remedies, including repair or replacement, for defective goods, the new Directive extends beyond this period by promoting reparability throughout the product's lifespan.

The new EU Directive interacts with existing consumer rights frameworks, particularly those established by Directive 2019/771, by expanding the scope and duration of repair rights. It supplements the existing two-year guarantee period by ensuring that manufacturers make spare parts and repair information available for a longer period, even after the guarantee has expired.

The implementation of the EU Directive faces several legal challenges and potential implementation issues. One key challenge is ensuring effective enforcement of the Directive's provisions across all Member States([Errington & Childe, 2013](#)). Variations in national legal systems and enforcement mechanisms could lead to inconsistencies in applying the Directive, potentially undermining its effectiveness. Furthermore, the Directive's success depends on active consumer awareness and engagement. Many consumers may be unaware of their new repair rights or face practical barriers to accessing repair services. Overcoming these

challenges requires a multi-faceted approach, including robust enforcement mechanisms, consumer education campaigns, and support for independent repair networks.

Another challenge lies in balancing the interests of consumers, manufacturers, and repair service providers. The Directive aims to incentivize manufacturers to design more repairable products, which may require significant investments in product design and manufacturing processes. Some manufacturers may resist these changes, arguing that they could stifle innovation or increase production costs. The Directive requires Member States to establish effective monitoring and enforcing compliance systems, including imposing penalties for non-compliance. However, each Member State is left to determine the specific details of these enforcement mechanisms.

To ensure consistent and effective enforcement across the EU, the Commission should develop guidelines for Member States on best practices for monitoring compliance. Moreover, standardisation of repair procedures is crucial. Standardised diagnostic tools and repair manuals would facilitate the repair process, enabling independent repairers to compete effectively with authorised service centres.

The complexity of modern products, particularly electronic devices, poses a significant challenge to repairability. Many products are designed with proprietary components or software that can only be accessed by authorised repairers ([Lefebvre et al., 2018](#)). This creates a barrier to independent repair and limits consumer choice.

The EU Directive should encourage manufacturers to adopt open standards and provide independent repairers with access to necessary repair information and tools. This could lead to a fragmented enforcement landscape where the level of protection afforded to consumers varies depending on their location within the EU. Another legal challenge relates to interpreting and applying key concepts within the Directive, such as "reasonable cost" for repairs and "reasonable period" for the availability of spare parts. These concepts are inherently subjective and open to interpretation, which could lead to disputes between consumers, manufacturers, and repairers. To address this issue, the Commission should issue clear guidelines on the interpretation of these concepts, providing concrete examples and benchmarks to ensure consistent application across Member States.

The Directive introduces the concept of "extended producer responsibility", and this requires manufacturers to take greater responsibility for the end-of-life management of their products ([Hörnle et al., 2018](#)). However, the specific details of these schemes are left to the discretion of each Member State, which could lead to inconsistencies in the application of the Directive and potentially undermine its effectiveness.

The potential for conflicts with other EU legislation, such as the Eco-design Directive (2009/125/EC), requires careful attention because this directive establishes minimum energy efficiency standards for a wide range of products ([Stevels & Smit, 2019](#)). The Eco-design Directive aims to reduce the environmental impact of products throughout their life cycle, including setting requirements for product design, energy consumption, and durability ([Heyen et al., 2017](#)). It complements the new Directive by ensuring that products are designed to be more durable and energy-efficient from the outset.

6. Economic and Environmental Impacts

Assess the economic and environmental implications of the Directive, taking into account its potential impacts on businesses, consumers, and the environment. The Directive's economic impact is multifaceted, affecting businesses, consumers, and the repair sector in various ways. For businesses, the Directive introduces new obligations and costs related to the availability of spare parts, repair information, and product design for repairability ([Grigore & Kifor, 2021](#)). Manufacturers may need to invest in redesigning their products to make them easier to

repair and establish systems for providing spare parts and repair information to consumers and independent repairers. These costs could be significant, particularly for smaller businesses that lack the resources to adapt quickly.

However, the Directive also presents opportunities for businesses. The increased demand for repairs could stimulate the growth of the repair sector, creating new job opportunities and business prospects for independent repairers and specialised service providers. Moreover, businesses that adopt the principles of repairability and sustainability can gain a competitive advantage, attracting environmentally conscious consumers who are willing to pay more for products designed to last.

On the consumer side, the Directive is expected to result in long-term cost savings. By making products more durable and repairable, consumers can avoid the need to replace them as frequently, reducing their overall expenditure on goods. The availability of spare parts and repair information will also empower consumers to repair their products themselves or seek out independent repair services, potentially saving money on costly manufacturer repairs. However, the initial cost of more durable and repairable products may be higher, which could be a barrier for some consumers.

The principles of the circular economy are crucial for achieving the Directive's goals because of their potential to promote efficient resource utilisation and minimise the environmental burdens associated with conventional linear production and consumption models (Ruiz et al., 2019). By emphasising product durability, repairability, and reuse, the Directive aligns with the circular economy's core tenets, encouraging a shift away from the "take-make-dispose" approach. The paradigm of regeneration is obvious in maintenance and retirement processes, where products are repaired, reused and disassembled (Diez et al., 2016).

7. Conclusion

The EU Directive on reducing, reusing and repairing represents a significant step forward in promoting sustainable consumption and waste reduction within the European Union. By granting consumers enforceable rights to product repair, the Directive addresses critical market shortcomings, incentivising manufacturers to design more durable and repairable products while empowering consumers to extend the lifespan of their goods.

The detailed legal analysis reveals the Directive's multifaceted nature, encompassing key aspects such as the scope of consumer rights, obligations imposed on manufacturers and sellers, and enforcement mechanisms. The Directive introduces a new legal framework that prioritises repair over replacement, challenging the prevailing culture of disposability that has contributed to environmental degradation and resource depletion (Michelini et al., 2017).

Moreover, the Directive's emphasis on access to spare parts, repair information, and independent repair networks is crucial for fostering a competitive and consumer-friendly repair market. This can lead to more significant innovation in the repair sector and more affordable repair options for consumers.

Looking ahead, the successful implementation of the Directive will require ongoing collaboration among policymakers, businesses, consumers, and other stakeholders.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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ENHANCING CIRCULAR ECONOMY THROUGH NATURE-BASED SOLUTIONS IN HIGHER EDUCATION

DOI: 10.26341/issn.2241-4010-2025-16a-4-K02225

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Abstract

Circular economy entails core sustainability concepts, such as reducing waste, preserving the environment and recycling goods in order to promote sustainable development. Nature-based Solutions (NBS) have been identified as tools for protecting biodiversity and natural resources, thus supporting healthier ecosystems and leading to sustainable development. NBS includes the concept of circular economy, as by protecting and sustainably managing natural resources, natural cycles are enhanced and promoted. Both concepts lie in the heart of the European Commission's efforts to strengthen environmental protection and economic development at the European and global level. Higher Education Institutions (HEIs) as primary agencies of education and training, which are to deliver and promote Sustainable Development Goals (SDGs), are called to integrate those concepts not only into their everyday campus practices but in their courses and academic curricula as well.

This paper aims to explore the level of integration of those concepts in the Greek HEIs by examining and analyzing policies, strategies and initiatives at the campus level as well as by exploring relevant university curricula. It highlights the importance of interdisciplinary cooperation and innovative learning methods in order to leverage the integration of circular economy by implementing NBS in HEIs.

Key words: *Circular Economy, Nature-based Solutions, Higher Education Institutions, sustainable development*

Introduction

Our societies need to take urgent action to address current environmental concerns, with climate change and biodiversity loss being the most pressing ones. International community's efforts have led to the adoption of the Sustainable Development Goals (SDGs), as tools to achieve the overarching goal of sustainable development (UNGA, 2015).

SDGs include inter alia the target of "Quality Education" (SDG 4) "that will allow many other Sustainable Development Goals (SDGs) to be achieved" (UNGA, 2015). Quality education is crucial for achieving sustainable development (Laurie R. et al., 2016) and current research focuses especially on the role of higher education institutes in promoting sustainable development and transforming their curricula towards sustainability and eco-citizenship (Lozano R. et al., 2013, Filho W. et al. 2019, Serafini et al. 2022). This transformation requires several reforms and integration of new concepts in academic teaching, such as the concepts of circular economy, nature-based solutions (NBS) and eco-citizenship, as well as new pedagogical approaches (Lozano R. et al. 2017, Martín-Garin A., 2021).

This article explores the integration of the concept of circular economy into higher education institutions (HEIs) programs, especially through other environmental concepts and particularly nature-based solutions (NBS). It aims at highlighting NBS and circular economy education programs in Greece and discussing the integration of these concepts in higher

education institutions' curricula and campus policies. It emphasizes the need for state and institutional support for promoting innovative teaching programmes as well as the significance of interdisciplinary cooperation towards a greener and more inclusive higher education.

The paper is structured as follows: after the introductory part, the second part clarifies the research question and explains the methodology. Presentation of the research findings follows regarding the integration of NBS and circular economy in Greek universities' curricula and courses. Finally, conclusions and recommendations for future research are presented.

Research Question and Methodology of Research

The concepts of Nature-Based Solutions (NBS) and circular economy have gained a lot of leverage in the last few years because of their significant potential to address environmental (as well as social) challenges and their dynamic in fostering global efforts towards biodiversity conservation and restoration and adapting to climate change.

According to the European Commission's definition, NBS are 'solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience; such solutions bring more, and additional diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions' (European Commission: European Research Executive Agency 2024). In literature, NBS have been identified as means of natural solutions which may address both environmental protection and social challenges (Viti M., 2022). Nature-based Solutions (NBS) are critical tools for restoring biodiversity and protecting natural resources, thus fostering healthier ecosystems and a green transition.

The United Nations Environmental Assembly (UNEP 2019) has attempted a definition of circular economy, or maybe "a shared understanding of some of its basic principles" (United Nations Economist Network, 2022). The United Nations Environmental Assembly has defined circular economy as "one of the current sustainable economic models, in which products and materials are designed in such a way that they can be reused, remanufactured, recycled or recovered (4-R) and thus maintained in the economy for as long as possible, along with the resources of which they are made, and the generation of waste, especially hazardous waste, is avoided or minimized, and greenhouse gas emissions are prevented or reduced" (UNEP 2019).

Circular economy entails sustainability concepts such as reducing waste, preserving the environment and recycling goods, as well as "sustainable management of natural resources, the closing of material loops, the preservation of natural capital, and circular consumption and production behaviours in the economy in order to promote sustainable development" (United Nations Economist Network, 2022). Nature-based Solutions (NBS) include the concept of circular economy, as by protecting and sustainably managing natural resources, natural cycles are enhanced and promoted.

Both concepts lie in the heart of the European Commission's efforts to strengthen environmental protection and economic development at the European and global level. The economic benefits of nature-based solutions (NBS) and a nature-based economic approach can act in a complementary way to achieving circular economy (European Commission Knowledge Centre for Biodiversity, 2023).

Following these new targets and goals at the global as well as the EU level, and as Higher Education Institutions (HEIs) are considered primary agencies of education and training, they are expected to deliver and promote Sustainable Development Goals (SDGs) and SDG 4 in particular (Chankseliani, M., McCowan, T. 2021, McCowan T., 2023). Thus, higher

education institutions are called to integrate circular economy, nature-based solutions and other sustainability concepts not only into their everyday campus practices (Nunes, B. T. et al., 2018) but in their courses and academic curricula as well (Stefanakis, A. I. et al., 2021). Integrating nature-based solutions and circular economy (Renfors, S.-M., 2024) into higher education institutions is a critical parameter towards sustainable transition (Salas, D. A. et al., 2021, Vergani F., 2024).

Therefore, the research question of this article is formulated in order to explore the current projects, programmes and initiatives which foster integration of NBS and circular economy in Greek universities and the possible barriers, challenges and obstacles which could impede educators in higher education institutions to integrate nature-based solutions and circular economy concepts in their courses and university curricula.

In order to explore the level of integration of NBS in Greek universities, the author of this article has elaborated previous desk research and field work in the framework of the Erasmus Plus Project "Integrating Nature-Based Solutions into Higher Education towards exploiting the transformative potential of Social Economy for a green and inclusive future" (acronym: "SEgoesGreen"), funded by the European Union (2022-1-PL01-KA220-HED-000087149) along with the rest of the partners of the project, aiming at identifying different best practices on nature-based solutions in different EU countries. The goal of the project was to support university faculties to integrate sustainability teaching within their courses and curricula with a specific focus on exploiting the educational potential of Nature-Based Solutions. SEgoesGreen aimed at a) offering flexible training tools and resources to HEIs educators, b) exploring the state of the art in NBS education, c) identifying any barriers against the integration of NBS in HEIs, d) promoting students' interest in green education and eco-citizenship.

The research conducted in the framework of the project has explored the integration of NBS in universities and academic institutions in five European countries, namely Poland, Croatia, Greece, Cyprus and Portugal (Murzyn, D., et al. 2024). Desk research aimed at identifying the best practices in integrating NBS in the abovementioned countries and a combination of research methods has been used, such as best practices analysis, interviews with stakeholders and constructed discussions in small groups of professionals, educators, and other stakeholders. The author has built upon the research on nature-based solutions by adding the parameter of circular economy and focusing explicitly on the Greek higher education institutions.

Research Findings

The first part of the research in the framework of the SEgoesGreen project identified a set of best practices in Greece by using specific parameters such as "the country and city of implementation, the field of study, the educational institution, the level of study, course(s), NBS category, topic of the best practice, its specific objectives, the results or impact achieved, stakeholders involved, pedagogical approaches utilised and any significant considerations pertinent to the best practice" ((Murzyn, D., et al. 2024).

Building upon the research conducted on Nature-based Solutions within the SEgoesGreen project, this article explored the level of integration of the concept of circular economy in Greek higher education institutions' courses and curricula and focused particularly on the synergy creation between nature-based solutions and circular economy.

The first findings of this research on the integration of circular economy in Greek higher education institutions demonstrate that circular economy is gradually being integrated into Greek universities. However, the level of implementation varies across institutions, programmes and levels of tertiary education (master programmes, undergraduate programmes

etc.). The integration of circular economy principles in Greek universities may be identified in courses and curriculum development, in research projects and initiatives, as well as in other sustainability projects, and collaborations with external stakeholders.

The most important methods and tools for integrating circular economy in Greek higher education institutions are first of all, through curriculum and academic programmes. During desk research it was found that Greek universities have started including the concept of circular economy, and the principles related to it, into their academic courses and programmes. Thus, one may find a number of specialized courses, modules, and entire degree programs, which focus on sustainability, environmental management, circular economy and sustainable consumption. For instance, the University of West Attica¹ and the Aristotle University of Thessaloniki² are currently offering courses related to sustainability and circular economy as part of their environmental sciences, engineering or business programs. Similarly, the Technical University of Crete (TUC), offers a master's program for students on the topics of Circular Economy and Bioeconomy³ and generally it is a university very much involved in sustainability research, trying to integrate the concept of circular economy into courses that examine sustainability and resource management.

Apart from the specialized programmed and courses, the Greek higher education institutions foster circular economy through research and collaborations with other universities and research centers abroad. They participate in and/or lead research projects that focus on circular economy (i.e. funded projects⁴ or international partnerships and collaborations⁵). Greek universities have also been very active in initiating or supporting respective research initiatives on relevant topics. Areas of focus include waste management, renewable resources, sustainable production processes, and others. The Athens University of Economics and Business⁶ and NTUA⁷ (National Technical University of Athens), actively participate in European and international research initiatives related to the circular economy, addressing issues like recycling, eco-design, and green technology. Greek HEIs also cooperate with research centers: for instance the Centre for Renewable Energy Sources⁸ (CRES) in Greece focuses on developing sustainable energy solutions, which is closely tied to circular economy principles.

In addition, the Greek HEIs have developed and/or are developing collaboration schemes with the private sector and relevant government agencies. Almost all Greek universities are working closely with local businesses, municipalities, and governmental organizations to pilot circular economy practices. By developing such collaboration schemes, higher education institutions in Greece can offer their students real-world application of circular economy principles in various sectors of the economy, such as waste management, agriculture, and manufacturing. An example of this process is the collaboration of the Harokopio University of Athens with the Hellenic Recycling Agency⁹ in the integrated LIFE project LIFE-IP CEI-Greece which aims to contribute towards the implementation of the National Waste

¹ MSc "Circular Economy and Sustainability Strategies", <https://msc-circular.uniwa.gr/>

² Elective course on "Waste treatment and circular economy (sustainability management and circular economy), <https://qa.auth.gr/en/class/1/600216145>

³ <https://www.tuc.gr/en/university/in-the-spotlight/item/tuc-participates-in-masters-program-on-circular-economy-and-bioeconomy>

⁴ For example: BIOREGIO Interreg at <https://fodsakm.gr/en/projects/other-programs/bioregio/>

⁵ COST Action CA21103 Implementation of Circular Economy in the Built Environment at <https://circularb.eu/>, CA22124 – EU Circular Economy Network for All: Consumer Protection through reducing, reusing, repairing (ECO4ALL) at <https://eco4all.org/>

⁶ For example: <https://www.dept.aueb.gr/en/ReSEES/content/circular-economy-balkan-countries>

⁷ For example: <https://unescochair.simor.ntua.gr/>,

⁸ Centre for Renewable Energy Sources at http://www.cres.gr/kape/index_eng.htm

⁹ <https://circulargreece.gr/partners/>

Management Plan, the National Waste Prevention Plan and the National Strategy for Circular Economy. Other university departments work with local waste management organizations and municipal authorities in pilot projects that explore sustainable waste processing and resource management.

Another aspect of the Greek HEIs' engagement in circular economy and Nature-based Solutions are the initiatives developed for promoting sustainability and "greening" the universities' campuses. For instance the University of Patras¹⁰ has established the Sustainable-Green University Committee which promoted a combination of nature-based solutions and circular economy practices, such as adopting circular economy solutions by promoting resource reuse practices, redesigning of the campus map to include new green zones planting and transplanting of trees, green routes for pedestrians and cyclists, procurement of electric and conventional bicycles, creation of a parking base and photovoltaic charging system, etc., with the aim to provide quality living, sports and recreation to all members of the community and others. The higher education institutions in Greece are trying to develop and adopt circular economy principles in their everyday operations, through initiatives such as:

- **Waste minimization:** The Greek universities have recycling programs in place for paper, plastic, and electronic waste. Some of them also encourage cycling within campus grounds.
- **Energy efficiency:** Universities are investing in green energy and energy-saving systems, which align with the goals of circular economy and sustainability by reducing consumption and minimizing their environmental footprint.
- **Green infrastructure:** Campuses also embrace circular economy practices through nature-based solutions by integrating sustainable infrastructure, such as green roofs, rainwater harvesting systems, and energy-efficient buildings.

Last but not least, the Greek HEIs are promoting and taking measures to enhance student and community engagement. The main vehicle towards student and local communities' engagement is the uptaking of initiatives which raise awareness both within the academic community and beyond it. These efforts include organizing conferences, workshops, and seminars on sustainability, nature-based solutions and circular economy, such as hackathons and innovation challenges related to circular solutions, student-led sustainability projects, i.e. organizing zero-waste events or supporting the use of shared mobility (bike-sharing programs) on campuses.

Conclusions and Future Research

This article provided a study on the emerging field of promoting circular economy through nature-based solutions (NBS) in higher education institutions focusing on the Greek universities. It offered insights into the ways in which Higher Education Institutions develop and support effective ways for integrating circular economy and NBS in their settings. The data and information collected have been synthesized in a study that elaborated on how circular economy concepts and practices may be further strengthened through the adoption of NBS solutions in Greek universities.

The study conducted was based on desk research and data collection from Greek higher education institutions and can be further developed to include surveys and interviews with the academic community (researchers, educators, students, management) and other stakeholders which may foster the integration of circular economy through applying nature-based solutions in the Greek universities' curricula and in the campuses, as well.

¹⁰<https://www.upatras.gr/en/university/sustainability/>

There are certainly several barriers and obstacles that limit the adoption of nature-based solutions and circular economy learning in higher education. The most important challenges are the lack of appropriate state funding, the lack of knowledge and experience within the academic community, especially within educators who are not familiar with these concepts and sometimes the lack of time needed to familiarize and gain knowledge on these topics.

These challenges could be addressed by developing interdisciplinary and multidisciplinary collaboration schemes/partnerships within the academic community and by involving other external stakeholders (including government agencies, the civil society and the private sector) in the whole process. It is crucial for the achievement of sustainable development to promote integration of circular economy principles across all disciplines and university policies and nature-based solutions offer a vehicle for facilitating this integration.

A few recommendations towards this goal could be first of all, to develop a curriculum that will be particularly designed to offer students hands-on project approach and research experience using nature-based solutions. Second, it is crucial to engage students by helping them to develop better awareness about environmental challenges, circular economy and the potential contribution of nature-based solutions. Furthermore, both educators and students need to be trained and build specific skills in order to take action towards sustainable transition and transformation of the Greek higher education institutions, by endorsing circular economy and NBS concepts. Eco-citizenship approaches in Greek academic institutions may only be promoted by fostering behavioural transformation of students, researchers, educators, professors, employees and the academic community in general. Engaging experts and academics from different fields/disciplines shall offer a new dimension of the NBS/circular economy synergy.

In conclusion there is great potential for Greek universities to serve as key players in promoting circular economy strategies, given their research capabilities, innovation culture, and position in the broader European sustainability landscape. By integrating circular economy practices, such as reusing materials or designing products for longer life cycles, with nature-based solutions, new systems are created that have the potential to regenerate both human-made and natural environments. Universities can offer their students an advanced approach in sustainability transition by exploring real world problems and promoting the Sustainable Development Goals. The outcome of this process will be building resilience and sustainability and enhancing a harmonious relationship between human activities and nature.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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THE EU's PROBABILISTIC DEPENDENCY STRUCTURE TOWARDS THE GOAL OF A CIRCULAR ECONOMY

DOI: 10.26341/issn.2241-4010-2025-16a-5-K02227

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Abstract

This paper explores the interdependencies among key circular economy (CE) indicators across the European Union using data from the EUROSTAT Monitoring Framework. The dataset spans the years 2012–2021 and includes information from 27 EU member states, covering thematic areas such as production and consumption, competitiveness and innovation, and global sustainability and resilience. A Bayesian network is employed to learn the probabilistic structure among seven selected indicators, revealing conditional relationships that characterize the dynamics of the EU's circular economy. Scenario analysis shows that increased consumption levels are associated with higher material use and waste generation, alongside a notable rise in patent activity related to recycling—suggesting that environmental pressure may stimulate innovation. These findings highlight the value of understanding indicator interdependencies to support evidence-based policymaking and guide the EU's transition toward a more circular and resilient economy.

Key words: *Circular Economy, Bayesian networks, Probabilistic dependency, CE indicators, EUROSTAT, European Union*

Introduction

The EU's aim to achieve a circular economy over a linear one requires transformative actions targeting countries' policy frameworks, governance structures, and operational practices. These actions must prioritize sustainability, resource efficiency, and innovation across all sectors. Key steps include implementing regulations to support circular business models, enhancing local government capacities for waste management and recycling, and fostering public-private partnerships for sustainable development. However, these actions depend heavily on the economic resilience of the participating countries which in turn depend on the continuous availability of resources for production. This challenge underscores a long-overlooked truth: humanity has only recently come to fully recognize that natural resources are, in fact, finite.

The concept of the circular economy (CE) originated from Boulding's (1966) call for a shift from unlimited resource use to a closed-loop system, recognizing the planet's finite resources. Pearce and Turner (1989) later formalized this idea by introducing the term "circular economy," promoting a circular model over a traditional linear one to enhance economic resilience. Since then, as pointed out by Cinicioglu and Korkmaz Tümer (2024) interest in CE has grown significantly. On that, Merli *et al.* (2018) document the rise in CE-related publications and offer a comprehensive review of the field. Much of this research has been concentrated in Europe and China, where CE has been adopted as public policy. Europe has advanced the agenda through frameworks like the European Green Deal (European Commission, 2019), while China embedded CE into national laws such as the Circular

Economy Promotion Law. Winans *et al.* (2017) emphasize the importance of supportive policies for standardized recycling to encourage industry adoption.

This paper explores the probabilistic dependency structure of EU member states using datasets from the EUROSTAT database, focusing on production & consumption, competitiveness& innovation and global sustainability & resilience. To analyze these relationships, the study employs Bayesian networks, a powerful probabilistic graphical modeling tool that reveals conditional dependencies among the set of selected circular economy indicators. The insights gained from this approach will shed light on the interplay between resource dependency, self-sufficiency, and eco-innovation, offering valuable implications for policymaking and institutional reforms necessary for achieving a circular economy.

The remainder of this paper is structured as follows: In the next section, we present our methodology which will be used as the main tool of our analysis. This is followed by an introduction to the set of indicators obtained from Eurostat database, along with a description of the data cleaning procedures applied on the data set. The subsequent section is devoted on the construction of the Bayesian network and the analysis conducted on it. This includes an exploration of the dependency structure, as well as scenario analysis on it, which provides insights into the interdependencies among EU countries with respect to the circularity indicators. Finally, we conclude the paper by summarizing the key findings and implications.

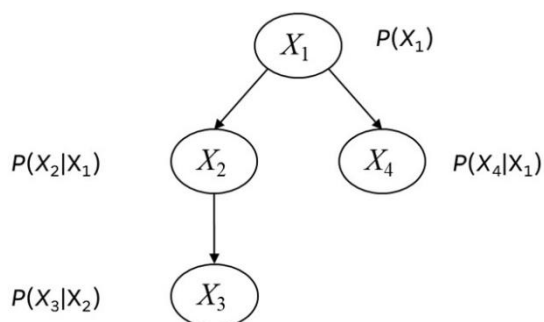
Methodology: Bayesian Networks

Bayesian networks are acyclic probabilistic graphical networks in which variables are represented through nodes and the probabilistic dependencies between the variables are represented through directed arcs. In a Bayesian network (BN) if there is an arc between two variables then the variable from which the arc is pointed is called as the parent variable of the node to which the arc is pointed. Each variable in a Bayesian network $X_1, \dots, X_N$ follows a probability distribution conditioned on its parent variables and the joint probability distribution of the network is formed by the product of these conditional probability distributions as it is shown in Equation 1 below. Each variable in a Bayesian network is conditionally independent given its parents.

$$P(X_1, \dots, X_N) = \prod_{i=1}^N P(X_i | Pa(X_i)) \quad (1)$$

Below in Figure 1 a small Bayesian network with four variables X_1, X_2, X_3 and X_4 which follow the probability distributions $P(X_1)$, $P(X_2 | X_1)$, $P(X_4 | X_1)$ and $P(X_3 | X_2)$ are represented. In this small Bayesian network X_1 is the parent variable of X_2 and X_4 , X_3 is the child variable of X_2 and X_4 is the child variable of X_1 . Notice that in the small BN X_1 stands without any parents with its marginal distribution and therefore is called as to root variable of the network. In BNs there is no limit regarding the parent variables and children that a variable can take. Once an observation(s) for the state(s) of the variables is observed, the BN is updated accordingly, representing the posterior probabilities of the variables in the network. As represented in Figure 1 given below the variables X_3 and X_4 do not possess any children. One of the most important advantages of Bayesian network is that it allows us to use the backpropagation algorithm which ensures that an observation downstream in the network will result in an updating process upstream in the network.

Figure 1. A Bayesian network representation with four variables



The chain rule that is represented in Equation 1 ensures that Bayesian networks are acyclic graphical networks in the sense that if you follow the direction of arcs beginning from one node you cannot close the cycle and cannot end up in your starting node. Another aspect regarding the Bayesian network is that it possesses two different layers, one is the graphical network structure which is represented through the graph and the other is the computational background where the conditional probability distributions of the variables are represented which constitute the parameters of the variables. Consequently, the inference process in Bayesian networks relies on continual application of the Bayesian updating rule. The graphical interface of Bayesian network provides an intuitive appeal and understanding to the audience outside the field and the computational background and inference process ensures the correct demonstration of the joint probability distribution represented by the set of variables in the network.

Bayesian networks are first introduced by Pearl (1985) which later became an important part of artificial intelligence, and its use spread to many different application areas from healthcare, risk assessment, medicine, targeted advertising, competitiveness and innovation, finance, Maritime industry and numerous more. Some examples are as follows: Cinicioglu *et al.* (2024) provide a benchmark procedure for the evaluation of the sovereign risk of countries using Bayesian networks which involves a comprehensive analysis involving several steps conducted comprehensive analysis involving conducted on the BNs for each of the 3-month intervals of the COVID-19 pandemic. Their study illustrates the use of artificial intelligence methods to understand the working mechanism of economic systems. Kyrimi *et al.* (2025) advocate the use of BNs as a healthcare governance tool since it allows for counterfactual reasoning which can be used to assess what would have happened if treatments other than those occurred has been selected. Animah *et al.* (2024) provides a comprehensive literature review on Bayesian network applications in maritime industry emphasizing that uncertainty-related tasks such as accident investigation, reliability prediction and port sustainability are key priorities of the industry, making Bayesian networks a convenient and reliable method for analysis. Cinicioglu *et al.* (2017) explores the interaction between competitiveness and innovation using Bayesian networks and Cinicioglu *et al.* (2012) analyses the competitiveness of automotive industry using Bayesian networks.

As demonstrated, there exists a broad range of application areas for the use of Bayesian networks. This wide variety exemplified above can be further expanded to include even more domains. The reasons are as follows: The intuitive appeal of Bayesian networks makes it a convenient tool accessible to a wider audience. Additionally, their strong computational foundation and ability to update in light of new evidence allow for accurate inference. Moreover, scenario analysis conducted on Bayesian networks enables the researcher to explore the answers of what-if questions, drawing insights from the updated network after

incorporating new evidence(s). Another key advantage is their ability to represent and explore multiple input and output variables, unlike regression analysis, which is limited to a single output variable. This capability significantly enhances their prediction power. Lastly, Bayesian networks support counterfactual reasoning and backward propagation further strengthening their analytical and decision-making capabilities. In the following section, we describe the data set obtained from the EUROSTAT database which will be used for learning the Bayesian network for analysis.

Data Set: EU Circularity Indicators

The Circular economy Action plan was launched in 2020 as a key initiative under the European Green Deal and its goal is set as to transform the EU into a leader in sustainability and resource efficiency. The European Commission's Monitoring Framework, designed to keep track toward a circular economy, collects data of European countries across five thematic sections of production & consumption, waste management, secondary raw materials, competitiveness and innovation and global sustainability and resilience. These thematic sections encompass a total of eleven statistical indicators, some of which also feature sub-indicators. Seven different sub indicators from the EUROSTAT database are selected in this work to infer the probabilistic dependency structure in EU regarding the selected circularity indicators. For that purpose, using the data set obtained from EUROSTAT database between the years of 2012-2021 containing the data of 27 European countries the corresponding Bayesian network will be learned. The list of the countries is provided in Table 1 below which were selected on the basis of availability of data for the time frame considered. The list of the sub indicators selected for analysis are provided in Table 2 following along with their codes as used in the EUROSTAT database.

Table 1. The list of countries included in the data set used to learn the Bayesian network

Belgium (BE)	Estonia (EE)	Hungary (HU)	Malta (MT)	Slovenia (SI)
Bulgaria (BG)	Greece (EL)	Ireland (IE)	Netherlands (NL)	Slovakia (SK)
Cyprus (CY)	Spain (ES)	Italy (IT)	Poland (PL)	United Kingdom (UK)
Czech Republic (CY)	Finland (FI)	Lithuania (LT)	Portugal (PT)	
Germany (DE)	France (FR)	Luxemburg (LU)	Romania (RO)	
Denmark (DK)	Croatia (HR)	Latvia (LU)	Sweden (SE)	

Table 2. The list of countries included in the data set

Thematic section	Online data code	Indicator name	Sub indicator code	Corresponding sub indicator
Production & Consumption (cei_pc)	pc020	Material footprint	A, T_HAB, TOTAL, RMC	Annual total raw material consumption per inhabitant
	pc050	Generation of plastic packaging waste per capita	A,W150102,GEN,KG_HAB	Annual generation of plastic packaging in kilograms per inhabitant
Competitiveness & Innovation (cei_cie)	cie012	Private investment and gross added value related to CE sectors	A, GVA, PC_GDP	Gross value added on CE per capita
	cie012		A, INV, PC_GDP	Private investment in CE per capita
	cie_020	Patents related to recycling and secondary raw materials	A,Y02W,P_MHAB	Annual number of patents related to waste management per million inhabitants
Global Sustainability and Resilience (cei_gsr)	cei_gsr_010	Consumption footprint	A_SWS_P_HAB	Annual single weighted score per inhabitant
	cei_gsr030	Material import dependency	A_TOTAL_PC	Ratio of imports over direct material inputs

According to the EUROSTAT database, the set of variables used for this study are defined as follows:

Material Footprint (pc020): This indicator measures the global demand for raw materials (biomass, metal ores, non-metallic minerals, and fossil energy materials) that results from consumption and investments by households, governments, and businesses within the EU.

Generation of Plastic Packaging Waste per Capita (pc050): This indicator tracks the amount of plastic waste produced per person, specifically focusing on packaging materials. Packaging, in this context, refers to any material used to contain, protect, handle, deliver, or present goods throughout their lifecycle, from raw material to consumer. It also includes non-returnable packaging items.

Private Investment and Gross Added Value Related to Circular Economy Sectors (cie012): This indicator assesses the financial investments and value added by private sectors that are directly involved in circular economy activities. It reflects the economic contributions from industries focused on sustainability, recycling, and the reuse of materials.

Patents Related to Recycling and Secondary Raw Materials (cie_020): This indicator counts the number of patents issued that are related to recycling technologies and secondary raw materials. These patents are categorized using the Cooperative Patent Classification (CPC), focusing on innovations that improve recycling processes or create new uses for secondary raw materials.

Consumption Footprint (cei_gsr_010): The consumption footprint measures the environmental impacts of consumption in the EU and its member states. It combines data on

how intensely products are consumed with the environmental effects of producing these goods, helping to assess the overall sustainability of consumption patterns.

Material Import Dependency (cei_gsr_030): This indicator calculates the EU's reliance on imported materials by comparing the volume of material imports to direct material inputs (DMI). It is expressed as a percentage, highlighting how much the EU depends on external sources for its raw materials.

The data set obtained from EUROSTAT database constitutes 10 years of annual data for the twenty seven countries listed in Table 1. This data set is transformed into a form where a country's data for each year corresponds to a line, resulting in 270 observations for the seven variables given in Table 2. Since the variables used in this study use different range of values all the variables are discretized using hierarchical discretization technique. Hierarchical discretization is an unsupervised method that begins with one bin per record and merges bins with the smallest mean differences until the desired number of states is reached (Cinicioglu *et al.*, 2024). Accordingly, each variable is discretized with five states where the state beginning *s1* refers to the lowest values for that variable and the state beginning as *s5* refers to the state referring to the highest values of that variable. In the following section the discretized data set will be utilized for learning the BN.

Bayesian Network Analysis:

Exploring Dependency Structures via Bayesian Network

Using the discretized data set described in the previous section we will learn the corresponding Bayesian network demonstrating the dependency structure between the circular economy indicators selected. For learning the structure of the Bayesian network from the data, Bayesian search algorithm is employed which uses the hill-climbing structure with random starts. The Bayesian search algorithm identifies the most probable Bayesian Network (BN) structure G given the data D by maximizing the log-likelihood scoring function shown below. In this context, n denotes the number of variables in the BN, q_i represents the number of configurations of the i th variable's parent set, and r_i indicates the number of categories (or states) of the i th variable (Bouckaert, 1995). The terms N_{ijk} and N_{ij} correspond to the number of instances in the dataset D , where N_{ij} is the marginal count over the states k of the variable.

$$LL(G | D) = \sum_{i=1}^n \sum_{j=1}^{q_i} \sum_{k=1}^{r_i} N_{ijk} \log \left(\frac{N_{ijk}}{N_{ij}} \right) \quad (2)$$

Once the structure learning of the Bayesian Network (BN) is completed, the parameters of the variables are estimated using the Expectation-Maximization (EM) algorithm (Dempster *et al.*, 1977; Lauritzen, 1995). This algorithm follows an iterative process to estimate the conditional probability tables of the variables, aiming to maximize the likelihood of the observed data given the network model.

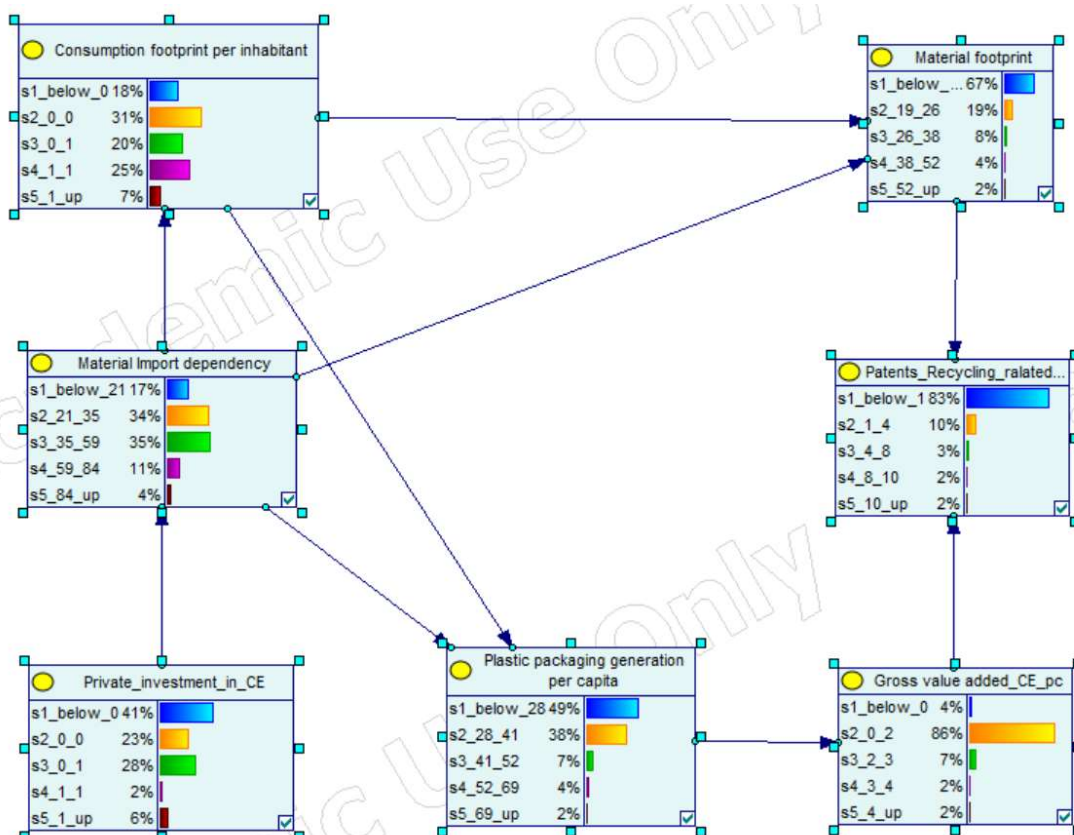
Figure 2 below illustrates the Bayesian network structure learned directly from the dataset. Each node in the network represents a variable, and alongside these nodes, marginal probabilities for each distinct state are displayed, providing clear insight into the distribution and trends of each variable across the data. For example, consider the node labeled "Patents related to Recycling," which reflects the annual count of patents filed per million inhabitants in relation to waste management and recycling technologies. Observing the probabilities, we

note that state s_1 , representing the lowest category (below a value of 1), holds a substantial marginal probability of 83%. This significant finding indicates that, across most European countries examined during the ten-year span covered by the data, innovation and patent activity in recycling-related technologies remain strikingly limited. Given the context where a higher number of patents would indicate more robust innovative efforts and potential advancement towards circular economy goals, the observed concentration in the lowest patent state clearly highlights a notable gap in scientific and technological developments. Consequently, this analysis reveals a somewhat concerning stagnation in research outputs and innovation, suggesting that the current trajectory of scientific effort dedicated to advancing circular economy practices may not yet be sufficient to meet the ambitious targets envisioned by policy frameworks and sustainability initiatives.

Moreover, as illustrated in Figure 2 below, which shows the Bayesian network structure learned from the data, we observe a direct dependency between “Material import dependency” and both “Material footprint” and “Plastic packaging per capita”. Specifically, “Material import dependency” acts as a parent node to the other two variables. While in a Bayesian network the use of the chain rule and the assumption of conditional independence allows the influence of a variable to extend beyond its immediate children, the presence of an arc between two nodes always indicates a strong dependency structure. In this case, the arcs from “Material import dependency” to the other two variables confirm a substantial direct influence. More generally, wherever an arc is present between two variables in the network, it signals that a significant statistical dependency exists between them.

Another noteworthy observation concerns the variable “Consumption footprint,” which measures the sustainability of consumption by combining product use intensity with the environmental impact of production across EU member states. As illustrated in Figure 2, the marginal probabilities associated with this variable reveal a high degree of variation across its different states, encompassing low, medium, and high consumption profiles. This pattern stands in contrast to most other variables in the Bayesian network, which tend to exhibit one or two dominant states characterized by significantly higher marginal probabilities. Notably, two other variables—“Material import dependency” and “Private investment in the Circular Economy”—also exhibit broader variation across states, though less pronounced than that of “Consumption footprint.” This wider distribution suggests diverse structural conditions and policy environments across EU countries, as well as significant heterogeneity in consumption-related environmental pressures. It also reflects the longitudinal nature of the dataset, which spans a 10-year period during which consumption patterns and related indicators may have shifted considerably. In the following subsection scenario analysis will be conducted which will further shed light in the dependency structure and explain how the realization of different scenarios is changing our inferences regarding the set of variables.

Figure 2. The Bayesian network structure showing the probabilistic dependencies and marginal probabilities of the variables



Scenario Analysis

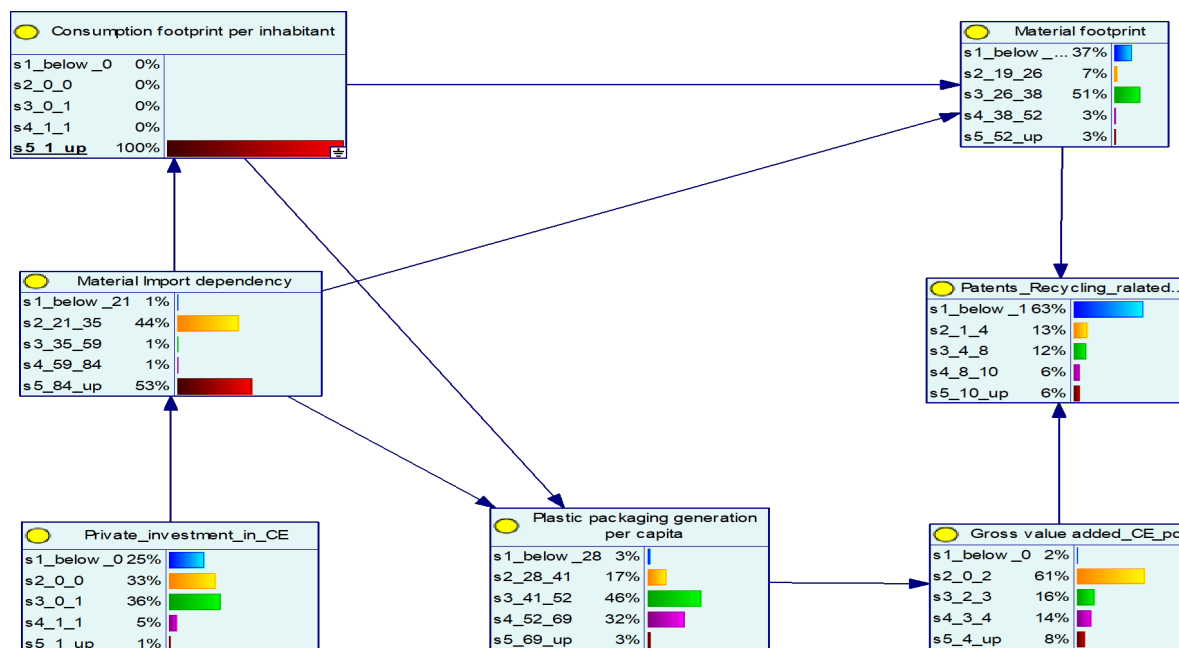
As the next step in our analysis, we apply the evidence propagation functionality of Bayesian networks to perform scenario analysis. This approach involves setting one or more variables to a specific state—effectively assigning a probability of 1 to that state—and then examining how this observation influences the posterior probabilities of other variables throughout the network.

In Figure 3, the variable “Consumption footprint per inhabitant” is observed in its fifth state $s5$, representing the highest level of consumption. By comparing the updated posterior marginal probabilities in Figure 3 with the baseline probabilities presented in Figure 2 (prior to the evidence), we observe a substantial increase in the likelihood of higher states for both “Plastic packaging waste per capita” and “Material footprint.” This result aligns with expectations: as consumption intensifies, both plastic waste generation and material usage tend to rise accordingly.

However, more nuanced insights emerge when examining the response of two other variables—“Material import dependency” and “Patents related to recycling.” Following the observation of high consumption ($s5$), the posterior probabilities for both variables shift towards higher states. This suggests a potential causal chain where increased consumption leads to greater reliance on imported materials, likely due to the depletion or insufficiency of domestic resources. Simultaneously, the rise in the state associated with patent activity implies that as environmental pressure from consumption intensifies, greater scientific and technological efforts are directed toward recycling and waste management solutions.

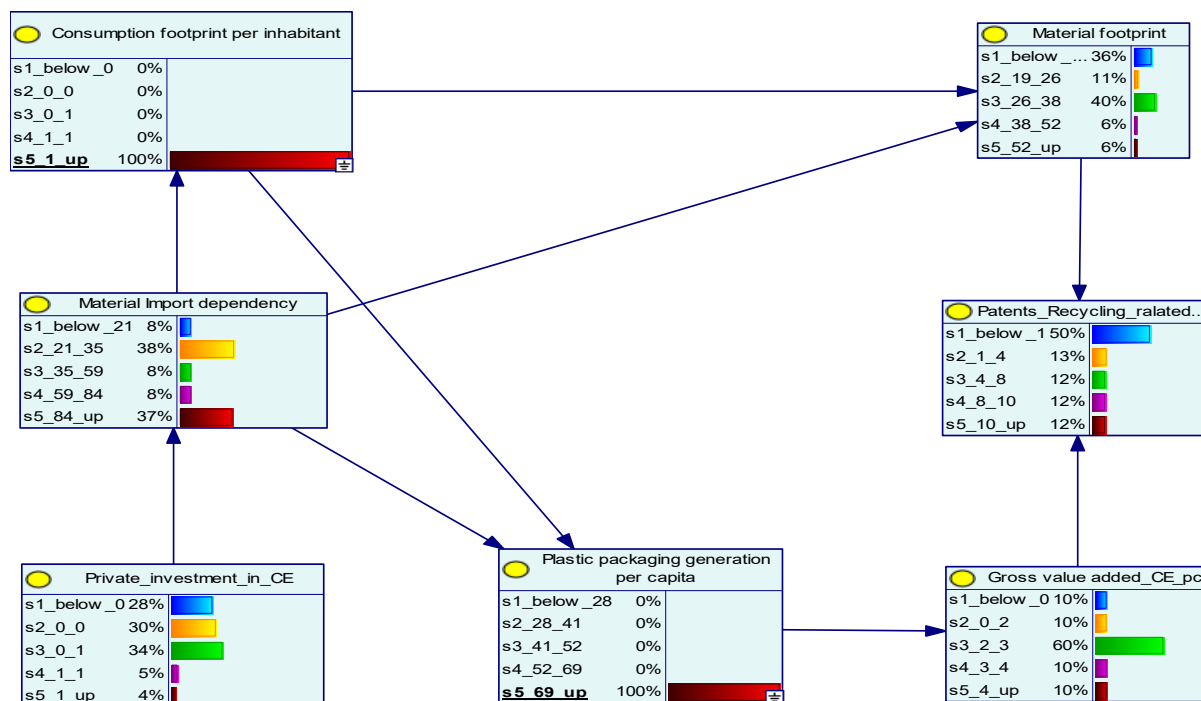
It is important to note, however, that this observed relationship might also reflect structural patterns in which countries with the highest consumption levels are concurrently those investing the most in circular economy research and innovation. Therefore, while the scenario analysis supports intuitive dependencies, it also highlights the potential influence of underlying economic and policy environments that shape both consumption behavior and CE-related advancements.

Figure 3. The updated BN after observing the evidence for P (Consumption footprint per inhabitant = s5|Material Import Dependency)



As the next step of the analysis, we extend our investigation by incorporating additional evidence: namely, that “Plastic packaging generation per capita” is in its fifth state ($s5$), representing the highest level of plastic packaging use which is represented in Figure 4 below. At this stage, both observations—“Consumption Footprint per inhabitant” and “Plastic packaging generation per capita”—are simultaneously set to their fifth state ($s5$), indicating the highest levels for each. Upon entering this evidence, the updated posterior probabilities in the Bayesian network reveal slight improvements in the probabilities of higher-value states for the variables “Patents related to CE” and “Gross value-added CE”. These two indicators reflect positive developments in the context of the circular economy, where higher values represent a more favorable position. Consequently, one may interpret this result to suggest that increased environmental waste can potentially trigger a counter-response by accelerating progress toward circular economy solutions. As represented through these scenario analyses conducted Bayesian networks represent a favorable tool in terms of the policy analyses. In the following section, we summarize our research and conclude.

Figure 4. The updated BN after observing the evidences for P (Consumption footprint per inhabitant = $s5|Material$ Import Dependency) & P (Plastic packaging generation per capita = $s5|Material$ Import Dependency, Consumption footprint per inhabitant = $s5$)



Conclusions

The fast depletion of natural resources and the substantial increase in the amount of waste generated over the years is the result of the reckless consumption pattern that humankind has followed over the last century. As a response to the resource-intensive and environmentally harmful patterns of consumption and production, the circular economy has emerged as a significant and rapidly growing concept. Launched alongside the 2015 UN Agenda for Sustainable Development, the EU's Circular Economy Action Plan and European Green Deal aim to promote sustainable growth, improve resource efficiency, and reach climate neutrality by 2050. On the other hand, for impactful consideration and implementation of circular economy, it is important to apply the right set of Circular economy indicators to assess the current state and guide progress effectively. Moreover, it is also very important to observe the dependency structure between the set of CE indicators used for identification purposes. Understanding how changes in one or more circular economy (CE) indicators affect others is essential for effective policy analysis and responsible legislation. In this study, we use seven CE indicators from the EU Monitoring Framework published by Eurostat, covering the thematic areas of production and consumption, competitiveness and innovation, and global sustainability and resilience. Our analysis shows that "Consumption footprint" varies significantly across EU countries, reflecting diverse environmental pressures. Scenario analysis reveals that higher consumption levels increase plastic waste, material use, and import dependency, while also correlating with greater innovation in recycling. These findings suggest that rising environmental impact may drive circular economy advancements, highlighting the value of Bayesian networks for policy analysis.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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A REVIEW OF GREENWASHING AND CIRCULAR INDUSTRIAL PRACTICES FROM CONSUMER'S PERSPECTIVE

DOI: 10.26341/issn.2241-4010-2025-16a-6-K02231

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Abstract

Conscious consumers prefer green products and actively seek information about companies' circular practices. Demonstrating the role of consumers as key drivers of sustainable consumption is crucial for adequate supply chain management. Different industry branches have different potential for the application of circular processes such as reducing, reusing, and repairing. The paper is based on critical reviews of the relevant literature and aims to emphasize the biggest strengths and benefits for organizations from implementing circular strategies from the consumer's point of view. In this regard, effective transitioning towards sustainable supply chains involves tackling greenwashing. Therefore, it is important to understand to what extent industries are using greenwashing to mislead their stakeholders in the supply chain. It was possible to identify possible solutions to prevent greenwashing across four main dimensions: consumers, relationships between companies and suppliers, certification programs and reporting assessment; and corporate leadership. Due to the significance and validity of the research, the paper highlights the impact of sustainable consumption on the development of greenwashing practices.

Keywords: Circular economy, Customers behavior, Sustainability, Greenwashing, Industry sector, Informational asymmetry

Introduction

There is growth of the production and consumption of circular products. However, greenwashing is a marketing practice of presenting products as environmentally responsible without reasons, which can influence consumer perceptions and attitudes toward the consumption of circular products. In this regard, greenwashing tactics can increase consumer confusion. In the field of sustainability, circular consumption and greenwashing have gained significant attention. The recent study by the European Commission (2022) revealed that 80% of online shops, web pages, and advertisements searched contained green claims such as "green" or "friendly to nature", of which 55.45% were implicit (images, design, color suggesting environmental benefits), 35% were explicit (logos and labels), and about 21% were vague or general environmental claims.

By supporting sustainable businesses and circular consumption, consumers can proactively create more sustainable society. Understanding consumer attitudes to sustainability and sustainable behaviors is a major driver of changing consumer behavior. Despite consumers' willingness to make decisions with sustainability and the environment in mind, consumers often make a trade-off between managing higher prices and making sustainable lifestyle choices. Consumer spending accounts for over a quarter of all emissions and it is the single largest contributor to total greenhouse gas emissions. Some of the consumers most valued sustainable or ethical practices are producing sustainable packaging and products; Reducing waste in manufacturing processes; Committing to ethical working practices; Respect for human rights; Reducing carbon footprint. Some of the main reasons for not adopting a more sustainable lifestyle are high costs, a lack of interest in sustainability, and not having enough information (Deloitte, 2025).

First, this paper contributes to the literature on greenwashing by empirically examining how consumers' perceptions of greenwashing affect circular economy practices. While most previous research has predominantly focused on corporate behavior, this paper is focused to individual consumer perceptions and behaviors, thereby filling research gap. In this regard, accelerating the transition to a circular economy is a policy priority in Europe. With a circularity rate of 11.8% in 2023, Europe consumers have higher proportion of recycled materials than other world regions. Monitoring the circular economy involves tracking material flows environmental degradation. Undertakings and consumers are showing early signs of adopting new business models and consumption patterns, but linear business models continue to prevail (European Environment Agency, 2024). To reduce waste and maximize resource use, circular consumption involves strategies including repairing, recycling, and reusing. On the other hand, greenwashing refers to the practice of businesses using exaggerated or misleading environmental claims to take advantage of customers' growing environmental concerns. Green consumerism is now a politically and economically acceptable and ecologically benign presumption. However, the rise of greenwashing techniques is causing many to question the veracity of businesses' environmental promises (Lopes, Gomes, & Trancoso, 2023).

In according to the main purpose of the paper, paper is organized in the next interconnected sections. Besides Introduction, the second section is devoted to literature review, the third section is related to research results and discussion about the consumer behavior in environmental issues and circular economy. The last section gives concluding remarks and policy recommendations which can ensure adequate regulation in this area.

Literature review

There is several monitoring frameworks currently focused on Europe's circular economy, including the European Commission's Circular Economy Monitoring Framework (CEMF) which provides effective understanding of macrophenomena (Eurostat). On one hand, knowledge creation and innovation are essential pillars to support circularity, so in 2023, almost 4000 scientific articles were published related to circular economy. This shows a growing level of research and innovation activity for circularity (European Environment Agency, 2024). Some studies investigate whether the phenomenon of environmental, social, and governance (ESG) issues has given rise to a new form of greenwashing in a broad sense, not limited to the environmental sphere, but also extended to social and governance issues. Whether companies engaged in the transition to sustainable and to circular models are actually focusing on concrete sustainable actions and less on distorted communication (Todaro, & Torelli, 2024).

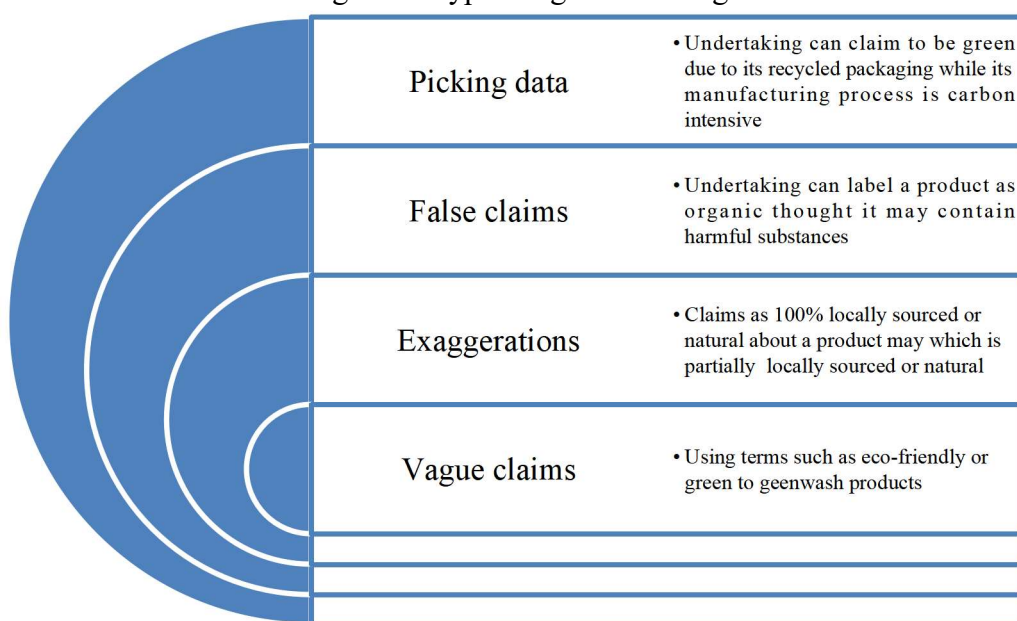
On the other hand, a growing number of consumers are choosing sustainable solutions as environmental awareness grows. Due to this change in customer behavior, marketing and advertising campaigns that highlight how goods and services affect the environment have increased. But not all sustainability claims are as truthful as they appear.

According to a 2020 European Commission investigation, 42% of online environmental claims were either misleading, inflated, or overstated (Carbon Train, 2024).

Environmentalist Jay Westerveld coined the phrase "greenwashing" in 1986 to describe a deceptive practice employed by undertakings to make their goods or services appear more environmentally friendly than they are. This is accomplished by using deceptive marketing techniques to appeal to customers who care about the environment. Therefore, greenwashing is a tactic used by undertakings to profit from the growing demand for eco-friendly goods. Greenwashing also happens when businesses highlight a product's sustainable features to draw attention away from their involvement in ecologically harmful activities. Greenwashing, fake green marketing, or eco-manipulation are terms that refer to the act of making exaggerated or false claims about the environmental benefits of a product or service (Savić, & Erfulanović, 2024). Greenwashing activities use information asymmetry and misleading buyers (Jakubczak & Gotowska, 2018).

There are several examples of greenwashing used by undertakings to encourage the consumption, such as (a) powerful images that companies use related to ecology and nature to convey that they are responsible and environmentally aware; (b) misleading labels claiming that products have environmental benefits; (c) certifications that do not exist on how the products are natural and sustainable; (d) red herrings to try to divert consumers' attention, highlighting aspects of the products as ethical and sustainable; and (e) approximate terminology with self-denomination by companies that their products are green (Safdie, 2023). Figure 1 shows different forms of greenwashing which are most found in industrial practice. It can be product oriented, process oriented, image oriented or can emphasize the environmental facts or combination of the mentioned phenomena.

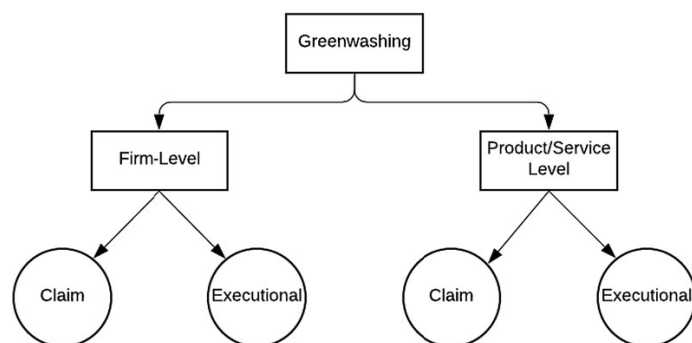
Figure 1. Types of greenwashing



Source: Authors illustration

Two different major classifications of greenwashing: Claim greenwashing and Executional greenwashing. Figure 2 shows the main classifications in the phenomenon of greenwashing.

Figure 2. levels of greenwashing implementation



Source: de Freitas Netto, S. V., Sobral, M. F. F., Ribeiro, A. R. B., & Soares, G. R. D. L. (2020). Concepts and forms of greenwashing: A systematic review. *Environmental Sciences Europe*, 32, 1-12.

Greenwashing refers to the practice of falsely promoting an organization's environmental efforts or spending more resources to promote the organization as green than are spent to actually engage in environmentally sound practices. Recent researches show what extent greenwashing may endanger the industry in addressing challenges related to the implementation of more sustainable circular economy in the context of designing with intention of recycle, reduction of by-products, lower energy consumption, and wise purchase habits (Adamkiewicz, Kochańska, Adamkiewicz, & Łukasik, 2022). In other words, greenwashing is based on highlighting one good practice. Some studies on the consumption theory showed that there is a strong relation between consumption values and the green trust. Eco-labeling influenced the consumer perception as a mark of superior quality, higher value, and an indicator of a lifestyle (Zaidi, et al. 2019).

Greenwashing is more likely in the sectors of consumer staples, energy, industrial, information technology, materials, and utilities, all which impact environmentally sensitive areas. Greenwashing firms have a lower-weighted average cost of capital due to a higher debt-to-capital ratio. They are larger, have higher institutional ownership, and lower dividend yields. On the other hand, greenwashing firms have more ESG-related controversies that can hurt firm revenues and market value, they have higher unsystematic risk, and they have lower dividend yields and return on equity (Gregory, 2024). In greenwashing, there is a complicated link between customer intentions and behavior. Greenwashing positively affects consumers' environmental concerns and their propensity to seek sustainable information. These positively impact consumer intentions toward circular consumption. The findings challenge the traditionally negative perception of greenwashing, suggesting its paradoxical contribution to promoting sustainability. Insights into consumer behavior related to sustainability has practical implications for policymakers in shaping effective circular economy strategies (Lopes, Gomes, & Trancoso, 2023). Some authors outline the predicted effects of greenwashing on green consumer confusion, green perceived risk, and green trust. Decrease in greenwashing and an increase in green initiatives and more transparent marketing are definitively beneficial to promote the customers' green trust. Green marketing is more efficient and can encourage green consumption (Adamkiewicz, Kochańska, Adamkiewicz, & Łukasik, 2022).

Greenwashing poses a significant obstacle to consumer intentions. When perceived, it decreases purchase intention and creates a discrepancy between what customers intend to do and what they do. Greenwashing hurts consumers who care about the environment and are willing to pay more for goods (Testa, et al. 2021), whereas the suppliers who sell the goods

don't honestly address how the items affect the environment (Apaolaza, et al. 2023). Although consumers' determination to combat greenwashing has grown, the results have been unclear (Rotkirch, & Lenk, 2021). Greenwashing can have negative effects on both consumers and the environment, as it can lead to confusion and mistrust among consumers and encourage the production and consumption of products that are not sustainable. It is important for consumers to be aware of greenwashing and to look for evidence to support companies' environmental claims. Additionally, undertakings can take steps to be more transparent and honest in their ecological claims, build consumer trust, and promote truly sustainable practices (Savić, & Frfulanović, 2024).

Numerous studies analyze the direct and indirect practices of greenwashing in the fashion industry and its impact on consumers and highlight the existence of greenwashing in the industry's supply and consumption chain. Greenwashing has a disruptive impact on the fashion industry's supply chain. Some undertake resort to greenwashing by promoting a green image without making substantial environmental or social changes. Therefore, transparency and honesty in the industry's green marketing strategies is *conditio sine qua non* (Badhwar, et al. 2024). Braga, et al. (2019) found that when greenwashing is recognized in a product, its aspects of loyalty, satisfaction, and benefits are lost, and it becomes a product that causes confusion in the consumption of it. Bulut et al. (2021), show that the perception of greenwashing diminishes the effects of environmental concern on green behavior., while Zhang et al. (2018), claim that the perception of greenwashing has a direct negative effect on green purchasing intent.

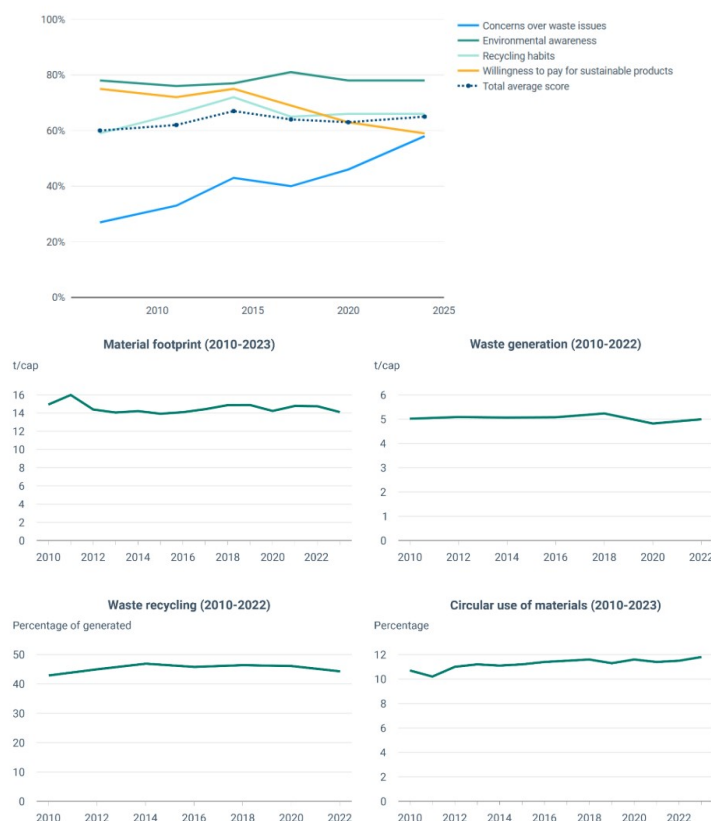
Research results and discussion

Some of the main motivations for greenwashing are: attracting eco-conscious consumers, enhancing brand image, competitive advantage which can lead to customer loyalty and increased market share, meeting regulatory and investor expectations, cost savings due to greenwashing, companies get an image of being environmentally conscious without any costs for implementing real environmental change, and mitigating negative publicity. Greenwashing occurs in a variety of sectors:

- Greenwashing, as used in the automotive industry, is the practice of deceiving consumers about the environmental benefits of cars by inflating efficiency or reducing environmental effect in marketing campaigns.
- When businesses significantly rely on fossil fuels while claiming to be ecologically benign by employing renewable energy sources, this is known as "greenwashing" in the energy sector.
- In the food industry, greenwashing refers to companies making misleading claims about their products, while ignoring sustainability issues in their supply chain. Single-use plastic is not sustainable due to it cannot be recycled 100%, and recycling can never make up for the volume of plastic produced.
- Greenwashing in fashion takes place when brands assert unfounded statements about the eco-friendliness of their clothing collections or methods, disregarding the environmental consequences of fast fashion and inadequate labor practices.
- Certain furniture companies practice greenwashing by misleadingly advertising the environmental advantages of their products, such as asserting the use of sustainable materials or techniques.
- In the banking sector, greenwashing happens when financial institutions promote "green" financial offerings or sustainability efforts while simultaneously funding industries that negatively impact the environment.

Monitoring changes in material flows and waste generation and management is key to assessing the impact that the circular economy has on the environment and consumer behavior. Figure 1 outlines the trends among EU citizens in environmental and circular economy efforts in Europe: the EU's material footprint, waste generation, recycling of total waste and the circular use of materials.

Figure 1. Trends among European union consumer behavior in environmental issues and circular economy



Source: European Environment Agency (2024). Available at:

<https://www.eea.europa.eu/en/analysis/publications/europes-circular-economy-in-facts>,

Accessed on: 20th January 2025.

The material footprint reflects the resources needed to produce the goods and services Europeans consume. It stood at 14.1 tons per capita in 2023 while waste generation was at 5 tons in 2022. The results suggest that high numbers stem from an unsustainable use of resources. If the world consumes resources at the level of the EU, the capacity of the planet to provide these resources will be exceeded. On the other hand, resource productivity in the EU is increasing in 2022, for every kilogram of material consumed in the EU economy, 2.1€/kg worth of production activity was generated. This is more than 2.5 times the global average. The material footprint does not show dramatic changes over time so it can be concluded that circularity has not yet taken off. On the other hand, in the period from 2010 to 2023, the EU economy grew, meaning that we were able to produce more with a stable material input. If major mineral waste is excluded, the EU landfills only 306kg per person annually (2022) and it recycles almost half of the waste it generates. However, recycling is not enough to establish

circularity in Europe. Functional secondary markets are required so that secondary materials find their way back into manufacturing, thus offsetting primary resources.

Data supplied by all stakeholders in the recycling value chain needs to be trustworthy and validated to address the life cycle of waste generation, prevent contamination of recycled materials by hazardous substances, and protect recycling operations from legal risks, financial losses and reputational damage. Transparency in waste data is also a powerful tool against greenwashing (The [Global Waste Management Outlook 2024](#)). Moral hazard in greenwashing is exacerbated by the lack of stringent regulatory frameworks and enforcement mechanisms. When companies realize that the penalties for being caught are minimal or non-existent, they are emboldened to make false or exaggerated environmental claims. This behavior not only damages the reputation of individual brands but also erodes the credibility of the entire organic product industry (Srisathan, & Naruetharadhol, 2025). According to certain studies, a company's market power may be diminished if regulators uncover greenwashing and it becomes widely known.

Conclusion and policy recommendations

Customers should be educated in how to recognize greenwashing so that they can make informed decisions. Businesses that engage in greenwashing leverage the attitudes of customers who are fostering green consumption. The lack of information of consumers favors the development of disinformation practices regarding the alleged pro-ecological activity of companies. It can be concluded that the phenomenon of greenwashing is aimed against green consumption and thus against sustainable development.

Greenwashing is a persistent issue in today's markets. Together, consumers can play an instrumental role in building a more sustainable future by demanding transparency and accountability from companies. Advocating for genuine sustainability and making informed choices can contribute to a healthier planet. The Negative Impact of Greenwashing refers to: consumer distrust, Damage to Genuine Sustainability Efforts, Hindrance to Environmental Progress, regulatory and Legal Consequences. False or misleading environmental claims can lead to fines, penalties, and damage to the company's reputation.

Fundamental shifts in consumption patterns are needed through using low impact products and services or by switching to sharing and product-as-a-service models. Consumption culture is under the strong influence of marketing and needs to change. Consumers' choices are framed by current production systems. The recently adopted eco-design for sustainable products regulation (EU, 2024) is geared to promote safe and sustainable products and was designed for circularity from the outset. One of the main findings highlight the importance of consumer education to prevent misinterpretation of green-related terms and to promote sustainable consumption practices. The question is where the limit in environmental awareness and who should be responsible for it. Consumers and undertakings should work together for a more sustainable industry, and transparent and reliable certification schemes should serve as a guarantee of sustainability.

The objectives of the circular economy must be taken into consideration when enforcing competition law. Customizing competition strategy involves undertakings that use the circular economy approach rather than those that impose the linear economy approach. Competition authorities must exercise caution due to the possibility of greenwashing. In that case these undertakings couldn't have a circular economy friendly approach of the antitrust regulations. When regulators discovered greenwashing and this became public recognized, it can reduce market power and market share of the company (Liu, Wang, & Wang, 2025).

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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IMPLEMENTATION OF THE GLOBAL GATEWAY STRATEGY THROUGH THE NEW EU CIRCULAR ECONOMY RESOURCE CENTRE

DOI: 10.26341/issn.2241-4010-2025-16a-7-K02102

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Abstract

Circular economy is a crucial component within European Green Deal strategy that is continuously emphasized in various policies. Parallel to this, the management technologies on economic circularity related to standardization and digitalization takes on significance. Important to note that a new initiative on the establishment of a EU Circular Economy Resource Center is in process. The initiative prioritizes knowledge, policy-making, and business features as part of the circular economy ecosystem that is necessary to study. In this context, the EU enlargement and integration policy (such as The Global Gateway) refers to these priorities; that means the circular economy can be considered as a research object within the implementation of the Global Gateway and the development of the Circular Economy Resource Center.

The paper investigates the circular economy management ecosystem in the framework of the knowledge-driven, sustainability-oriented, and technology-based policy-making. Green deal, circularity approaches and bio-economy that are important components of EU policies are discussed within EU Circular Economy Resource Centre. In the paper, the policy interoperability with non-EU countries, which are interconnected with EU through strong documentary base, are considered. Integration of partners from geographical large areas like Neighborhood countries, Asia, Africa and Latin America through EU circular economy know-how, is a completely new policy that targeted networking rather than dependence. In this paper the peculiarities of this approach also is considered as a soft policy that brings common benefit.

The achievement of this interdisciplinary research is related to conceptualization of field-related policy documents, regulations, and cross-border cooperation in the circular economy

within sustainable development. In general, local initiatives contributing global tendencies on sustainability through circular technologies is the main conclusion of the research.

Key words: *The Global Gateway, circular economy, green deal, bio-economy, technology*

Introduction

The Directorate-General for International Partnerships (DG INTPA), - which is responsible for formulating the EU's international partnership and development policy, with the ultimate goal to reduce poverty, ensure sustainable development, and promote democracy, human rights, and the rule of law across the world, - established the EU Circular Economy Resource Center (hereafter: CER Center) in 2024. The establishment of the CER Center under the Global Gateway strategy will facilitate peer-to-peer exchanges and partnerships between EU and third-country stakeholders, fostering the uptake of sound circular economy policies and business models worldwide. Additionally, the CER Center's activities align with the objectives of the Circular Economy Action Plan (CEAP) which aims to reduce consumption footprints and double Europe's circular material use rate within the next decade, in line with the goals of the European Green Deal. The aim of this paper is to explore the matching activities between the Global Gateway and the CER Centre, considering the European Green Deal and the New Circular Economy Action Plan.

The bio-economy and digital monitoring are another important directions of circularity and green agenda that are discussed in the study as a part of the CER Center's activity deriving from the Global Gateway implementation principles and priorities. Interdisciplinary specification of bio-economy related to energy, food, agriculture, forestry, and other sectors, as well as digitalization agenda for monitoring, are core components of the research promoting activities with the EU partner countries.

Waste electrical and electronic equipment (WEEE) is one of the fastest growing waste streams in the Union, currently growing by 2 % per year, resulting in severe risk for both human health and the environment, if not properly treated. Circular models such as reuse, repair or remanufacturing of small consumer electronics, as well as recycling the precious and critical raw materials contained in them, therefore contribute to waste prevention by reintroducing products, components, and secondary raw materials into the economy. Applying circularity principles to the entire lifecycle and extending longevity of small consumer electronics can therefore lead to significant benefits in terms of resource efficiency, decarbonization, and depollution, and in supporting a market for secondary raw materials. The Communication from the Commission of 2019 related to the European Green Deal highlights that the transition to a circular economy must focus on resource-intensive sectors such as the electronics sector.

Among the relevant actions proposed, was an assessment of the benefits of supporting take-back schemes to incentivize the return of unwanted devices, such as mobile phones, tablets and chargers (EU Recommendation 2023/2585). This is further detailed in the Commission Communication of 2020 on Circular Economy Action Plan, which calls for improving the collection and treatment of WEEE including by exploring options for take-back schemes to return used and waste mobile phones, tablets, and chargers.

The Directive 2012/19/EU on WEEE lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste from electrical and electronic equipment (WEEE) and by reducing overall impacts of resource use and improving the efficiency of such use (EU Directive 2012/19/EU on WEEE).

It is also necessary to update Union law on the management of waste batteries and to take measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste, by reducing the impact of resource use and by improving resource efficiency. Such measures are crucial for the transition to a circular and climate-neutral economy and toxic-free environment, and for the Union's long-term competitiveness and strategic autonomy. They can create important economic opportunities, increasing synergies between the circular economy and energy, climate, transport, industry and research policies, and protecting the environment and reducing greenhouse gas emissions (EU Regulation 2023/1542).

In general, the study concentrates on the CER Centre's activity derived by the Global Gateway logic within green deal, circular economy action plan, and bio-economy. However, there is a future research topic in this framework that is related to WEEE.

Key Objectives of the Global Gateway that Align with the Green Deal

The Global Gateway is an EU initiative designed to enhance global partnerships and drive sustainable investments, particularly in areas such as infrastructure, technology, and climate action. Key objectives of the Global Gateway that align with the Green Deal include:

- **Promoting green infrastructure and technology:** This includes supporting renewable energy projects, sustainable transportation, and digital technologies that reduce environmental impact. The Green Deal focuses on ensuring that all new infrastructure supports sustainability.
- **Climate resilience:** The Global Gateway aims to support developing countries in becoming more climate-resilient, particularly through green technologies, climate-smart agriculture, and infrastructure improvements aligned with the Green Deal's goal to reduce carbon emissions.
- **Sustainable development:** The initiative emphasizes investing in projects that meet the social, environmental, and economic needs of the Global South, ensuring projects are aligned with environmental sustainability goals.
- **Decarbonizing economies:** The Global Gateway focuses on initiatives that support a transition to cleaner energy, reduction of greenhouse gas emissions, and decarbonization of industries, which is central to the EU Green Deal's objectives for a climate-neutral economy by 2050.

All the above-mentioned components are related to the CER Center's Circular Economy Labs, in particular, the Promoting green infrastructure and technology can be considered within Business Lab, Climate resilience and sustainable development within Knowledge Lab, and Decarbonizing economies within Policy Lab.

The other focus of the study is to highlight the assessment of the environmental, social, and economic impacts of the Global Gateway that could be emphasized in the framework of CER Center. Exploring the documentary base such as regulations, directives, and policy papers, there is outlined the main directions of impact of the Global Gateway initiative:

- **Environmental Impact Assessment (EIA):** This process helps evaluate the potential environmental consequences of the projects funded under the Global Gateway, ensuring that they align with the EU's green policies, such as minimizing biodiversity loss, reducing emissions, and supporting circular economies.
- **Social Impact Assessment (SIA):** This includes understanding how projects affect local communities, including issues like access to clean energy, job creation, and human rights. The focus is on social inclusivity and the improvement of livelihoods.

- **Economic Impact Analysis:** This can be measured by assessing the economic benefits of investments, such as job creation, infrastructure development, and economic growth, alongside long-term impacts such as the fostering of green industries and sustainable trade partnerships.
- **Monitoring and evaluation:** Ongoing tracking of each project's social, economic, and environmental outcomes is necessary for adaptive management and ensuring alignment with the Green Deal.

These directions are a profound base on bioeconomy that can be considered as a target for the CER Center's activity. Being a combination model of economy including biodiversity, sustainable development and circularity, bioeconomy can be a driver of the CER Centre.

There are defined also the Global Gateway implementation strategies and challenges in this study. The strategies are discussed as follows.

- **Partnership with local governments and stakeholders:** Ensuring the active involvement of local governments, NGOs, businesses, and communities is essential for success. This also includes aligning with local regulatory frameworks and needs.
- **Sustainability-focused investments:** Encouraging investments that prioritize long-term sustainability, which includes environmental protection, social equity, and economic benefits. The EU aims to create a green investment pipeline that follows the EU's green taxonomy and standards.
- **Technology transfer and capacity building:** Supporting countries with the necessary technology and expertise to implement the Green Deal objectives, focusing on renewable energy, energy efficiency, and digital infrastructure.
- **Funding mechanisms:** Mobilizing public and private sector funds, including innovative financing mechanisms such as green bonds, to support large-scale infrastructure and development projects.

Following to these, challenges are considered:

- **Political and economic instability:** In some regions, political and economic uncertainties can hinder the successful implementation of the Global Gateway projects.
- **Access to financing:** Despite the EU's commitment, obtaining sufficient financing, especially for low-income countries or projects with high initial costs, remains a challenge.
- **Geopolitical risks:** Global competition and tensions, such as those between the EU and China, can create risks in establishing effective partnerships and maintaining momentum on green investments.
- **Monitoring and transparency:** Ensuring that environmental and social standards are adhered to and that projects are regularly monitored is crucial. There can be challenges related to transparency in some regions, especially in countries with weak governance structures.

The CER Center should consolidate resources to mitigate the challenges. Important to note that the Belt and Road Initiative, as another worldwide project, focuses on solutions that ignore the mentioned challenges and promote project activities in an even unstable, risky, and not transparent environment.

Analysis of the New Circular Economy Action Plan in the Context of the Global Gateway Implementation

According to the CER Center's initiative, the objectives of the New Circular Economy Action Plan (NCEAP) is prioritized. This is a factor for NCEAP as a cornerstone of the European Green Deal, driving the transition to a resource-efficient and climate-neutral economy (European Commission, 2020). In the context of the Global Gateway, - the European Union's

strategy for global infrastructure and connectivity, - the NCEAP enhances sustainability by embedding circular economy principles into international partnerships and investments (European Commission, 2021). These efforts align with the Global Gateway's objective to address global challenges such as climate change, environmental degradation, and resource scarcity, which are integral to achieving the United Nations Sustainable Development Goals (SDGs).

The NCEAP promotes sustainability by emphasizing systemic changes in production and consumption patterns. It provides a framework for reducing waste, enhancing resource efficiency, and fostering innovation in sustainable practices. By prioritizing circular economy principles, the NCEAP supports the Global Gateway's aim to develop sustainable infrastructure and foster inclusive growth in partner countries. For instance, the plan's focus on creating a well-functioning market for secondary raw materials facilitates the decoupling of economic growth from resource use, addressing one of the critical pillars of sustainable development outlined in the Global Gateway (European Commission, 2020).

The NCEAP's emphasis on digital tools further supports the Global Gateway. Digital solutions enable better resource management, enhanced monitoring of environmental impacts, and improved efficiency in infrastructure development. For example, the deployment of Digital Product Passports, - a concept highlighted in the NCEAP, - can aid in ensuring transparency and traceability of materials, a critical aspect of sustainable supply chains in the Global Gateway projects. Such innovations enhance accountability and help ensure that international investments meet stringent environmental standards (European Commission, 2020).

Although there are positive alignments between the CER Center's activity and NCEAP in the framework of the Global Gateway, however detailed discussions on opportunities and challenges in integrating circular economy principles are studied. The opportunities are discussed through the following aspects.

Resource Efficiency and Cost Savings: Incorporating circular economy principles can reduce resource consumption and waste. Circular infrastructure has the potential to mitigate climate change and address resource scarcity by adopting the 6R principles: refuse, reduce, reuse, repair, refurbish, and recycle. This approach can lead to cost savings and long-term sustainability in infrastructure projects, enhancing their economic viability (Global Infrastructure Hub, 2023).

Innovation and Job Creation: Circular economy projects foster innovation in recycling technologies, material science, and design processes. These advancements can lead to new business models, such as product-as-a-service and extended producer responsibility, creating jobs in emerging sectors and stimulating local economies in partner countries (European Commission, 2020).

Climate Action Alignment: Circular economy practices, such as reducing embodied carbon in infrastructure materials and improving waste management systems, directly contribute to the Paris Agreement goals. By integrating these practices, the Global Gateway can enhance its credibility as a global leader in climate action (European Commission, 2019).

Partnerships and Capacity Building: The NCEAP promotes international cooperation, offering opportunities for knowledge transfer and capacity building in partner countries. Initiatives like Horizon Europe can support research and innovation partnerships, ensuring the adoption of best practices tailored to local needs (European Commission, 2018).

The study shows that there are challenges also in NCEAP and the Global Gateway interoperability that should be considered within the architecture of the CER Center.

Policy and Regulatory Gaps: Implementing circular economy principles requires robust regulatory frameworks, which may be lacking in some partner countries. Harmonizing standards and regulations across regions poses significant challenges, particularly in areas like

waste management, secondary raw material markets, and eco-design (European Commission, 2020).

Financial Barriers: Transitioning to a circular economy demands significant upfront investments in infrastructure, technology, and capacity building. Securing these funds, especially in developing regions, remains a challenge despite the Global Gateway's commitment to mobilizing €300 billion by 2027 (European Commission, 2021).

Cultural and Behavioral Shifts: Achieving circularity requires changes in consumer behavior and business practices, which can be slow and resistant to change. Public awareness campaigns and stakeholder engagement will be critical to overcoming these barriers (European Commission, 2021).

Data and Measurement Challenges: Effective implementation of circular economy principles requires reliable data on material flows, waste generation, and environmental impacts. Developing standardized metrics and ensuring data availability are ongoing challenges (Global Infrastructure Hub, 2023).

The NCEAP provides a comprehensive strategy for embedding circular practices globally, which can be effectively leveraged through the Global Gateway's infrastructure and development initiatives. The following components are discussed as supporting the transition to circular practices in partner countries.

Technical Assistance and Capacity Building: The NCEAP's emphasis on research and innovation can guide capacity-building efforts in partner countries. Programs like Horizon Europe and Team Europe initiatives can provide technical assistance, training, and funding to local stakeholders, enabling them to adopt circular practices in areas such as waste management, eco-design, and sustainable production (European Commission, 2018).

Policy Dialogue and Knowledge Sharing: The Global Gateway can facilitate policy dialogues that promote circular economy principles, using the NCEAP as a model. These discussions can help partner countries develop tailored strategies and policies that align with their unique socio-economic contexts. Knowledge-sharing platforms can disseminate best practices, success stories, and technical expertise (European Commission, 2021).

Financing Mechanisms: To address financial barriers, the NCEAP can integrate innovative financing mechanisms into the Global Gateway's investment strategy. Blending grants, loans, and guarantees can de-risk investments in circular economy projects. Public-private partnerships can further mobilize resources and drive innovation (European Commission, 2021).

Focus on Priority Sectors: The NCEAP's sector-specific approach—targeting key value chains such as electronics, plastics, textiles, and construction—can be mirrored in Global Gateway initiatives. For example, promoting sustainable building materials and designs in infrastructure projects can reduce resource consumption and embodied carbon (European Commission, 2020).

Digital Transformation: Digital technologies play a crucial role in enabling circularity. The NCEAP's focus on digital tools, such as the Digital Product Passport, can enhance transparency, track resource flows, and optimize supply chains. These tools can be integrated into Global Gateway projects to ensure accountability and efficiency (Global Infrastructure Hub, 2023).

Monitoring and Evaluation: Establishing robust monitoring and evaluation systems is essential for tracking progress and ensuring the effectiveness of circular economy initiatives. The NCEAP's proposed metrics can be adapted for use in partner countries, enabling continuous improvement and alignment with global sustainability standards (European Commission, 2020).

Based on the examinations, the New Circular Economy Action Plan and the Global Gateway are complementary frameworks that can collectively advance global sustainability

goals. By aligning their strategies and leveraging their respective strengths, the EU can foster transformative change in partner countries. The NCEAP's emphasis on innovation, capacity building, and systemic change provides a robust foundation for integrating circular economy principles into the Global Gateway's initiatives. However, addressing challenges such as policy gaps, financial constraints, and behavioral inertia will require concerted efforts and sustained collaboration among all stakeholders. Together, these frameworks have the potential to create resilient, inclusive, and sustainable economies worldwide.

Analysis of the Sustainable bio-economy for Europe in the context of the Global Gateway implementation: How does the Sustainable Bio-Economy for Europe align with the goals of the Global Gateway?

The Sustainable Bio-Economy for Europe aligns closely with the goals of the Global Gateway through its emphasis on sustainable development, global cooperation, and innovation. The European bioeconomy, with an annual turnover of €2 trillion and employing 18 million people, already contributes significantly to the EU's economic and environmental goals. The bioeconomy includes agriculture, forestry, fisheries, bio-based industries, and energy, which are important in order to achieve climate neutrality by 2050 under the European Green Deal. These objectives are positioned in the Global Gateway's focus on supporting inclusive growth, improving global connectivity, and promoting sustainability.

One of the most striking alignments is in job creation and socio-economic development. The bioeconomy has the potential to create 1 million new green jobs by 2030, specifically in rural and coastal areas, where economic opportunities are often limited. For example, the establishment of a single biorefinery can generate approximately 4,000 jobs over four years. This capacity to create employment directly supports the Global Gateway's aim to improve economic stability and reduce inequalities in partner regions.

The Global Gateway's objective to support infrastructure and innovation is also closely tied to the bioeconomy. The EU has allocated €10 billion under Horizon Europe (2021–2027) for research and innovation in food systems, natural resources, and the bioeconomy. This funding is important to scale up technologies like biorefineries, algae farming for renewable biomass, and bio-based materials such as biodegradable plastics. For instance, algae farming not only offers a renewable source of biomass but also contributes to carbon sequestration, reducing greenhouse gas emissions by up to 2.1 tons of CO₂ per ton of wood used in construction instead of concrete. Such improvements can be transferred to partner regions under the Global Gateway framework, in order to support not only innovation but sustainability as well.

Another important alignment is seen in the emphasis on resource efficiency and climate action. The EU bioeconomy supports the reduction of dependency on fossil fuels and encourages the use of bioenergy, which currently accounts for more than 50% of renewable energy production in the EU. Sustainable bioenergy, along with bio-based products, helps mitigate climate change while promoting resource efficiency. This directly supports the Global Gateway's ambition to combat climate change through sustainable energy transitions in partner countries.

The bioeconomy also supports the Global Gateway's goal of improving global cooperation by building sustainability-oriented trade relations. Approximately one-third of the biomass input to the EU bioeconomy is imported from non-EU countries. This highlights the interconnectedness of the bioeconomy with global markets. The Global Gateway can use this trade relationship to promote sustainable practices and strengthen global value chains in bio-based industries.

Moreover, the bioeconomy's contribution to circularity aligns with the Global Gateway's focus on sustainable economic models. Circular bioeconomy practices, such as transforming

agri-food waste into biodegradable plastics or fertilizers, save costs and reduce environmental impacts. For instance, avoiding food waste in the EU could save up to €143 billion annually, a model that could be extended to partner regions through Global Gateway initiatives.

The environmental restoration aspect of the bioeconomy also reflects the Global Gateway's emphasis on resilience. The bioeconomy contributes to ecosystem restoration, such as reducing ocean plastic pollution by up to 90% by 2025 through bio-based alternatives. It also aligns with the EU's target of restoring 15% of degraded ecosystems, a priority that can be shared with Global Gateway partners to address global environmental challenges.

In this study, the opportunities, as well as risks and challenges for promoting bioeconomy principles in Global Gateway projects are subject of examination that is conceptualised through the following context. The key opportunities are seen as:

Scaling bio-based industries for economic and environmental benefits: The bioeconomy sector in the EU generates an annual turnover of approximately €2 trillion, employing over 18 million people and contributing €621 billion in added value annually, which accounts for 4.2% of the EU's GDP . These figures highlight the economic potential of bio-based industries, important for the process of transition from fossil-based materials to sustainable alternatives. Global Gateway projects can replicate this success by investing in renewable bio-based materials such as bio-plastics, chemicals, and biofuels. This will support additionally the global decarbonization efforts and create employment opportunities in both urban and rural settings.

Transforming biomass into drivers for energy decarbonization and circularity: The EU produces approximately 1.5 billion tonnes of biomass annually, of which 500 million tonnes are identified as sustainably available for additional uses by 2030 . This biomass can support various sectors, including bioenergy, bio-based materials, and food systems, with the aim to contribute to energy security and reduce dependence on non-renewable resources. For example, biomass currently supplies around 10% of global final energy, with projections suggesting it could meet approximately 15% of global energy demand by 2050 . With the integration of sustainable biomass use into Global Gateway projects, developing countries can improve their energy mix while preserving ecological integrity.

Some statistics on EU bio-based industries including energy, food, and other sectors are included in image 1.

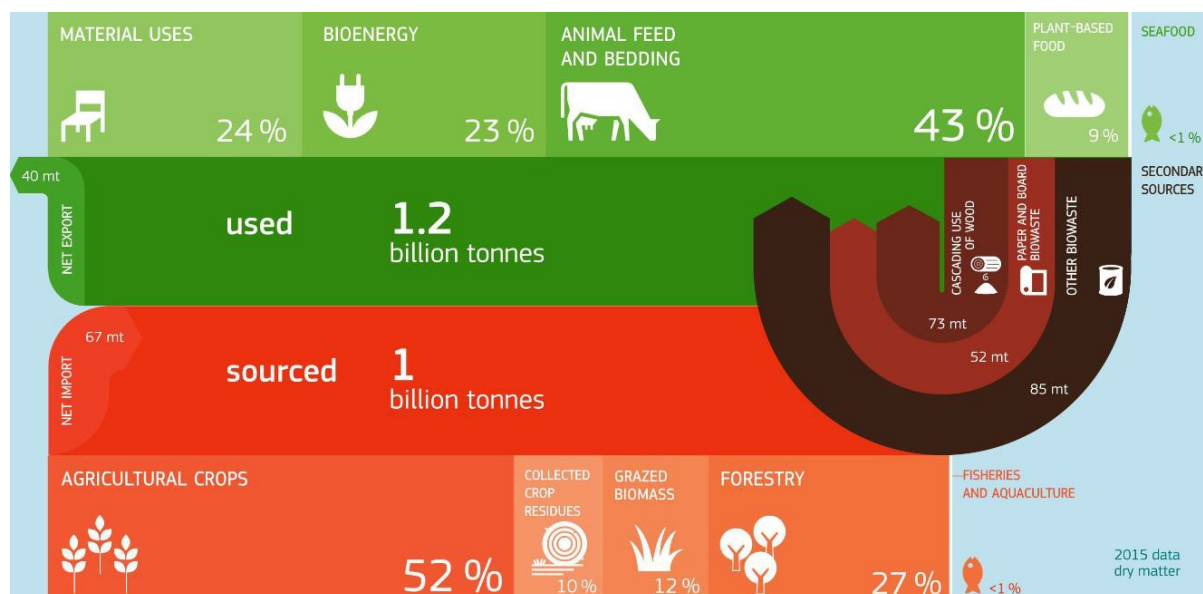


Image 1: Source: JRC

https://ec.europa.eu/knowledge4policy/sites/know4pol/files/20190925_jrc_biomass_ri_days_final_pubsy_0.pdf

The image shows the distribution and utilization of biomass in the EU, highlighting its significant contributions to material uses (24%), bioenergy (23%), and animal feed and bedding (43%), among other applications. Biomass is sourced primarily from agricultural crops (52%) and forestry (27%), with smaller contributions from grazed biomass and crop residues. This flow of resources provides an overview of the EU's capacity to manage biomass sustainably, contributing to a circular economy. Supporting this, the 2018 EU Bioeconomy Strategy emphasizes that sustainably sourced biomass is key to fulfilling the demands of energy, materials, and food systems. The strategy outlines that annual biomass production in the EU amounts to 1.5 billion tonnes of dry matter, with approximately 500 million tonnes identified as sustainably available for additional uses by 2030. This sustainable management of biomass not only reduces dependence on fossil resources but also supports biodiversity and ecosystem restoration, aligning with the goals of the European Green Deal and Sustainable Development Goals.

Creating green jobs and supporting rural economies: Bioeconomy-driven initiatives are projected to create one million new green jobs in the EU by 2030, particularly in rural and coastal areas . Global Gateway projects can leverage this model by deploying small-scale biorefineries and promoting agroforestry, which provides diverse revenue streams for farmers, foresters, and fishermen. For example, better recycling of organic waste streams in Amsterdam generates €150 million in added value annually, creating 1,200 jobs and reducing CO₂ emissions by 600,000 tonnes .

Supporting urban circular bioeconomy: Cities can become major hubs for the circular bioeconomy. Initiatives like Amsterdam's circular economy plan demonstrate the potential to recycle high-value organic waste streams into resources for bio-based industries. For Europe's largest 50 cities, adopting such practices could multiply economic and environmental benefits by at least 50 times . Global Gateway projects can adapt these urban models to cities in developing countries, fostering local economies while addressing urban waste management challenges.

Strengthening food security and sustainable agriculture: Approximately 76% of EU bioeconomy employment stems from agriculture and food production . By deploying sustainable agricultural practices such as precision farming, crop diversification, and nutrient recycling, Global Gateway projects can improve food security while reducing environmental pressures. For example, innovations in turning organic waste into animal feed could save land currently used for feed production, with the potential to feed three billion additional people globally .

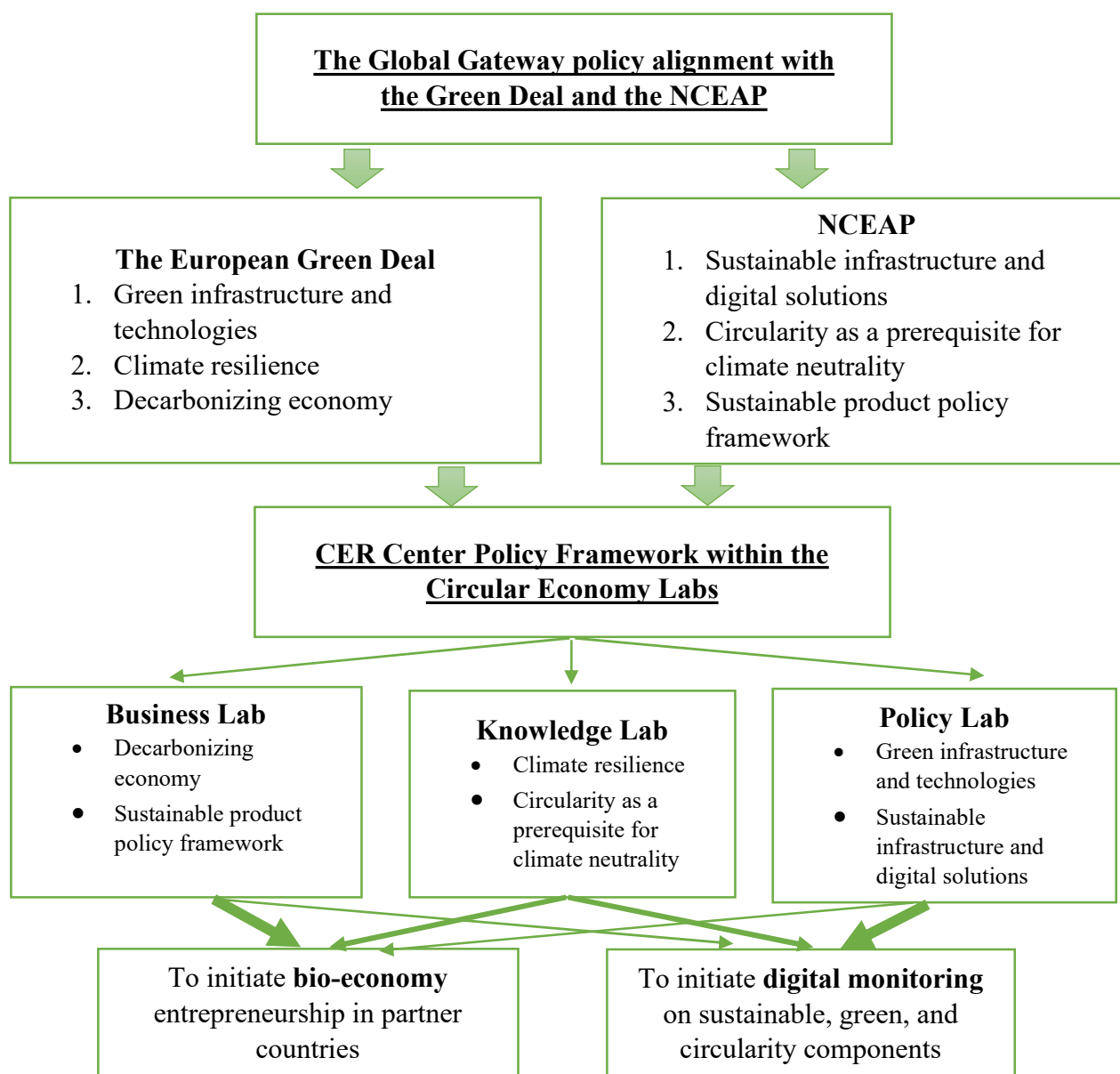
Advancing biodiversity and ecosystem restoration: The bioeconomy promotes the sustainable management of natural resources, including forests, oceans, and soils. EU initiatives aim to protect at least 30% of land and sea areas while restoring 15% of degraded ecosystems by 2030 . Global Gateway projects can incorporate these principles to preserve biodiversity hotspots in developing regions while supporting local communities through eco-tourism and sustainable forestry.

Challenges and risks in implementing bio-economy strategies in partner regions arise from factors spanning environmental, economic, and societal dimensions. One major challenge is the sustainable management of biological resources and land use. The EU Bioeconomy Strategy highlights that balancing the competing demands of food production, bio-based materials, and ecosystem conservation is complex. For instance, while there is enough sustainable biomass within the EU to meet projected needs by 2030, this requires integrating strategies that address carbon balance, biodiversity trade-offs, and socioeconomic constraints.

Modelling the CER Centre activities

Based on the interoperability analyses of the Global Gateway functions with the European Green Deal, and the NCEAP, as well as considering specifications of the bio-economy in relation to the Global Gateway and other field-related policies, the study suggests functional directions for the CER Centre that presents in Figure 1.

Figure 1. CER Center Activity Modeling



The model shows interoperability between certain policy directions of the Global Gateway, the Green Deal, and the NCEAP related to the circularity and sustainability functions. Delegating these functions between the Business, Knowledge, and Policy Labs, it will be possible to formulate new policy directions for CER Center related to bio-economy and digital monitoring.

1. To identify the policy compliance between the Global Gateway, the Green Deal, and the NCEAP – as the basic regulations for the CER Centre - in the framework of circularity and sustainability.
2. To delegate the identified policy directions to the CER Centre as a Global Gateway policy implementation unit.
3. To distinguish between delegated policy directions related to circularity and sustainability within the CER Center's Circular Economy Labs.
4. To generate new policies for bio-economy and digital monitoring, based on the delegated circularity and sustainability functions. Thin, thick, and thicker arrows show the power of influence of each lab over the bio-economy and digital monitoring policies.

The initiatives within bio-economy and digital monitoring can be new policy direction for the Global Gateway implementation derived by the Green Deal and NCEAP, and providing through the CER Center.

Economic challenges are significant in regions with underdeveloped bio-based sectors. Despite the potential to create up to one million green jobs in rural and coastal areas by 2030, barriers such as insufficient investments, high upfront costs for establishing biorefineries, and limited market uptake for bio-based products hinder progress. The EU has proposed initiatives such as a €100 million Circular Bioeconomy Investment Platform to address these issues, but disparities in regional capacities remain a concern .

Environmental risks include the potential for overexploitation of natural resources, which could lead to soil degradation, water scarcity, and biodiversity loss. To mitigate these risks, strategies must incorporate ecological boundaries. Monitoring systems and frameworks like the EU Green Deal are in place to ensure that bio-economy activities align with sustainability goals. However, implementing these measures consistently across regions is a challenge, particularly in areas with limited governance structures .

Socially, the transition to a bio-economy may lead to disruptions in traditional sectors, creating resistance among stakeholders. Training and education programs are necessary to build local capacity and acceptance. Moreover, ensuring equity in resource distribution and benefits is critical to avoid exacerbating existing inequalities, especially in rural areas .

Technological challenges include the development and deployment of innovations needed for a circular and sustainable bioeconomy. For instance, advanced biotechnologies, bio-based product standards, and waste-to-resource technologies require significant research and development investments, as highlighted by the EU's allocation of €10 billion under Horizon Europe. Lastly, there are risks associated with policy coherence and coordination. Bioeconomy strategies must align with broader climate, energy, and circular economy policies, requiring cross-sectoral cooperation. The European Commission's progress report emphasizes that gaps in policy coherence could undermine efforts to integrate bioeconomy principles effectively across regions.

Conclusion

The study of the implementation of the Global Gateway strategy through the new EU Circular Economy Resource Centre was discussed in the paper considering (1) the Green Deal agenda, (2) the New Circular Economy Action Plan, and (3) the Bio-Economy. Important to note that the WEEE framework is mentioned in the study as a future research object in this context.

There are suggested in the study to prioritize key activities in the relevant labs focusing on circularity and sustainability components. In particular, promoting green infrastructure and technologies can be relevant with the Business Lab, climate resilience and sustainable development activities: Knowledge Lab, and decarbonizing economies: Policy Lab.

Although the environmental, social, and economic impacts of the Global Gateway are clearly emphasized, however, we assume to delegate the monitoring and coordination functions to the CER Centre. Moreover, the study shows challenges on political and economic instability; access to finance; geopolitical risks; monitoring and transparency; that are necessary to manage. In the context of these risks the Belt and Road Initiative, - as another worldwide project, focuses on solutions that ignore the mentioned challenges and promotes project activities in even unstable, risky, and not transparent environment. We assume that the management of these challenges should be coordinated by the CER Center. This will enable to harmonize environmental, social, and economic benefits within risk analyses and promote effective solutions.

The study examined also the possible policy framework of the newly-established CER Center, modeling the activities toward the bio-economy and digital monitoring prioritization. In this context, the Global Gateway implementation is discussed as a policy toolkit to promote bio-economy and digital monitoring.

Based on the examinations, the New Circular Economy Action Plan, the Green Deal, and the Global Gateway are complementary frameworks that can collectively advance global sustainability goals as a macro solution, and promote circularity and bio-economy in micro levels. By aligning their strategies and leveraging their respective strengths, the EU can foster transformative change in partner countries emphasizing on innovation, capacity building, and systemic change, providing a robust foundation for integrating circular economy principles into the Global Gateway's initiatives. However, addressing challenges such as policy gaps, financial constraints, and behavioral inertia will require concerted efforts and sustained collaboration among all stakeholders, that could be implemented by the CER Center.

The bioeconomy also supports the Global Gateway's goal of improving global cooperation through Green Deal and the New Circular Economy Action Plan. However, this is a subject of cross-border cooperation, as approximately one-third of the biomass input to the EU bioeconomy is imported from non-EU countries. This highlights the interconnectedness of the bioeconomy with global markets through various regulations and directives, that could be a part of the CER Centre's coordinating functions.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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CIRCULAR ECONOMY AND SUSTAINABLE CONSUMPTION AS LEVERAGE FOR GREEN GROWTH AND CONSUMER PROTECTION

DOI: 10.26341/issn.2241-4010-2025-16a-8-K02150

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Abstract

The concept of circular economy (CE) is a new economic model of growth with respect for all dimensions of sustainable development. The circular economy indicators will be used to assess the green growth on the country level. We will consider how the circular economy through the green transition of producers and consumers behavior affects green growth that takes into account the environmental and social dimensions of sustainable development. By applying adequate methods to official data, we will assess the impact of circular economy indicators on green growth on the country level. We will use the circular economy indicators and green GDP. Special emphasis will be placed on competitiveness and innovation

indicators of the circular economy (gross added value, investments, employed persons, patents, etc. related to CE sectors). A comparative analysis of the countries will show the impact of the circular economy on the economic growth that respects environmental and social sustainability, and give some recommendations.

Keywords: Sustainability, circular economy indicators, competitiveness, innovation, green growth indicator, circular carbon economy indicator, green transition, consumer protection.

1. Introduction

The earth's life-support systems are increasingly at risk due to environmental issues such resource depletion, excessive land use, air, water, and soil pollution, and biodiversity loss (Jackson, 2009). Therefore, the main concerning global challenges are climate change, global warming, and the depletion of natural resources (Wang and Azam, 2024; Avdullahi and Shala, 2023). Rapid population increase and industrialization have placed significant pressure on planet's limited resources, leading to shortages in several regions (Huo and Peng, 2023; Liu, Saleem, Al-Faryan, Khan, and Zafar, 2022).

Additionally, cultural factors and environmental degradation, which are characterized by pollution and climate change, are thought to be crucial components of economic development (Najia et al, 2025). Countries have to validate economic policy in order to be more efficient and social culture oriented (Kafka, 2020). Culture is influenced in several ways to improve sustainability and economic performance(Adebayo et al, 2020).

In this context, the concept of Circular Economy (CE) has emerged as a transformative economic model that seeks to decouple economic growth from environmental degradation. In contrast to conventional linear models based on a "take-make-dispose" approach, the circular economy places a strong emphasis on waste minimization, resource efficiency, and system-level sustainability. As countries strive to balance economic expansion with objectives for social and environmental sustainability, the importance of the circular economy continues to grow. This paradigm shift is especially pertinent to green growth, which is a method that combines environmental stewardship with economic growth.

This study explores the relationship between circular economy indicators and green growth at the national level, analyzing how CE strategies influence broader sustainable development objectives through producer and consumer behaviors. By leveraging key indicators such as the Green Growth Index and the Circular Carbon Economy Index, we will assess the impact of circular economy practices on national economic performance while integrating the social and environmental dimensions of sustainability. Additionally, competitiveness and innovation metrics, such as gross added value, investments, employment in CE sectors, and patents, will be considered. A comparative analysis across countries will highlight the impact of circular economy adoption on economic growth that aligns with environmental and social sustainability principles, offering key policy recommendations.

2. Literature review

The circular economy (CE) concept has gained attention among researchers and practitioners, yet interpretation and application remains diverse (Kirchherr et al., 2017). Kirchherr et al. (2017) found that CE is most commonly portrayed as a mix of reduce, reuse, recycling initiatives, based on their analysis of 114 definitions of the circular economy. However, the conceptual scope of CE encompassing systemic transformations that align with sustainable development goals (SDGs). Geissdoerfer et al. (2017) identified eight distinct kinds of

relationships in the literature and highlighted the most obvious similarities and divergences between the ideas of sustainability and the CE. In literature, the circular economy is seen as a prerequisite for sustainability, a mutually beneficial relationship, or a trade-off (Geissdoerfer et al., 2017).

Since both the circular economy and sustainability seek to establish systems that promote long-term ecological balance, economic resilience, and social well-being, they are inextricably intertwined (Rosário et al., 2024). Some authors identify circular economy as a model implemented to support sustainable development (Zaccone et al., 2022), reinforcing its role as a catalyst for green transitions. The transition toward CE models has become essential for harmonizing economic growth with environmental sustainability. CE advocates a systematic shift from linear, resource intensive practices to models prioritizing resource efficiency, waste minimization, and sustainable resource use (Munaro and Tavares, 2023; Tambovceva et al., 2021). Significant barriers, such as informational, political, and technological challenges, impede CE implementation, especially in resource-intensive sectors like construction (Owojori and Okoro, 2022). Addressing these barriers requires coordinated actions among public and private stakeholders, emphasizing governance frameworks as critical enablers (Munaro and Tavares, 2023; Tambovceva et al., 2021).

Abbasi et al. (2021) examined data from the top 18 countries ranked by the Economic Complexity Index (ECI) from 1990 to 2019 to investigate the relationship between the CO₂e, economic complexity index (ECI), tourism (TR), gross domestic products (GDP), gross domestic products per capita (GPC), and energy price indices (EPI). Their results indicate positive long-term and short-term correlations between ECI, GDP, and CO₂e, and validate the existence of cross-sectional unit relationship and slope heterogeneity among nations (Abbasi et al., 2021). In addition, in the medium and long run, their results found that TR, GPC, and EPI reduce carbon emissions. A carbon dioxide equivalents (CO₂e) is a composite indicator that compares the impact of different greenhouse gases on global warming potential by converting the amounts of those gases into an equivalent amount of carbon dioxide with the same global warming potential (Eurostat).

Effective management of raw materials and minimizing the material footprint are central to CE strategies, directly affecting carbon emissions and environmental sustainability (Lenzen et al., 2022; Smol et al., 2020). Bherwani et al. (2022) demonstrated through the ReSOLVE framework (Regenerate, Share, Optimize, Loop, Virtualize, Exchange) that substantial reduction in carbon (up to 15.7%) and material footprints (up to 25%) can be achieved, particularly in high-impact sectors like transportation and construction. Smol et al. (2020) also highlights that improved recycling and raw material efficiency are critical for Europe's CE transition, reinforcing that sustainable raw material management mitigates ecological impacts.

According to David et al. (2020), nature-based solutions like green building materials, green building systems, and green construction sites can help promote CE while reducing negative effects of urbanization. In addition, Weiyang and Yu (2020) found in their empirical research that the per capita consumption of renewable energy, gross domestic products, and foreign direct investment have a long-term and stable equilibrium relationship, suggesting that integrating CE strategies into energy and investment policies can further accelerate sustainable transitions.

Innovation, particularly through patents related to CE technologies, plays a crucial role in driving sustainable economic outcomes. Hysa et al. (2020) confirm that increased CE-related patents and private investments significantly correlate with enhanced economic performance in European countries. Their findings underscore innovation and financial investment as essential components for the successful advancement of CE, aligning with broader sustainability objectives. Additionally, Dionizi et al. (2025) emphasized the importance of integrating local community lifestyles in fostering CE acceptance.

Another dimension of CE involves collaborative consumption models, which enhance access to resources for economic actors who had limited or no access to them (García-Sánchez et al., 2021). By shifting from ownership-based consumption to shared services, these models enhance affordability, economic inclusivity, and sustainable resource use. The expansion of recycling, remanufacturing, and sustainable design industries within CE frameworks also fosters green job creation, reinforcing the social equity aspect of sustainability. The increased emphasis on sustainable consumption cycles supports local economic development.

Specifically, community-based agroecosystems management demonstrate effective CE implementation by aligning sustainable business practices with local values, thus supporting environmental conservation and socio-economic resilience (Dionizi et al., 2025). Employment dynamics in CE sectors reveal significant shifts, including job creation in recycling and reuse activities, counterbalancing potential losses in traditional industries (Repp et al., 2021). However, such transitions necessitate policy intervention to address labor market adjustments, ensuring equitable and inclusive growth (Sulich and Sołoducho-Pelc, 2022). Sverko Grdic et al. (2020) illustrate a clear link between CE implementation and positive economic outcomes, including increased GDP, reduced resource extraction, and higher recycling rates in EU contexts. This evidence reaffirms CE's potential to simultaneously achieve economic development and environmental sustainability, highlighting the critical role of CE strategies in pursuing sustainable economic growth.

The integration of circular economy principles into consumer protection frameworks is very important. Comparative analyses of international guidelines and national policies will help identify the best practices and areas for improvement. Consumer protection laws continue to evolve in line with technological advancements, digital transformation and dynamic market conditions (Mishra and Varshney, 2024). Recent studies emphasize the necessity of developing effective consumer protection measures in the gradual process of green growth and decarbonization of the economy (Paduszyńska and Kozar, 2024).

3. Methodology

3.1. Research hypotheses

The research hypotheses are structured as follows:

- **H₀:** EU member states exhibit significantly higher levels of GGI and CCEI compared to non-EU countries (Western Balkan countries and Turkey).
- **H₁:** Material consumption and Material footprint correlate with sustainability performance in EU countries.
 - **H_{1a}:** Raw Material Consumption (RMC) is associated with GGI and CCEI in EU countries.
 - **H_{1b}:** Material Footprint is associated with GGI and CCEI in EU countries.
- **H₂: Drivers of Green Growth Index (GGI) in EU Countries**
 - **H_{2a}:** Employment in circular economy (CE) sectors positively influences the Green Growth Index (GGI).
 - **H_{2b}:** CE-related patents positively influence the Green Growth Index (GGI).
 - **H_{2c}:** Private investments in CE sectors positively influence the Green Growth Index (GGI).
 - **H_{2d}:** Gross Value Added (GVA) in CE sectors is positively linked to the Green Growth Index (GGI).
- **H₃: Drivers of Circular Carbon Economy Index (CCEI) in EU Countries**

- **H_{3a}**: Employment in circular economy (CE) sectors positively influences the Circular Carbon Economy Index (CCEI).
- **H_{3b}**: CE-related patents positively influence the Circular Carbon Economy Index (CCEI).
- **H_{3c}**: Private investments in CE sectors positively influence the Circular Carbon Economy Index (CCEI).
- **H_{3d}**: Gross Value Added (GVA) in CE sectors is positively linked to the Circular Carbon Economy Index (CCEI).

3.2. Data Sources

This study employs quantitative research methods to investigate the impact of circular economy (CE) indicators on green growth and carbon transition performance. The analysis is based on a panel dataset covering:

- 27 EU member states and
- 6 non-EU member states (Western Balkan countries and Turkey), which maintain close economic and regulatory ties with the EU.

The data sources are given in Table 1.

Table 1. Research Variables

Variable	Indicator	Measurement	Source	Category
Independent variable	Raw Material Consumption (RMC)	2023 data (tons per capita)	Eurostat	Resource efficiency metrics
	Material Footprint	2023 data (tons per capita)	Eurostat	Resource efficiency metrics
	Employment in CE Sectors	2023 data (Full-Time Equivalents - FTE)	Eurostat	Innovation metrics
	CE-Related Patents	2023 data (number of patents filed)	OECD, EPO	Innovation metrics
	Private Investments in CE Sectors	2023 data (Million euros)	Eurostat	Financial metrics
	Gross Value Added (GVA) in CE Sectors	2023 data (Million euros)	Eurostat	Financial metrics
Dependent variable	Green Growth Index (GGI)	2023 Index scores (0-100)	GGI Report 2023	
	Circular Carbon Economy Index (CCEI)	2023 Index scores (0-100)	CCEI Report 2023	
Control variables	Supplementary data	GDP Growth and Population Demographics	World Bank, OECD	

Source: Author's compilation based on Eurostat, OECD, and World Bank datasets

The Green Growth Index (GGI) evaluates national performance across the following four dimensions of sustainable development:

- Efficient and Sustainable Resource Use: Energy productivity, water efficiency, material footprint.
- Natural Capital Protection: Biodiversity conservation, forest cover, soil health.
- Green Economic Opportunities: Renewable energy adoption, circular economy investments, green job creation.
- Social Inclusion and Resilience: Income equality, access to education, healthcare quality.

The scoring framework for GGI is explained in Table 2.

Table 2. Scoring framework for GGI

Score Range	Performance Level	Example Country
80–100	Very high performance	Sweden (81.2)
60–80	High performance	Germany (74.5)
40–60	Moderate performance	Poland (58.9)
20–40	Low performance	Turkey (39.8)
<20	Critical underperformance	No countries in 2023

Source: Author's compilation based on the Green Growth Index, Available at:
<https://greengrowthindex.gggi.org/>

The Circular Carbon Economy Index (CCEI) assesses countries' capacity to transition to net-zero emissions through four pillars:

- Reduce: Decarbonization of energy, industry, and transport sectors.
- Recycle: Carbon capture/utilization in industrial processes.
- Reuse: Integration of waste carbon into value chains (e.g., synthetic fuels).
- Remove: Scaling carbon dioxide removal technologies (e.g., direct air capture).

The scoring framework for CCEI is explained in Table 3.

Table 3. Scoring framework for CCEI

Score Range	Performance Level	Example Country
5+	Global leaders	Denmark (78.3)
50–75	Advanced transition	France (68.7)
25–50	Emerging potential	Romania (42.1)
<25	Structural challenges	Bosnia and Herzegovina (24.6)
<20	Critical underperformance	No countries in 2023

Source: Author's compilation based on Circular Carbon Economy Index, Available at:
<https://cceindex.kapsarc.org/>

3.3. Data Editing and Harmonization

To ensure methodological consistency and temporal alignment, dataset underwent rigorous curation. The following steps were taken:

- Data exclusion: Countries with incomplete or unreliable data - specifically Luxembourg, Malta, and Montenegro (due to missing 2023 CCEI entries) and Serbia (excluded for an implausible raw material consumption value of 0 tons per capita) - were omitted, resulting in a final sample of 27 EU member states (e.g., Germany, Sweden) and six non-EU economies (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia, and Turkey).

- Temporal adjustments: to align patent data with the study's timeframe, 2023 patent counts were linked to 2023 GGI/CCEI scores to account for innovation's lagged impact

(supported by literature advocating a three-year lag for technological influence), while employment, investment, and gross value-added metrics from 2021 were integrated with 2023 indices under the assumption of structural stability in circular economy sectors, justified by the absence of major policy disruptions between 2021 and 2023.

- Handling missing data: it was addressed through listwise deletion, removing 7% of initial entries to preserve analytical consistency.

- Outlier treatment: skewed variables, such as patent counts and investment figures, were mitigated via Winsorization at the 5% level, balancing outlier reduction with statistical robustness.

- Financial harmonization: monetary values were converted to million euros using 2023 exchange rates, while raw material consumption (RMC) and material footprint were standardized to tons per capita.

Collectively, these steps ensured a balanced, cross-nationally comparable dataset, enabling rigorous longitudinal and regression analyses of circular economy dynamics.

4. Research Results and Discussion

4.1. Descriptive Statistics

Descriptive statistics for the 2023 dataset were computed using SPSS 27 (Table 4), providing insights into green growth and circular economy indicators across the EU-27 and 6 non-EU economies. Table 4 presents mean, standard deviation, minimum and maximum values, skewness, and kurtosis for the key variables.

Table 4. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
GGI	67.8	7.9	41.5	81.2	-0.28	2.08
CCEI	51.6	13.4	24.6	78.3	0.22	1.95
RMC (Tons/Capita)	17.3	8.7	6.8	42.1	1.12	3.55
Employment (Thousands)	1,320	1,450	25	6,200	1.92	4.85
CE Patents (Number)	410	320	45	1,550	1.34	3.18
Private Investments (M€)	3,200	3,800	70	18,000	1.72	4.25
Gross Value Added (M€)	14,500	15,600	110	85,000	2.15	5.47
Note: All financial metrics use 2023 exchange rates (€1 = \$1.08). Employment and patent data reflect harmonized Eurostat 2023.						

Source: Authors

The descriptive statistics reveal critical insights into the dynamics of green growth and circular economy (CE) transitions across the sample. The Green Growth Index (GGI) exhibits moderate variability (Mean = 67.8, SD = 7.9), with scores ranging from 41.5 (Turkey) to 81.2 (Sweden), reflecting incremental progress in sustainable resource use and social inclusion. In contrast, the Circular Carbon Economy Index (CCEI) demonstrates higher dispersion (Mean = 51.6, SD = 13.4), underscoring stark disparities in net-zero transition readiness, as scores span from 24.6 (Bosnia and Herzegovina) to 78.3 (Denmark).

Resource efficiency metrics, such as Raw Material Consumption (RMC), average 17.3 tons per capita but display right-skewed distribution (Skewness = 1.12), driven by resource-intensive economies like Finland (42.1 tons). Innovation and financial metrics further highlight asymmetries: CE-related patents (Mean = 410) and private investments (Mean = 3,200 million euros) exhibit significant right-skewness (Skewness = 1.34 and 1.72,

respectively), reflecting concentrated innovation in technologically advanced economies (e.g., Germany's 1,550 patents and the Netherlands' 18,000 million euros investments). Employment in CE sectors (Mean = 1,320 thousand jobs) and Gross Value Added (Mean = 14,500 million euros) also show non-normal distributions (Skewness = 1.92 and 2.15), dominated by outliers such as Germany (Employment 6,200 thousand jobs, 85,000 million euros Gross Value Added).

These patterns validate the methodological use of Winsorization to mitigate outliers and emphasize the dominance of EU industrial economies in CE value generation. The pronounced variability in CCEI scores and the concentration of innovation and investments in EU nations align with hypotheses H_{2b} and H_{2c} , reinforcing the centrality of technology and finance in driving circular transitions, while underscoring the need for targeted policy interventions to bridge gaps in non-EU economies.

4.2. Using Correlation and Regression Analysis for Hypothesis Testing

4.2.1. Comparison of Green Growth and Carbon Transition Performance Between EU and Non-EU Member States (H_0)

The study uses a multi-step analytical approach to test the hypotheses. To test H_0 , a Mann-Whitney U test (non-parametric alternative to the independent samples t-test) was conducted to compare GGI and CCEI scores between EU ($n = 27$) and non-EU group of countries ($n = 6$), addressing the small sample size and non-normal data distributions in the non-EU group of countries. This approach ensured robustness against violations of parametric assumptions while providing interpretable effect magnitudes. Table 5 presents the results of the Mann-Whitney U test conducted to test H_0 .

Table 5. Mann-Whitney U Test Results

Index	EU Median	Non-EU Median	U Statistic	p-value	Effect Size (r)
GGI	69.2	56.8	24.5	0.002	0.62
CCEI	54.7	35.4	18.0	<0.001	0.75

Source: Authors

As shown in Table 5, the Mann-Whitney U test results robustly confirm the EU's superior performance in both green growth and carbon transition readiness compared to non-EU economies. EU countries exhibited significantly higher median scores for the Green Growth Index (GGI: Median = 69.2 vs. 56.8; $U = 24.5$, $p = 0.002$) and the Circular Carbon Economy Index (CCEI: Median = 54.7 vs. 35.4; $U = 18.0$, $p < 0.001$). The large effect sizes ($r = 0.62$ for GGI; $r = 0.75$ for CCEI) underscore the magnitude of these disparities. The GGI gap highlights the EU's institutional strengths, such as stringent environmental regulations and integrated green policies, while the CCEI disparity reflects structural barriers in non-EU economies, including limited access to decarbonization technologies and financing. These findings confirm the hypothesis (H_0) that EU countries outperform non-EU counterparts in green growth performance and carbon transition readiness and emphasize the urgency of targeted interventions to bridge sustainability gaps.

4.2.2. Resource Efficiency and Sustainability Performance (H_1)

To evaluate H_{1a} and H_{1b} , Pearson correlation analysis assessed linear relationships between material metrics (RMC and Material footprint) and the indices, while multiple regression models isolated their independent effects on GGI/CCEI controlling by GDP and population.

Table 6 summarizes the results of the correlation analyses conducted to test the H_{1a} and H_{1b} hypotheses. Table 6 summarizes the results of the correlation analyses conducted to test the H_{1a} and H_{1b} hypotheses.

Table 6. Correlation Test Results

Variable	GGI (r)	CCEI (r)	GGI (β)	CCEI (β)
RMC	0.35*	-0.08	0.12*	-0.05
Material Footprint	0.18	0.12	0.07	0.03

Source: Authors

As summarized in Table 6, the analysis of material consumption metrics reveals nuanced relationships with sustainability performance. For H_{1a} , Raw Material Consumption (RMC) exhibits a weak but statistically significant positive correlation with the Green Growth Index ($r = 0.35$, $\beta = 0.12$), suggesting that higher material use may coexist with certain green growth outcomes, such as renewable energy adoption. However, RMC shows no meaningful association with the Circular Carbon Economy Index ($r = -0.08$), indicating that material efficiency alone is insufficient to drive decarbonization. For H_{1b} , the Material Footprint demonstrates negligible correlations with both GGI ($r = 0.18$) and CCEI ($r = 0.12$), rejecting the hypothesis and underscoring the limited role of material throughput metrics in explaining sustainability outcomes. These findings emphasize the need for complementary policies - beyond material efficiency - to achieve net-zero transitions, such as scaling clean technologies and strengthening governance frameworks.

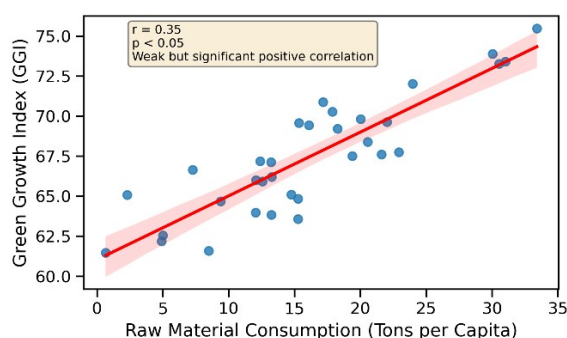


Figure 1. Correlation between RMC and GGI

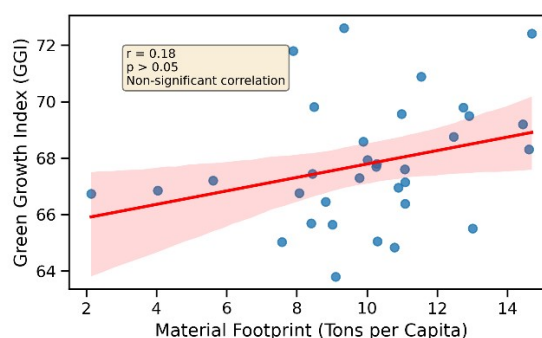


Figure 2. Correlation between Material Footprint and GGI

The scatter plot in Figure 1 refers to H_{1a} and illustrates a weak but statistically significant positive correlation ($r = 0.35$, $p < 0.05$) between Raw Material Consumption (RMC) and the Green Growth Index (GGI). This suggests that while higher material consumption is generally associated with increased green growth performance, the relationship is relatively modest, indicating the influence of other contributing factors such as economic, industrial, or policy-related factors affecting material use.

The scatter plot in Figure 2 refers to H_{1b} and demonstrates an insignificant correlation ($r = 0.18$, $p > 0.05$) between Material Footprint and the Green Growth Index (GGI). This result indicates that material footprint alone does not have a statistically meaningful impact on green growth performance within the sample, highlighting the need for additional variables to explain sustainability outcomes.

4.2.3. Drivers of Green Growth and Circular Carbon Economy Performance (H_2 and H_3)

For H_{2a} , H_{2b} , H_{2c} , and H_{2d} two multiple linear regression models were estimated:

- 1) Model 1 examined predictors (employment, patents, private investments, gross value added - GVA) for GGI, and
- 2) Model 2 replicated this for CCEI.

Multicollinearity was mitigated by ensuring Variance Inflation Factor (VIF) values remained below 5, confirming no redundancy among predictors. Table 7 presents the results of the regression analysis for the model considering GGI as the dependent variable.

Table 7. Regression Results for Model 1 (GGI)

Variable	β	Std. Error	t-value	p-value	VIF
Employment (H_{2a})	0.08	0.06	1.33	0.192	2.1
CE Patents (H_{2b})	0.31**	0.09	3.45	0.001	1.5
Private Investments (H_{2c})	0.25*	0.10	2.52	0.016	2.3
GVA (H_{2d})	0.21*	0.08	2.63	0.014	1.9
<i>Dependent Variable: GGI / Model Summary = 0.38</i>					

Source: Authors

As shown in Table 7, the regression analysis for the Green Growth Index (GGI) demonstrates that H_{2b} and H_{2c} are supported, with CE-related patents and private investments significantly driving green growth. A one-unit increase in patents raises GGI by 0.31 points ($\beta = 0.31$, $p < 0.01$), while a 1 million euro increase in investments boosts GGI by 0.25 points ($\beta = 0.25$, $p < 0.05$). In contrast, H_{2a} and H_{2d} are weakly supported, as employment ($\beta = 0.08$, $p = 0.19$) and Gross Value Added ($\beta = 0.21$, $p = 0.01$) show limited influence, suggesting that job creation and economic output in CE sectors lag behind technological and financial drivers. The model exhibits moderate explanatory power, with an adjusted $R^2 = 0.38$, indicating that 38% of the variance in GGI scores is explained by these predictors.

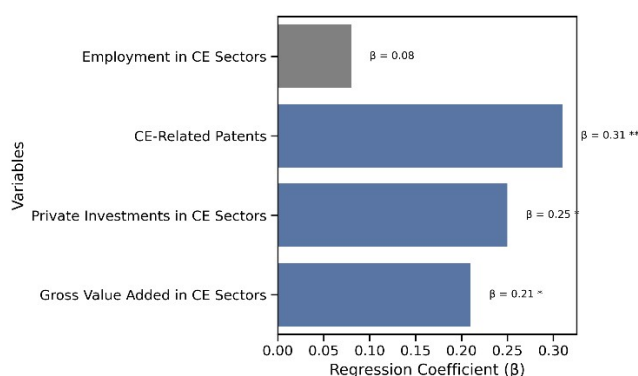


Figure 3. The regression results for the Green Growth Index (GGI) concerning circular economy drivers

The coefficient plot in Figure 3 presents the regression results for the Green Growth Index (GGI) concerning circular economy drivers. CE-related patents ($\beta = 0.31$, $p < 0.01$), private investments ($\beta = 0.25$, $p < 0.05$), and gross value added ($\beta = 0.21$, $p < 0.05$) show statistically significant positive effects on GGI, underscoring the importance of innovation and financial factors. Employment in CE sectors demonstrates a positive but statistically insignificant relationship ($\beta = 0.08$, $p = 0.192$), suggesting a limited influence on green growth performance.

Table 8 reports the regression analysis results for the model, where CCEI is considered as the dependent variable.

Table 8. Regression Results for Model 2 (CCEI)

Variable	β	Std. Error	t-value	p-value	VIF
Employment (H_{3a})	0.11	0.08	1.38	0.178	2.1
CE Patents (H_{3b})	0.45***	0.12	3.75	<0.001	1.5
Private Investments (H_{3c})	0.38***	0.11	3.45	0.001	2.3
GVA (H_{3d})	0.16	0.10	1.60	0.120	1.9
<i>Dependent Variable: CCEI / Model Summary=0.47</i>					

Source: Authors

As shown in Table 8, the regression analysis for the Circular Carbon Economy Index (CCEI) reveals that H_{3b} and H_{3c} are strongly supported, with CE-related patents and private investments emerging as pivotal drivers of carbon transition. A one-unit increase in patents raises CCEI by 0.45 points ($\beta=0.45$, $p < 0.001$), while a 1 million euro increase in investments boosts CCEI by 0.38 points ($\beta=0.38$, $p < 0.001$).

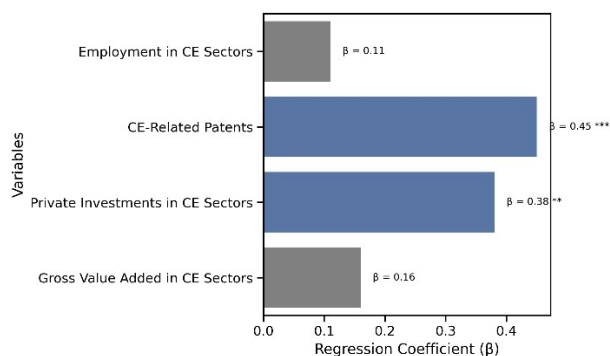


Figure 4. The regression results for the Circular Carbon Economy Index (CCEI) concerning circular economy drivers

The coefficient plot in Figure 4 illustrates the regression outcomes for the Circular Carbon Economy Index (CCEI) with circular economy variables. CE-related patents ($\beta = 0.45$, $p < 0.001$) and private investments ($\beta = 0.38$, $p = 0.001$) exhibit strong and statistically significant positive effects on CCEI, highlighting their critical roles in carbon transition readiness. Employment in CE sectors ($\beta = 0.11$, $p = 0.178$) and gross value added ($\beta = 0.16$, $p = 0.120$) show positive but statistically insignificant relationships, indicating a lesser contribution to decarbonization efforts.

Table 9. Summary of Hypothesis Test Results

	Hypothesis	Status
H_0	EU states outperform non-EU in GGI/CCEI	Supported
H_{1a}	RMC correlates with GGI/CCEI	Partially supported for GGI
H_{1b}	Material Footprint correlates with GGI/CCEI	Not supported
H_{2a}	CE employment $\rightarrow$ GGI	Not supported
H_{2b}	CE patents $\rightarrow$ GGI	Supported
H_{2c}	CE investments $\rightarrow$ GGI	Supported
H_{2d}	CE GVA $\rightarrow$ GGI	Supported
H_{3a}	CE employment $\rightarrow$ CCEI	Not supported
H_{3b}	CE patents $\rightarrow$ CCEI	Supported
H_{3c}	CE investments $\rightarrow$ CCEI	Supported
H_{3d}	CE GVA $\rightarrow$ CCEI	Not supported

Source: Authors

Findings shown in Table 9 underscore the critical role of innovation ecosystems (e.g., Germany has 1,550 patents) and green financing (e.g., the Netherlands has 18 billion euros investments) in scaling circular technologies and advancing sustainable resource use and green economic opportunities. The hypothesis H_0 is supported, H_1 is mostly unsupported, and H_2 is mostly supported. In contrast, H_{3a} and H_{3d} are rejected, as employment ($\beta=0.11$, $p=0.18$) and Gross Value Added ($\beta=0.16$, $p=0.12$) lack statistical significance, highlighting the dominance of technological and financial drivers over labor and economic metrics. The model demonstrates strong explanatory power, with an adjusted $R^2 = 0.47$ indicating that nearly half of the variance in CCEI scores is explained by these predictors.

5. Conclusions

This study highlights the multifaceted drivers and barriers of green growth and circular carbon transitions, revealing strong asymmetries between EU and non-EU countries. It underscores the irreplaceable roles of innovation, finance, and governance in achieving systemic sustainability. The findings challenge conventional assumptions about material consumption, employment, and growth, offering a roadmap for policymakers to recalibrate strategies in alignment with planetary boundaries and equitable development. These insights will be synthesized into actionable pathways for diverse stakeholders.

Innovation through CE-related patents and substantial private investments emerged as pivotal drivers of sustainability outcomes, underscoring their importance in achieving green growth and efficient carbon management as stated by (Hysa et al., 2020). Innovation, measured via CE-related patents, demonstrated significant positive correlations with both GGI and CCEI, confirming previous research suggesting that technological advancements substantially enhance sustainability performance (Hysa et al., 2020). Countries excelling in innovation within CE sectors consistently achieve superior sustainability outcomes, reinforcing innovation as a foundational component of effective CE transitions.

The strong correlation between circular economy (CE)-related patents and green growth indices (GGI: $\beta = 0.31$; CCEI: $\beta = 0.45$) confirms that innovation is the cornerstone of decarbonization. For EU member states, this necessitates doubling down on initiatives like Horizon Europe to prioritize high-impact technologies - such as carbon capture, bio-based materials, and waste-to-energy systems - while streamlining patent frameworks to accelerate commercialization. Non-EU regions, particularly emerging economies in the Western Balkans and Turkey, require targeted interventions to bridge innovation gaps. Establishing regional hubs, such as a Balkan Circular Economy Network, could catalyze cross-border R&D collaboration, leveraging EU knowledge spillovers through joint ventures and technology transfer agreements. Globally, addressing the North-South innovation divides demands novel mechanisms, including tax incentives for SMEs adopting circular technologies and expanded intellectual property (IP) sharing frameworks to democratize access to climate-critical innovations.

Similarly, private investments in CE sectors showed robust positive impacts on both sustainability indices. These investments facilitate infrastructure development and technological advancements essential for enhancing resource efficiency and reducing environmental footprints, aligning with findings from recent literature emphasizing the pivotal role of private sector financing in sustainability transitions (Hysa et al., 2020; Sulich and Sołoducho-Pelc, 2022).

The disproportionate influence of private investments on both GGI ($\beta = 0.25$) and CCEI ($\beta = 0.38$) highlights the urgency of redirecting investments toward circular infrastructure. EU policymakers must institutionalize accountability by mandating “circularity clauses” in corporate ESG reporting, ensuring private capital flows to verified projects like industrial

symbiosis parks or closed-loop manufacturing. For non-EU countries, where financial barriers are acute, multilateral development banks (e.g., EBRD, World Bank) should deploy blended finance instruments - such as partial risk guarantees and concessional loans - to de-risk green investments. Sector-specific green bonds targeting circular infrastructure, such as recycling facilities or carbon-neutral logistics networks, could further unlock funds while aligning with global climate finance agendas.

Interestingly, resource efficiency indicators, such as raw material consumption and material footprint, presented nuanced relationships with GGI and CCEI. While higher raw material consumption did not significantly hinder sustainability outcomes, this could reflect compensatory effects from parallel innovations and sustainable technologies. Such complexity indicates that absolute decoupling of resource use from economic growth remains challenging, requiring integrated policy interventions to achieve meaningful sustainable outcomes (Lenzen et al., 2022).

The weak correlation between raw material consumption (RMC) and GGI ($r = 0.35$) exposes a precarious reality: some EU nations maintain green growth despite high resource throughput, a strategy incompatible with net-zero targets. To decouple growth from material extraction, the EU must enforce stringent circular design standards under the Eco-design Directive - mandating recyclability in electronics, modularity in construction, and durability in textiles. Globally, carbon-adjusted border taxes (CBAM) on resource-intensive imports could incentivize circular practices, penalizing linear production models while fostering a race-to-the-top in sustainable manufacturing.

The huge gap in CCEI performance between EU (median = 54.7) and non-EU countries (median = 35.4) threatens regional climate resilience. Accelerating the Western Balkans' integration into EU circular frameworks - via pre-accession funding and regulatory harmonization - is critical to avoiding a "two-speed Europe". Concurrently, regional centers of excellence should be established to build institutional capacity in circular governance, equipping policymakers with tools for lifecycle assessment, circular procurement, and stakeholder engagement. A just transition in fossil fuel-dependent regions, such as Bosnia's coal hubs, demands targeted EU cohesion funds to repurpose legacy industries toward circular sectors like remanufacturing or regenerative agriculture.

The limited influence of CE-sector employment and gross value added (GVA) on sustainability indicates a misalignment between job creation and ecological outcomes. Labor policies must prioritize quality over quantity, upskilling workers for high-value roles in renewable energy engineering, circular supply chain management, and carbon removal technologies. Redefining "green jobs" to emphasize net-zero emission - rather than economy on scale - will ensure labor markets drive substantive decarbonization.

Employment and gross value added (GVA) in CE sectors exhibited weaker and less direct relationships with GGI and CCEI, suggesting these may be lagging indicators or outcomes dependent on preceding innovation and investment. Employment shifts identified by (Repp et al., 2021) emphasize that policy support and workforce training are crucial for managing labor market transitions effectively and ensuring broad socio-economic benefits from CE implementation. Further, (Dionizi et al., 2025) underlines the essential role of cultural and community integration for successful CE adoption and long-term sustainability. Findings indicate that the successful transition to CE fundamentally depends on robust innovation ecosystems and substantial financial investments, supported by comprehensive policy frameworks addressing employment, cultural alignment and sustainable resource management. Policymakers should thus prioritize enhancing technological innovation capacities, mobilizing private sector investments, fostering community engagement, and effectively managing socio-economic transition to fully exploit the CE's potential for sustainable development.

The moderate explanatory power of regression models (adjusted R^2 : GGI = 0.38; CCEI = 0.47) reveals gaps in capturing variables like governance quality and social equity. The EU's Circular Economy Monitoring Framework must evolve to include granular metrics - such as carbon reuse rates, material circularity ratios, and inclusive indices - to reflect the socio-technical complexity of transitions. Globally, standardized CCEI reporting under the United Nations Framework Convention on Climate Change (UNFCCC) auspices would enhance transparency, enabling cross-national benchmarking and accountability.

As climate deadlines approach, this study demonstrates that circular carbon transitions are neither uniform nor inevitable. They require tailored, context-sensitive strategies that harmonize technological innovation, inclusive finance, and equitable governance. For the EU, leadership lies in leveraging its regulatory and financial heft to model post-growth paradigms. For emerging economies, the imperative is to leapfrog linear legacies through technology and collaboration. Ultimately, the success of these transitions hinges on reimagining prosperity not as a function of material accumulation, but as the resilience of interconnected socio-ecological systems.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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CIRCULAR ECONOMY STRATEGIES FOR SUSTAINABLE RESOURCE MANAGEMENT IN THE CONSTRUCTION INDUSTRY

DOI: 10.26341/issn.2241-4010-2025-16a-9-K02198

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Abstract

The construction industry is one of the largest consumers of natural resources, generating significant waste and contributing to environmental degradation. Circular economy (CE) strategies offer a transformative approach to sustainable resource management by closing material loops, reducing waste, and enhancing resource efficiency. This study examines the implementation of CE principles in the construction sector, focusing on design and construction aspects, material reuse, recycling, and innovative business models. By adopting strategies such as modular construction, cradle-to-cradle design, and the use of secondary raw materials, the industry can achieve significant reductions in environmental impact. The integration of digital tools, such as Building Information Modelling (BIM), enables more effective lifecycle management and resource tracking. Several challenges are discussed, such as consumer protection in the construction industry, product lifecycle extension through reducing, reusing, and repairing, as well as socio-economic impacts of circular economy practices on consumer rights and possibilities for overcoming barriers to circular economy implementation. The findings underscore the critical role of policy frameworks, technological advancements, and cross-sectoral partnerships in driving systemic change.

Key words: *Circular Economy, Construction Industry, Consumer Protection, Barrier to CE implementation.*

Introduction

The conventional construction industry (CI) has a linear and unsustainable approach, based on the “take, make, dispose” model (zu Castell-Rüdenhausen et al., 2021). The result is the CI being the among the world’s largest consumer of natural resources as well as waste producer. Therefore, a paradigm shift in the construction is required which will transform the linear economy model to a circular model.

The Ellen MacArthur Foundation defines the CE principle as “an industrial system that is restorative or regenerative by intention and design” and then extended as “a new way to design, make, and use things within planetary boundaries” (*Circular Economy Introduction - Overview*, 2021). Circular economy (CE) strategies offer a transformative approach to sustainable resource management by closing material loops, reducing waste, and enhancing resource efficiency. To decrease resource consumption, the CE is based on a systematic approach which integrates the supply chain of materials and enables waste elimination by closing the materials flow. Also, CE can be aligned with industrial ecology (Deutz et al., 2017), considering it is based on sharing of resources between different sectors through industrial symbiosis and preserving the value of materials to be reused.

Even though there have been certain efforts in the CI to implement CE strategies, many unresolved issues persist, among which quantification of resources flow, assessing the ecological consequences, develop indicators and criteria for assessment, as well as

identification of strategies (Petit-Boix & Leipold, 2018). The CE challenges in the construction industry are multi-dimensional, and the areas of major challenges are pinpointed as: design & construction strategies, supply chain management, policy strategies for CE adoption, End-of-Life (EoL) principles, CDW management strategies, information exchanges & analytics for CE (Antwi-Afari et al., 2021). Also, in the business sector, at the company level, there are no common CE practices in terms of evaluation of circularity performances (Sassanelli et al., 2019)

This paper aims to make an overview of the implementation of CE principles in the construction sector, focusing on design and construction aspects, material reuse, recycling, and innovative business models. Also, the integration of digital tools in the construction industry is investigated, with a focus on Building Information Modelling (BIM), which enable implementation of CE principles as well as more effective lifecycle management and resource tracking.

Further, several challenges are discussed, such as consumer protection in the construction industry, product lifecycle extension through reducing, reusing, and repairing, as well as socio-economic impacts of circular economy practices on consumer rights and possibilities for overcoming barriers to circular economy implementation.

The findings underscore the critical role of policy frameworks, technological advancements, and cross-sectoral partnerships in driving systemic change.

In the following sections the methodology of this research is laid out followed by analysis of Circular Economy Design and Construction aspects, Digital tools development and implementation in CE

Methodology

The research methodology used in this paper is consisted of eight steps, such as (Xiao & Watson, 2019): (1) formulating the research problem; (2) developing and validating the review protocol; (3) conducting a literature search; (4) screening for inclusion based on publication language and date range; (5) assessing the quality of selected studies; (6) extracting relevant data; (7) analyzing and synthesizing the data; and (8) reporting the findings.

Scoping review is used to analyze the existing literature and to provide broad overview of the research topic. A scoping literature review aims to provide a comprehensive overview of studies across various quality levels (Xiao & Watson, 2019). The target papers, the Web of Science and Scopus databases were used with theme-based specific and relevant keywords in this research area being made referenced to, e.g. ‘circular economy’, ‘construction industry’, ‘consumer protection’, ‘resource management’. The study findings are organized and presented in subsequent sections further in this paper.

Circular Economy Design and Construction aspects

The construction sector is regarded as having significant potential to transition towards a Circular Economy (CE) model by embracing sustainable products and technologies (Smol et al., 2015). By enhancing the use of waste materials throughout various phases of the building life cycle, it can lead to a decrease in material expenses and overall construction costs, while also minimizing embodied energy and other environmental effects associated with the overconsumption of construction resources (Akanbi et al., 2019).

The recent focus on CE and its potential integration into the construction industry has prompted a reevaluation of supply chains to better facilitate waste reduction and reuse, as effectively recovering construction materials for recycling or direct reuse is crucial for a

successful transition to CE (Akinade & Oyedele, 2019; Pan et al., 2015). These initiatives have potential to reduce the demand for new raw materials and decrease the volume of waste sent to landfills.

Although producing construction materials typically requires substantial raw materials and energy, a large portion of these resources ends up being downcycled or wasted after use. Regrettably, the industry currently captures only a small fraction of the economic value and durability of these materials under existing practices. Adopting CE principles effectively can address these challenges by promoting material recirculation, such as through designing for disassembly with mechanical joints, thereby extending the lifespan of construction components for reuse in future projects or different applications (Schiller et al., 2019).

Initially, the CE concept was shaped around the 3R's principles, Reduce, Reuse, and, Recycle. The 3R's principles were later extended with intention to stimulate the transition towards CE, organized in three strategies (Rahla et al., 2021).

The first strategy consists of three actions:

1. *Refuse*: Depreciate a product with dire impacts and proposing a different one with identical or better functions and fewer impacts;
2. *Rethink*: Intensify the product use and adopt smarter strategies as sharing economy or products with multiple functions; and,
3. *Reduce*: Decrease virgin materials and energy consumption while enhancing efficiency.

The Second strategy considers product lifespan extension and consists of:

4. *Reuse*: Reuse a discarded product that keeps the same functions by another user;
5. *Repair*: Fix a damaged product to give back its initial performance;
6. *Refurbish*: Renovate an outdated product to make it as a new one;
7. *Recycle*: Include, into the manufacturing process of a product, materials that reached their end-of-life use to make materials with same, higher (upcycle), or lower (downcycle) qualities; and,
8. *Recover*: A process of retrieving heat, electricity, or fuel from non-recyclable materials by incineration.

The third strategy is comprised of the actions:

9. *Remanufacture*: Make a product using parts from a damaged product that had the same functions; and,
10. *Repurpose*: Make a product using parts from a damaged product that had different functions.

The Ellen MacArthur Foundation outlined three principles to embrace CE (*Circular Economy Introduction - Overview*, 2021):

1. "to preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows."
2. "to optimize resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles."
3. "to foster system effectiveness by revealing and designing out negative externalities."

Researchers aggregate the broader effects of implementing Circular Economy (CE) principles in the construction sector, such as (Hossain et al., 2020):

- (i) enhancing the use of sustainable materials by fostering collaboration among various stakeholders;
- (ii) increasing material efficiency through the recycling and reuse of construction resources; and
- (iii) preventing unnecessary waste generation and landfill disposal.

To facilitate the transition to circular construction, researchers propose several strategies, such as (Stephan & Athanassiadis, 2018):

- (i) utilizing sustainable and durable materials,
- (ii) adopting the design for disassembly approach,
- (iii) incorporating modular and prefabricated components, and
- (iv) creating recovery systems, akin to take-back programs in the manufacturing sector.

Other researchers present three tools to expedite CE adoption within the construction industry in Scandinavian countries (Høibye & Sand, 2018):

- (i) defining requirements and documentation standards for the quality of building materials, including sharing information on technical performance and recycling rates, and enhancing traceability;
- (ii) creating guidelines for reused building products and those made from recycled materials, which involves establishing minimum standards and green resource efficiency criteria, as well as facilitating the exchange of reused products; and (iii) setting requirements for waste and demolition plans, encompassing the screening, mapping, and sorting of valuable building items for reuse, establishing recycling targets and end-of-waste criteria, along with providing guidelines and training for demolition firms.

Authors (Minunno et al., 2018) propose seven strategies for circular prefabricated building construction, such as:

- (i) reduction of waste based on lean production chain.
- (ii) utilization of by-products in the production of new materials or components.
- (iii) reuse of replacement parts and components
- (iv) encourage design of adaptability (for another cycle with different applications).
- (v) design for disassembly using BIM (to improve the end-of-life deconstruction),
- (vi) design with attention for ensuring recyclability of reused materials is in the sixth strategy.
- (vii) use of tracking system for gathering information, tracking locations and life cycle to facilitate the materials or components being put to another cycle after disassemble or deconstruction.

Multitude of design and construction strategies are examined regarding their level of application and readiness to be utilized by the industry (Eberhardt et al., 2022), such as: assembly/disassembly, material selection/substitution, adaptability/flexibility, modularity, prefabrication, secondary materials, durability, standardisation, component and material optimisation, reusing, existing building/components/materials, optimised shapes/dimensions, accessibility, layer independence, material storage, short use, symbiosis/sharing. The most frequent strategy in the literature is assembly/disassembly, followed by material selection/substitution and adaptability and flexibility (Eberhardt et al., 2022).

Three priority barriers of CE in the design stage are identified, such as (Mahpour, 2018): agency and ownership issues of end-of-life of materials; lack of integration of sustainable waste management and potential reuse and associated uncertainty in C&D waste management. Also, other design challenges are durability of materials, lack of incentives of recycled materials or components, uncertainty of material flows, lack of material banks, material passports etc.

One of the most crucial parameters in DfD is the choice of the construction technology and how building elements will be assembled and disassembled. Researchers (Crowther, 2005) outlined a total of 27 principles for Design for Disassembly (DfD) that can be

categorized as reducing the amount of input and reliance on safe and healthy secondary materials, standardizing the connection between materials and components while considering disassembly at the end-of-life, and retaining information regarding all materials and components involved in a building.

Authors (Eberhardt et al., 2022) suggest that in order to convey a comprehensive and uniform adoption of CE in the building industry a new design typology is required which will facilitate CE-oriented decision-making in a building context and which will prioritise design and construction strategies according to their potential for minimising building-related environmental impacts.

The 'design for disassembly' principles are noted to have a potential to reduce the buildings embodied greenhouse gas emissions by 36% in case the concrete elements are reused. In other case study where a building is 'upcycled', it is shown it can have 46% lower embodied greenhouse gas emission compared to the 'design for disassembly' building when building components and materials were reused and recycled (Rasmussen et al., 2019). Nevertheless the environmental implications of CE strategies need to be further investigated (Eberhardt et al., 2022).

Digital tools and Circular Economy

The rapid advancement of digital tools and technologies enables an increased uptake of CE in the construction industry. Information and Communication Technologies (ICT) are recognized as a critical part of the path towards CE (Singh et al., 2021) and ICT-based solutions are prioritised for future CE implementation (Demestichas & Daskalakis, 2020).

The digital technologies can be utilized in various domains, such as: communication technologies (communication infrastructure, wireless transmission etc.); computing technologies (ex. cloud computing); cyber-physical systems (additive manufacturing (3D printing); GreenSensing Virtual Enterprise, digital twins); data analysis and artificial intelligence algorithms (big data analytics, case-based reasoning, data and model integration, data visualization, dynamic game theory, dynamic programming, evaluation models, fuzzy logic, heuristic algorithms, machine learning, recommender systems, semantic processing, and others); Data Collection and Internet of Things (IoT) (asset tagging, building information modeling (BIM), satellite imaging, GIS, SCADA, and others); data management and storage; software and simulation technologies (digital platforms, PLM systems, simulation technologies, smartphone applications, software tools); smart grids and products.

Regarding data collection and IoT it is noted that among the most widely used technologies are smart tags and radio-frequency identification (RFID) (Demestichas & Daskalakis, 2020). The smart tags are small devices which combine memory, data processing and communication services. Smart tags enable unique identification of items and tracking of the environmental conditions in which a product is maintained. This technology enables improved handling of resources and facilitates decision-making (Gligoric et al., 2019). The RFID tags, have a small microchip and enable identification of objects, using electromagnetic fields (Tuyls & Batina, 2006). Further, IoT is a global network of interconnected objects which have unique addresses and can communicate using standard protocols (Gubbi et al., 2013) and can have a range of implementation in resource management.

Building Information Modelling (BIM) enables creation of an accurate virtual model of a building and simulating all building life-cycle stages. The BIM model does not only represent the building in three dimensions (3D), but adds the dimension of time (4D), costs (5d) etc., providing opportunities for multitude dimensions. The BIM model integrates all building systems and technologies and enables identification of potential design, construction, or operational issues. In this regard, RFID and BIM technologies provide the building

elements to be more traceable, adaptable, and reusable in new designs. BIM provide analysis of the disassembly and deconstruction of a building, ensuring efficient materials recovery as well as for checking if building designs are compliant with the concepts of CE (Akanbi et al., 2019).

However, it is noted that there is an insufficient uptake of ICT technologies for CE in construction industry. Authors investigate several challenges in adopting circular ICT solutions, such as (Demestichas & Daskalakis, 2020): consumer attitude, corporate responsibility, cooperation and trust, data uncertainty, economic, environmental impact, information use, lack of capacity, policies, product design and security.

Data uncertainty is identified as another obstacle for the CE. Van Schalkwyk et al. underline that some simulation models are imperfect and need to be enriched with further data (van Schalkwyk et al., 2018). Also, "Noise" in lifecycle big data is noted with a possible negative impact on the accuracy and reliability of decisions (Zhang et al., 2017).

Also, the lack of government laws and regulations is also noted as a barrier in the CE uptake (Rizos et al., 2016). Authors (Watkins et al., 2013) note that current legislation does not adequately support the development of potential symbiotic products that make use of multiple residue streams of industrial processes.

CE Business models in the construction industry

A Business Model (BM) is a sustainable method of conducting a business (Nielsen & Lund, 2014). The successful implementation of the principles of CE, in large part depends on the business models which will be used. As the construction business environment is becoming more competitive, the Circular Economy Business Model (CEBM) are receiving considerable attention. As previously discussed, the implementation of CE in the construction industry imposes reforms in all value chains in the industry.

The distinctions in supply chains between traditional BMs and CEBM arise from the essential processes of closing, slowing, and streamlining material and energy flows (Bocken et al., 2016).

Value in a conventional BM is frequently focused on the financial benefit to investors and clients. In a CEBM, value is viewed more broadly, considering the environment, society, and a more comprehensive range of value chain partners (Huovila & Westerholm, 2022). Even more, the CEBM model needs to be integrated all phases of the building life-cycle, at every stage, from planning and design through construction.

Shafer et al. (Shafer et al., 2005) examined twelve criteria and found forty-two elements categorised as strategic decisions, value networks, and creating and capturing value. Others developed a framework that includes a customer interface, core strategy, strategic resources, and value network (Hamel, 2001).

Researchers propose categorization of existing CEBM in nine categories: product life extension, product as a service, waste as a resource, circular supplies, resource recovery, resell, remanufacture, sharing platforms, and repair (Guerra et al., 2021). Others (Mackenbach et al., 2020) identified four CEBMs, refurbishment and reuse, repair and maintenance, product as a service, and upcycling, considering their adaptability, applicability, and usability in modular construction. However, there is a scarce research on CEBM in the construction industry and none of these studies have properly defined or elaborated on the practical applicability of the model (Jayakodi et al., 2024). Therefore, researchers define CEBM from the perspective of a construction organisation (Jayakodi et al., 2024). The organisational aspects are required to ensure the integration of CE in all supply chain processes in the construction.

Also, there is a need to reconsider ownership by introducing new ideas like product leasing or product-as-a-service (Cimen, 2021; Hartwell et al., 2021) as well as to support supply-chain models which encourage stakeholder collaboration and value co-creation (Hossain et al., 2020).

Six elements are identified for CEBM in CI (Jayakodi et al., 2024): value creation, value delivery, value proposition, value capture, the collaboration of stakeholders, and the lifecycle perspective, Figure 1.

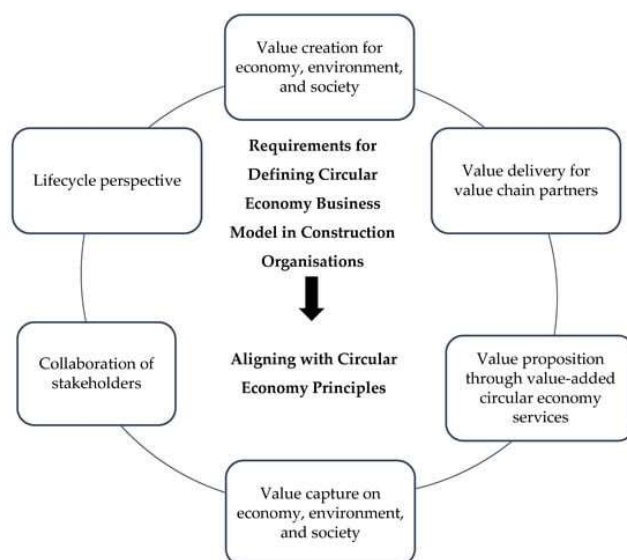


Figure 1. Requirements for defining circular economy business model in construction organisations (Jayakodi et al., 2024)

Consumer protection in the construction industry

In this section, several challenges are discussed, such as consumer protection in the construction industry, product lifecycle extension through reducing, reusing, and repairing, as well as socio-economic impacts of circular economy practices on consumer rights and possibilities for overcoming barriers to CE implementation. In the paradigm shift of sustainability and CE, the consumption behaviour is also changing. The alternative and collaborative ways of consumption, such as sharing, gifting, renting, bartering, swapping, lending, and borrowing are intensifying the use of idle assets, decrease the need for new product purchases, and promote possession reuse (Böcker & Meelen, 2017). Studies show that policy and governance, permits and specifications, technological limitation, quality and performance, knowledge and information, and, finally, the costs associated with the implementation of CE model at the early stage are the main barriers (Purchase et al., 2022), and they note an urgent need to introduce a global framework and a practicable pathway to allow companies to implement such models, regardless of their scale and location.

A considerable number of studies have explored consumer acceptance of remanufactured, refurbished, recycled, reused, or shared products as contributing to past circular strategies relating to slowing or closing the loop (Shevchenko et al., 2023).

The consumer activity that contributes to slowing or closing the material loop can be defined as a CE-oriented consumer activity, and researchers illustrate the tri-dimensional role of consumer activity in the CE model, Fig. 1. (Shevchenko et al., 2023).



Figure 1. Tri-dimensional role of the consumer in the CE (Shevchenko et al., 2023)

Consumer protection as the practice of safeguarding buyers of goods and services, and the public, against unfair practices in the marketplace also needs to deal with the new ongoing tide of CE transformation. While the CE practices hold the potential to significantly reduce the environmental footprint in construction industry, they also raise concerns related to consumer protection (CP). The consumer protection aims to protect consumers against defective goods, unsatisfactory services, unfair trade practices etc.

The CP in the construction industry should be aimed to provide consumers, i.e. property buyers, tenants, and investors, product quality and safety. Recycled and reused materials must meet stringent safety standards to guarantee that buildings constructed with these materials are structurally sound and free from health hazards. For instance, reclaimed wood, recycled concrete, or repurposed steel must be thoroughly inspected for contaminants or defects that could compromise building integrity or occupant safety. Regulators and industry stakeholders must establish robust certification systems and transparent documentation practices to assure consumers of the quality of materials and construction methods employed.

Transparency is another cornerstone of consumer protection in the circular economy. Buyers and tenants need access to detailed information about the materials and methods used in construction projects. Material passports—digital documents that provide comprehensive data about the origin, composition, and lifecycle of building materials—can play a crucial role in achieving this transparency. These passports empower consumers to make informed decisions and hold construction companies accountable for their environmental claims.

Economic considerations also intersect with consumer protection. The adoption of circular practices may lead to cost variations, with some materials or methods initially being more expensive due to limited supply chains or technological constraints. It is vital that consumers are not unfairly burdened with these costs. Policymakers can address this issue by offering subsidies or incentives for sustainable construction practices, thereby balancing affordability with environmental responsibility.

Lastly, legal frameworks must evolve to support consumer protection in the circular economy. Clear guidelines on warranties and liabilities are essential to address potential disputes over the durability and performance of recycled materials. Moreover, regulatory bodies should enforce strict penalties for greenwashing—the practice of misleading consumers about the environmental benefits of a product or service—to uphold ethical standards in the industry.

Conclusions

This research provides a comprehensive overview of the implementation of Circular Economy (CE) principles in the construction sector, with a particular focus on design and construction practices, material reuse, recycling, and innovative business models. Additionally, it investigates the integration of digital tools within the industry, emphasizing the role of Building Information Modelling (BIM) in enabling CE principles and enhancing lifecycle management and resource tracking. The study highlights several key challenges, including consumer protection in the construction sector, strategies for extending product lifecycles through reducing, reusing, and repairing, and the socio-economic implications of CE practices on consumer rights. It also explores pathways to overcome barriers to CE implementation.

The findings of the research underscore the pivotal role of policy frameworks, technological advancements, and cross-sectoral collaborations in fostering systemic change. By adopting strategies such as Design for Disassembly (DfD), adaptability, and materials upscaling, the construction industry can achieve significant reductions in environmental impact. Furthermore, the study emphasizes the need to address specific challenges, such as ensuring consumer protection, extending the lifecycle of construction products, and mitigating socio-economic impacts through equitable and sustainable CE practices.

To successfully adopt CE business models, it is crucial to identify key stakeholders, resources, activities, and services where CE can be effectively implemented. These models should be supported by a circular cost structure and benefit from the integration of digital technologies to facilitate new circular design and construction approaches. The literature reviewed in this study demonstrates that strategies such as adaptability, prefabrication, the use of sustainable and durable materials, and DfD principles are effective in achieving circular buildings. Future research should focus on evaluating the implications of various CE design and construction strategies in terms of consumer satisfaction, acceptance, and protection.

In conclusion, integrating CE principles into the construction industry also requires prioritizing consumer protection as a prerequisite for the widespread adoption of CE practices. Critical aspects such as safety, transparency, affordability, and robust legal frameworks must be emphasized. These measures will not only strengthen consumer confidence but also propel the construction industry towards a more sustainable and resilient future.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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THE CONTRIBUTION OF LOCAL GOVERNMENT ORGANIZATIONS AND CITIZENS TO THE ACHIEVEMENT OF THE 12TH SDG IN GREECE

DOI: 10.26341/issn.2241-4010-2025-16a-10-K02228

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Abstract

One of today's most pressing global challenges is ensuring sustainable production and consumption patterns, as outlined in Sustainable Development Goal 12 (SDG 12) of the United Nations 2030 Agenda. Waste generation—from food and construction waste to plastics and electronic equipment—is closely linked to unsustainable consumption models, posing significant environmental, social, and economic risks. This paper investigates the implementation of SDG 12 in the Greek context, with particular emphasis on waste and refuse management policies.

Adopting a qualitative policy analysis approach, the study explores legislative frameworks, strategic planning, and funding mechanisms at the European, national, and local levels. Special focus is placed on the role of local government organizations (LGOs) in operationalizing national strategies, citizen engagement, and behavioural practices that support sustainable waste management.

The study identifies challenges and progress in achieving waste reduction, reuse, and recycling targets from official EU documentation, national legislation, and policy instruments. Comparative insights are also offered regarding best practices from other European Union member states.

The findings underline the importance of a multi-level governance model integrating top-down regulatory action with bottom-up civic participation. The paper concludes by proposing targeted policy recommendations and individual actions to enhance Greece's alignment with SDG 12 and support the broader transition toward a circular economy.

Keywords: *SDG 12, Greece, waste management, circular economy, local governance, citizen participation*

Introduction

The present study focuses on waste and refuse management, one of the 17 Sustainable Development Goals (SDGs) adopted on 25 September 2015 during the 70th General Assembly of the United Nations and established by the United Nations (UN).

Regarding the subject of this work, it is important to note that more than 7 billion of us produce waste daily. Astonishingly, half of this waste is not collected, treated, or safely disposed of, creating a global waste crisis. Generating massive volumes of municipal solid waste (MSW) and its mismanagement creates serious environmental problems with social, political, and economic implications. Developing integrated waste management systems is imperative to reduce the impact on the environment, human health, and the economy.

More specifically, waste management in the European Union is a key sector in transitioning to a circular economy and consolidating overarching goals such as secure access to resources, social well-being, economic development, and environmental protection. Furthermore, the rapidly growing waste management industry enables the use of waste as a resource and the recovery of raw materials. At the same time, the health and environmental impacts of waste management must also be considered (European Commission, 2015).

Before delving deeper, it is essential to briefly highlight some of the major concerns surrounding waste management to fully understand why it constitutes such a critical issue in our time.

Firstly, globally, we produce vast quantities of waste: food and garden waste, construction and demolition debris, mining waste, industrial waste, liquid waste, old televisions, cars, batteries, plastic bags, paper, sanitary waste, old clothes and furniture, and the list goes on. The quantity of waste we generate is closely tied to our consumption and production patterns. The overwhelming number of products entering the market is a further challenge. Demographic changes—such as the rise in single-person households—also impact the volume of waste produced (e.g., goods are increasingly packaged in smaller units).

At the same time, it is widely known that poor waste management contributes to climate change and air pollution and directly affects many ecosystems and species. Some ecosystems, such as marine and coastal areas, can be severely affected by inadequate waste management and illegal or "irresponsible" individual littering. Marine litter is increasingly concerning—not only for aesthetic reasons: entanglement and ingestion are serious threats to many marine species.

Waste also indirectly impacts the environment, as any material not recycled or recovered represents a loss of raw materials and other inputs used throughout the value chain—in the production, transport, and consumption phases. The environmental impacts across the life cycle of a product are significantly greater than those solely linked to waste management (EEA Signals 2014 – *Well-being and the environment. Waste: a problem or a resource?*, 2021).

Moreover, illegal activities such as dumping, burning, and exporting play a role, though it is difficult to estimate their full extent or impact accurately. In general, directly or indirectly, waste affects our health and well-being in numerous ways.

Therefore, it is reasonably clear that the SDGs cannot be achieved unless waste management is treated as a priority. Failed economic models treat resources as infinite, and current consumption patterns encourage the perception of their endless availability. We must recognize that we cannot continue with a growing and increasingly urbanized global population without sorting and managing waste appropriately.

The goal of this study is to present the long-term strategic planning of waste management through legislative and administrative measures, infrastructure projects, and funding initiatives by the European Union and to investigate, as thoroughly as possible, the

implementation of the proposals and projects of the National Waste Management Plan (NWMP) for the management of Municipal Solid Waste (MSW) by the Regional Authorities.

Accordingly, the main themes of this paper include a comprehensive description of the relevant SDG, an analysis of the current situation, EU policies, actions, and funding instruments; Greece's national policies and projects, and the role of Local Government Organizations (LGOs) in ineffective waste management. Finally, the paper attempts to present concise proposals for individual actions that can contribute to achieving this goal.

Chapter 1: Description of SDG 12 (Responsible Consumption and Production): Waste and Refuse Management

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030. This paper focuses on Goal 12, which concerns the "promotion of sustainable consumption and production patterns (SCP)," and more specifically, on the target related to environmentally sound waste and refuse management.

According to the United Nations Regional Information Centre (UNRIC), the sub-targets of this goal include:

- By 2030, per capita global food waste will be halved at the retail and consumer levels, and food losses along production and supply chains, including post-harvest losses, will be reduced.
- By 2020, achieve environmentally sound management of chemicals and all wastes throughout their life cycle, per agreed international frameworks, and significantly reduce their release into the air, water, and soil to minimize adverse impacts on human health and the environment.
- By 2030, substantially reducing waste generation through prevention, reduction, recycling, and reuse.

(Goal 12 – Responsible Consumption and Production, <https://unric.org/el/στοχος-12-υπευθυνη-καταναλωση-και-παρα/>)

First, let us clarify the waste terminology and its types and classifications. A fundamental legislative text for the definition of waste is Directive 2008/98/EC of the European Parliament, which states: "*Waste means any substance or object which the holder discards or intends or is required to discard.*"

As for waste classification, many scholars group waste into various categories with different characteristics. Based on their physical state, waste can be classified into three main types:

- Liquid
- Solid
- Gaseous (Amasoumo & Baird, 2016)

Liquid waste refers to solid residues dissolved in a liquid medium (water or some organic solvent) and constitutes one of the main sources of environmental pollution today. Major sources include domestic, municipal, and industrial waste. (*modernanalytics.gr, Chemical and Microbiological Analyses › Waste*)

Solid waste includes urban refuse, industrial waste (e.g., packaging remnants, empty barrels, cardboard, plastic wrappings), construction and demolition debris, petroleum-based waste, agricultural and livestock waste, mining and excavation waste (from both land and sea), sludge from urban wastewater treatment and industrial processes, hospital waste, tyres, and scrap materials.

(modernanalytics.gr, *Chemical and Microbiological Analyses* › Waste)

Gaseous waste (or aerosols) includes urban aerosols and gaseous by-products from processing, typically consisting of fine particulate matter or misted liquid substances (e.g., solvents, acids) with high volatility. (modernanalytics.gr, *Chemical and Microbiological Analyses* › Waste)

Additionally, the **waste producer** is defined as any person whose activities generate waste (the original producer) or any person involved in pre-processing, mixing, or other operations that alter the nature or composition of the waste. The **waste holder** is either the producer or the natural/legal person possessing the waste.

Waste management itself is also defined in various ways. Solid waste management refers to handling waste in a manner that is safe for both the environment and the public, and it is inherently interdisciplinary, incorporating theory and practice from economics and public administration (Tchobanoglous et al., 1993). The main objectives of waste management are to protect human health and the environment and to conserve resources (Brunner & Fellner, 2007).

Directive 2008/98/EC states, "*Waste management means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites.*"

To support stakeholders in waste management regarding the complex issue of waste definition and classification, the European Commission has published a guidance list. This **European Waste Catalogue (EWC)** (see Appendix) classifies waste by its origin and its risk to human health and the environment (Wild et al., 2013).

The EWC is divided into 20 chapters, corresponding to 20 broad activity categories. Each category is further subdivided, specifying production activities and identifying specific types of waste.

Furthermore, the catalogue categorizes waste based on the risk it poses:

- **Inert waste:** Waste that does not undergo significant physical, chemical, or biological changes.
- **Hazardous waste:** Waste containing explosive, infectious, flammable, corrosive, or toxic substances or those causing mutagenesis, carcinogenesis, teratogenesis, irritation, or other reactions. These are marked with an asterisk (*) in the EWC.
- **Non-hazardous waste:** Waste that contains no hazardous characteristics and poses no harm to health or the environment.

At a European level, the **main principles of waste policy** include:

- The principle of health and environmental protection.
- The waste hierarchy principle.
- The proximity principle (disposal close to the point of generation).
- The producer responsibility principle.
- The life-cycle principle.
- The precautionary and remediation principles. (Amasoumo & Baird, 2016)

The **fundamental goals** of waste management are:

1. Waste prevention,
2. Recovery (recycling and secondary raw material or energy production),
3. Safe disposal of non-recoverable waste.

Finally, a key policy tool is the **waste hierarchy**, which evaluates actions from most to least favourable regarding resource and energy use. It aims to maximize the practical benefits of products and minimize waste generation. Proper application of the waste hierarchy can contribute to reduced greenhouse gas emissions, less pollution, energy savings, conservation of resources, job creation, and green innovation (*Wikipedia, Waste hierarchy*).

Chapter 2: Description of the Current Situation – Problems

Given the rapid urbanization and growing global population, annual waste generation worldwide is projected to reach **3.4 billion tonnes** within the next 30 years, up from **2.01 billion tonnes** in 2016.

According to the study *Material-Efficient Utilization of Waste Oils—Biodegradability and Other Chemical Properties of Vegetable Recycling Oils* (2012), high-income countries, although comprising only 16% of the global population, generate over one-third (34%) of the world's waste. In addition, the East Asia and Pacific region is responsible for nearly one-quarter (23%) of total waste. It is also projected that by 2050, waste generation in Sub-Saharan Africa will triple, while in South Asia, it will double. (*THE WORLD BANK Website, 2018*)

Simultaneously, waste management and disposal practices have significant environmental implications. For instance, landfilling occupies land resources and may pollute the air, water, and soil depending on construction quality, while incineration can lead to atmospheric emissions. Landfills, which are considered the final option in the waste hierarchy, release methane—a highly potent greenhouse gas linked to climate change. Methane is formed by microorganisms acting on biodegradable waste such as food scraps, paper, and yard waste. Once waste is collected, it is transported and processed, releasing carbon dioxide—the most prevalent greenhouse gas—as well as other air pollutants, including particulate matter. Based on the volume, composition, and treatment methods of waste, it is estimated that **1.6 billion tonnes of CO₂-equivalent emissions** were generated globally in 2016 from waste treatment and disposal—approximately **5% of total global emissions**.

As **Laura Tuck**, former Vice President for Sustainable Development at the World Bank, aptly stated:

"Poor waste management harms human health and the local environment, contributing to the climate challenge. Unfortunately, the poorest in society are often the most adversely affected by inadequate waste management. However, it does not have to be this way. Our resources must be used and reused continually so they do not end up in landfills."

Solid waste management is critical to developing sustainable, healthy, inclusive cities and communities. Nevertheless, it remains overlooked, particularly in low-income countries. While over one-third of waste is recovered through recycling and composting in high-income nations, **only 4%** of waste is recycled in low-income countries.

Supporting countries in making strategic decisions regarding financing, policy, and planning of Solid Waste Management (SWM) systems is critical. Key solutions include:

- **Providing funding** to countries most in need—especially those experiencing rapid development—for implementing state-of-the-art waste management systems.
- **Supporting large waste-producing regions** in reducing plastic and marine litter through comprehensive waste reduction and recycling programs.
- **Food waste is reduced through consumer education, organic waste management, and coordinated programs.**

Since 2000, the World Bank has committed **over \$4.7 billion** to more than **340 solid waste management projects** across the globe. (*THE WORLD BANK Website, 2018*)

Consequently, the overarching aim of waste management policies—particularly those of the European Union, which are a focal point of this paper—is to mitigate waste's environmental and health impacts and improve resource efficiency. The long-term objective is to **reduce waste generation** and, when unavoidable, to promote waste as a **resource**, achieving **higher levels of recycling** and ensuring **safe final disposal**.

Chapter 3: Policies and Actions – European Union Funding for Waste and Waste Management

In 2015, the European Commission adopted the **Circular Economy Action Plan**, establishing a long-term strategic framework to promote **waste prevention**, increase **recycling and reuse**, and reduce **landfilling and incineration**. The plan outlines specific measures to assist businesses, citizens, and public authorities in benefiting from the transition to a greener and more resilient economy.

The circular economy seeks to "close the loop" of product life cycles by maintaining the value of resources within the economy for as long as possible, thus promoting more efficient use of raw materials, products, and waste. It contributes directly to achieving the European Union's environmental and climate objectives while fostering local and regional development. Waste prevention, eco-design, and similar practices contribute to cost savings, increased business turnover, and job creation—particularly in the sectors of **reuse, refurbishment, repair, and product innovation**. The circular economy is also one of the 12 themes of the **Urban Agenda for the EU**, through which cities collaborate with the European Commission, Member States, and stakeholders to address waste, resource efficiency, and the sharing economy.

The **EU Cohesion Policy** is the cornerstone of circular economy implementation. The 2014–2020 investment framework allocated substantial resources to **waste management, resource efficiency, and low-carbon investments**. Investment data can be accessed through the European Commission's **Open Data Platform** and are often complemented by private funding and other EU instruments such as **Horizon 2020, LIFE, and COSME**. (*European Union Website, Cohesion Policy Support for the Circular Economy*)

EU investments are tailored to local needs and opportunities and have supported:

- Greater recycling capacity,
- Improved waste management systems,
- Resource and energy efficiency,
- Strengthening of the bio-economy,
- Innovative product design solutions,
- New business models, and
- Creation of green jobs.

During 2014–2020, the EU allocated approximately **€4.3 billion** to actions focused on waste prevention, reuse, and recycling. In less-developed regions, investments targeted critical infrastructure for waste treatment, resulting in an **additional 4.5 million tonnes/year of recycling capacity**. Furthermore, **€1.5 billion** was invested in green production and resource-efficient processes for **Small and Medium-sized Enterprises (SMEs)**. The circular economy package also promotes **water reuse**—many EU regions already recycle treated wastewater for park irrigation, street cleaning, or groundwater replenishment.

In May 2018, new legislative targets on recycling and landfilling were adopted. Specifically, **Directive 2018/851** of the European Parliament set ambitious targets for the **reuse and recycling of municipal waste—at least 55% by weight by 2025 and 65% by 2035**. Additionally, the share of municipal waste going to landfills will be reduced to **10% by 2035**.

(*European Commission, 2018a & 2018b*)

In March 2020, the European Commission proposed a new **Circular Economy Action Plan** aligned with the EU's goal of **climate neutrality by 2050** under the **European Green Deal**. This updated plan focuses on waste prevention and management and aims to strengthen EU leadership in green innovation and competitiveness at the global level. (*European Parliament Website, Circular Economy Transition Plan*)

On 9 February 2021, the European Parliament called for **stricter recycling regulations** and **legally binding targets** on material use and consumption, noting that limited resources and climate challenges necessitate a shift from the "take-make-dispose" model to a **climate-neutral, environmentally sustainable, and fully circular economy** free from toxic pollutants by 2050.

(European Parliament Website, Circular Economy Transition Plan)

Cohesion policy, however, extends beyond funding mechanisms. It offers a **comprehensive policy framework** for integrated regional development, emphasizing each region's unique strengths in implementing circular economy principles. It closely cooperates with local stakeholders, supporting regional authorities in building capacity and driving sustainable transformation. *A summary of the EU's legislative framework on waste management is provided in the Appendix.*

Project Example – Slovenia

With support from EU funds, Slovenia has achieved remarkable progress in waste recycling. In particular, the citizens of **Ljubljana** now benefit from a more sustainable waste management system. Since joining the EU, the Slovenian capital has enhanced **separate waste collection, increased recycling rates, and reduced landfill waste by 59%**. Investments also prioritized **waste prevention** and **reuse initiatives**. Ljubljana currently produces **41% less waste per capita** than the EU average and has **abandoned plans to construct two incinerators** originally scheduled.

A central element of this transformation is the **Ljubljana Regional Waste Management Centre**, an EU-funded project that initially served **17 municipalities** and later expanded to **37**, rendering additional waste treatment facilities unnecessary. *(European Union Website, Cohesion Policy Support for the Circular Economy)*

Chapter 4: Greece's Policies and Projects for Achieving the Waste Management Goal

Greece's newly emerging environmental policy sector is currently undergoing a transitional phase, focusing on addressing long-standing challenges across several thematic areas, including waste management, wastewater, environmental permitting, and renewable energy. The country has recently developed key strategies in circular economy, climate change adaptation, and biodiversity. These are supported—among other initiatives—through the **EU's LIFE Programme**, particularly via three integrated projects with a total budget exceeding **€47 million**, expected to leverage an additional **€1.5 billion** in complementary funding over the coming years.

Nevertheless, Greece continues to face long-term challenges in several environmental sectors. Identifying investment needs for green technologies and sustainable solutions and ensuring sufficient funding will be essential to achieving the country's climate and energy goals and shaping a new development model. While EU funding has already contributed to building a greener economy in Greece, further investment is required—especially in **energy and transport infrastructure**—to promote sustainable development. In 2019, new initiatives were launched to address environmental and energy challenges, including investment plans focused on **efficient waste management** and **clean energy** to boost the competitiveness of the renewable energy sector.

The first attempt to establish a **national waste management strategy** at both national and regional levels occurred in 1997 with **Joint Ministerial Decision (JMD) 113944/97 (Official Gazette B' 1016/1997)**. This was later supplemented by **Ministerial Decision 14312/1302/00 (Official Gazette B' 723/2000)** and replaced by **JMD 50910/727/2003 (Official Gazette B' 1909/2003)** in order to ensure full compliance with **EU Directive**

91/156/EEC. JMD 50910/727/2003 established the guidelines, measures, and procedures required to mitigate the negative environmental impacts of waste through improved management.

Additionally, the **National Waste Management Plan (NWMP)** defines Greece's overarching waste policy and serves as the strategic framework for developing Regional Waste Management Plans (RWMPs), which cover the entire national territory.

The NWMP outlines national strategy, objectives, and quantitative/qualitative targets for managing various waste streams. It also specifies the policy axes and necessary actions in alignment with Greek and European legislation. The NWMP is prepared by the **Ministry of Environment and Energy** and approved by the **Council of Ministers**, ensuring political commitment and a unified national approach to waste management. (*Ministry of Environment & Energy Website, Solid Waste Management*)

The central goal of the NWMP is to promote environmental and public health protection by developing strategic policies and action plans. In pursuit of this objective—and ultimately of the legal requirement to transition toward a circular and sustainable economy—two core actions are emphasized:

1. **Waste prevention and reduction**, and
2. **Reduced use of natural resources**, with improved efficiency in their utilization.

Regarding waste, the plan sets an ambitious target: to reduce **landfilling of Municipal Solid Waste (MSW)** to less than **10% by 2030**.

The NWMP is aligned with Greece's **National Energy and Climate Plan (NECP)**, ensuring a coherent approach to securing **long-term competitiveness**, promoting **sustainable economic growth**, and supporting **job creation** in the context of the EU's 2050 climate neutrality goal.

(*Official Government Gazette, Approval of the National Waste Management Plan – FEK A' 185*)

The latest NWMP (2020–2030) introduces ambitious targets aligned with EU legislation and the **Circular Economy Package**, particularly concerning **source separation**, **recycling**, and **reuse**. It aims to achieve:

- **At least 55% preparation for reuse and recycling of MSW by weight by 2025 and 60% by 2030**,
- Limiting **landfilling to 10%** of generated MSW by 2030.

To reach these goals, the NWMP outlines concrete measures and responsible stakeholders. It particularly emphasizes:

- Expansion of **separate waste stream** collection,
- Promotion of **source separation**,
- Implementation of the **"Pay-As-You-Throw"** principle,
- Upgrading and reinforcing **Material Recovery Facilities (MRFs)**.

(*Ministry of Environment & Energy Website, Solid Waste Management*)

Furthermore, the plan includes **public awareness and outreach campaigns**, which are critical for achieving these targets. It also introduces a series of **legislative measures** aimed at:

- Waste prevention,
- Enhanced recycling, and
- Improving overall waste management in line with the strategic directions of the NWMP.

Chapter 5: Policies and Actions of Local Government Organizations (LGOs) for Achieving the Waste Management Goal

In Greece, local Government Organizations (LGOs) are public legal entities established within specific territorial jurisdictions that administrate local affairs. Their governing bodies

are elected through universal suffrage by the local electorate. Implicit in the term is both a **geographical and demographic definition**, as each LGO has a defined area, headquarters, and population. According to the current administrative structure of Greece, every point in the country (except for Mount Athos) falls under the jurisdiction of a **primary-level LGO** (municipality) and a **secondary-level LGO** (region). (*Wikipedia, Local Government Organizations*)

The current administrative division of the country is detailed in **Official Gazette B' 1327/17.4.2019**, under the title: *"Primary and Secondary Local Government Organizations of the Country, in accordance with Law 3852/2010, as amended."* Ministerial Decision **28549/2019** provides an exhaustive list of all municipalities and regions, as established by Articles 1 and 3 of Law **3852/2010**.

Regarding the responsibilities of municipalities, **Article 75 of Law 3463/2006** specifies that they are responsible for the **cleanliness of public spaces, waste collection and management, construction and maintenance of sewage and biological treatment systems**, and the **implementation of preventative and corrective measures** to protect waste disposal sites, including fire safety compliance.

Furthermore, under **Article 228 of Law 4555/2018**, primary-level LGOs (municipalities) are assigned the following waste management responsibilities:

- Developing and implementing **Local Waste Management Plans (LWMPs)** and waste reduction/prevention programs;
- Establishing separate collection systems for at least **four recyclable waste streams**: glass, paper, plastics, and metals;
- Organizing a separate collection of **biowaste**, particularly from restaurants, households, large producers, and green waste from parks and gardens;
- Collecting and transporting **residual mixed municipal waste** and **source-separated recyclable materials** to suitable recycling, recovery, or disposal facilities following the respective **Regional Waste Management Plans (RWMPs)**;
- **Eradicating illegal waste disposal sites** and restoring existing **Uncontrolled Waste Disposal Areas (UWDA)**;
- Conducting **citizen awareness and outreach campaigns** within the municipal boundaries and encouraging actions aligned with circular economy principles;
- Registering all relevant data in the **Integrated Waste Management Information System**, developed by the General Secretariat for Waste Coordination and Management of the Ministry of the Interior, for monitoring project implementation and target achievement.

(Article 228, Law 4555/2018)

One notable initiative, **"Open Municipality – Active Citizens,"** includes proposals for promoting **recycling and source separation** at the municipal level. (*Theofilopoulos G., Open Municipality – Active Citizens, Recycling & Source Separation: Our Proposals*)

In parallel, each region's **RWMP** constitutes a comprehensive framework for managing all waste streams generated within its boundaries. It sets forth general management guidelines in alignment with the national NWMP and Articles 22 (Management Plans) and 23 (Waste Prevention Programs). The RWMP proposes appropriate measures that promote, in a hierarchical and integrated manner:

- a) Prevention,
- b) Reuse,
- b) Recycling,
- d) Other forms of recovery (e.g., energy recovery), and
- c) Safe final disposal.

The RWMP's policy pillars are centred on:

- **Preserving the public character** of waste management to protect public health and the environment under a sustainable development framework for the benefit of society;
- **Integrated planning** for all waste streams in the Attica Region at both regional and local levels, consistent with the National Waste Prevention Strategy;
- Ensuring **high-level protection of the environment and public health**, with adequate and appropriate infrastructure for collection, recovery, and disposal;
- Promoting **resource-efficient practices** for the benefit of society in an equitable manner;
- Strengthening the implementation of **Extended Producer Responsibility (EPR)** mechanisms;
- Enhancing the **quality of municipal waste management services** provided to citizens and businesses;
- Fostering **public engagement and participation** in waste-related initiatives;
- **Rationalizing service costs** and encouraging environmentally and economically sustainable investments.

(Special Inter-Municipal Association of the Attica Region, 2021)

Part II – Chapter 6: Proposals for Individual Actions to Achieve the Waste and Refuse Management Goal

Achieving sustainable waste management is not solely the responsibility of governments and institutions—it also depends heavily on the **daily behaviour of individuals**. The following actions, though simple, can significantly contribute to minimizing waste generation and promoting circular practices at the household and community levels.

Composting

Though often perceived as an advanced environmental practice, **composting** is a simple and highly effective method to divert food waste from landfills. Approximately **25% of household waste** could be removed from the waste stream and converted into nutrient-rich compost. While composting may require a certain commitment, the return on investment is tangible: within **3 to 12 months**, households can produce natural fertilizer for their gardens or plants.

Responsible Recycling

Recycling standards differ across regions. Familiarizing oneself with **local recycling guidelines** is crucial to avoiding common mistakes—such as recycling contaminated materials (e.g., greasy pizza boxes), which may result in entire loads being sent to landfills. Effective recycling begins with understanding **what is and is not recyclable** in each local context.

Waste Auditing

Awareness begins with self-observation. By monitoring one's daily waste output—**maintaining a record for a day or week**—individuals can identify opportunities to **replace disposable items with reusable alternatives**. This habit can gradually evolve into a **personal goal** to reduce single-use consumption and embrace more sustainable practices.

Sustainable Purchasing Habits

Households can reduce waste by purchasing products with **minimal or recyclable packaging**. Not all plastics are created equal: the **number within the recycling triangle symbol** indicates the recyclability of each item. In general:

- **PETE (1) and HDPE (2) are highly recyclable.**
- **PVC (3), LDPE (4), PP (5), and PS (6) are less or not recyclable.**
- **Type 7 (Other) is generally non-recyclable.**

Choosing products with packaging types 1 or 2 can ensure greater compatibility with local recycling systems.

Reducing Kitchen Disposables

Convenient items like plastic wrap, aluminium foil, paper towels, and zip-lock bags generate a significant volume of kitchen waste. Alternatives like parchment paper, reusable silicone baking sheets, and washable cloth napkins can reduce disposable usage and waste production.

Buying and Donating Second-Hand Items

Second-hand goods, especially clothing, are valuable to a sustainable consumption model. Purchasing or donating used clothing extends product life cycles and reduces textile waste. Initiatives like **Fabric Republic** offer structured systems for managing surplus clothing in line with **EU Directive 2008/98/EC**, contributing to developing a **European recycling society**. Moreover, buying second-hand supports **local charities** encourages **conscious consumption**, and promotes **cost savings**.

Supporting Local Farmers and Bulk Markets

Shopping at **local farmer's markets** helps reduce packaging waste while supporting **regional agricultural producers**. These products often require less refrigeration and transportation, contributing to lower environmental impact.

Avoiding Plastic Bags

Every hour, **200,000 plastic bags** end up in landfills. Investing in **fabric or reusable shopping bags** is a simple yet highly effective way to reduce plastic waste and its long-term environmental footprint.

Reducing Bottled Water Use

An estimated **60 million plastic water bottles** are discarded daily worldwide. The use of **reusable water bottles** offers an environmentally sound and cost-effective alternative.

Limiting Paper Use

In today's digital age, **paperless billing** is increasingly common. Many businesses offer incentives for choosing electronic communication. Reducing paper consumption—whether through digital receipts, notes, or subscriptions—can significantly contribute to reducing household waste.

Conclusions

It is evident that **sustainable waste and refuse management** constitutes a central pillar of the broader effort to transition toward a **circular and climate-resilient economy**, both at the European and national levels. The challenges are multifaceted—environmental, social, economic, and institutional—and call for coordinated actions across all levels of governance.

The legislative framework and funding mechanisms have been significantly reinforced at the European Union level through successive **Circular Economy Action Plans**, legally binding **recycling targets**, and a wide range of **cohesion policy instruments**. These measures aim to reduce environmental burdens, enhance resource efficiency, and generate green jobs through innovation, investment, and systemic change.

In **Greece**, significant progress has been made in aligning national strategies with European directives. The formulation and implementation of the **National Waste Management Plan (NWMP)** and the corresponding **Regional Plans** reflect a growing institutional commitment to modernize infrastructure, adopt new technologies, and promote best waste prevention, reuse, and recycling practices.

The role of **Local Government Organizations (LGOs)** is also pivotal. Municipalities and regional authorities serve as the operational backbone for implementing waste management policies, with responsibilities ranging from separate collection and recycling schemes to citizen awareness campaigns and digital monitoring systems. Their capacity to integrate local knowledge with national priorities enhances the effectiveness and inclusiveness of waste policy interventions.

However, technical solutions alone are not sufficient. The transition to sustainable waste management requires a **cultural shift**—a reconfiguration of values, habits, and consumption models. This underscores the critical role of **citizen participation**, **individual behavioural change**, and **community engagement** in complementing institutional efforts.

In this context, small-scale individual actions—such as composting, responsible recycling, sustainable purchasing, and reduction of single-use plastics—can collectively generate significant environmental benefits. Furthermore, promoting second-hand use, reducing food waste, and embracing minimal packaging practices contribute to a societal model in which **waste is no longer a by-product but a resource** to be reintegrated into the economic cycle.

In conclusion, achieving **Sustainable Development Goal 12** in waste and consumption is an **ongoing process** that requires strategic planning, regulatory coherence, robust infrastructure, informed policy-making, and an empowered and environmentally literate citizenry. Sustainability ambitions can only be translated into tangible outcomes for future generations through a holistic, multi-level, and participatory approach.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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REPORTING ON ESG UNDER THE NEW CSRD DIRECTIVE – ARE WE READY FOR A CHANGE IN THE PARADIGM OF CORPORATE GOVERNANCE AND BUSINESS?

DOI: 10.26341/issn.2241-4010-2025-16a-11-K02226

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Abstract

ESG reporting usually encompasses the disclosure of environmental, social and governance aspects of undertakings' business. In January 2023, the new CSRD Directive (Directive on Corporate Sustainability Reporting) entered into force, which essentially tightens non-financial reporting. The CSRD field of application has been expanded to a much larger number of undertakings and, according to estimates, it will cover approximately 55,000 companies operating in the EU internal market. Such a wide application will have great repercussions not only for EU undertaking, but also undertakings from the third countries that operate on the EU market. Following the above, this paper analyzes and examines the most significant novelties that come with the new CSRD directive and whether Croatian commercial companies (especially small and medium-sized ones) are ready for the novelties brought by the new CSRD directive. It is about changing the paradigm of corporate management and business in the EU single market, and consequently also in the Republic of Croatia. The conclusion provides an assessment of the situation and guidelines for better implementation of the new CSRD directive into the Croatian legal framework and into the corporate governance and operations of domestic companies.

Keywords: *ESG, CSRD, non-financial reporting; circular economy; sustainable reporting.*

1. INTRODUCTION

Nowadays, business sustainability is no longer focused only on financial but also on non-financial sustainability (Tuula, 2019; Tulla, 2020; Tuula, 2021; see also: Jovanović and Jovanović, 2023). In this regard, reporting on ESG, which includes: environmental (E), social (S) and governance (G) elements, is increasingly important. (Fornasari & Traversi, 2024; Brondoni & Plata, 2022; Yeaw and Seow, 2024; Raghavan, 2022).

At the international level, there are numerous examples of ESG soft laws instruments, policies and examples of good practice (see for instance so-called SDG, sustainable goals UN; Raghavan, 2022; Galant et al, 2024; Pizzi et al; 2020). In this regard, the EU is considered an

international leader in ESG regulation (in this context see: Brennan, 2024; Almeyda and Darmansya, 2021; Raimo et al., 2021). Thus, as part of the EU legislative activity, the CSRD Directive came into force in January 2023, bringing significant changes to ESG reporting (Fornasari & Traversi, 202). Among other things, the innovations relate to the expansion of the field of application to small and medium-sized enterprises (SMEs), more precise reporting and standardization of ESG reports, the introduction of the concept of double materiality, etc. All of the above will have a major impact on the Croatian market, because the Republic of Croatia had to incorporate the aforementioned CSRD Directive into its legislation (Zubović, 2024).

Therefore, the following issues are posed as key research questions in this paper: are Croatian companies ready for these changes? The paper first analyzes the background and reasons for adopting the new CSRD. Then, the innovations brought by the CSRD are analyzed. The central part of the paper examines how the aforementioned changes will affect the Croatian market and whether entrepreneurs to whom the CSRD Directive applies will be able to adapt to the changes. The concluding part of the paper provides an assessment of the situation and guidelines for *de lege ferenda* action.

2. HISTORICAL DEVELOPMENT AND ORIGIN OF THE CSRD DIRECTIVE

In the 1970s, lobbying by states and international organizations for environmental protection began, with the EU positioning itself as one of the leading international leaders in promoting environmental protection, even though it was not and is not currently a significant global polluter (Sgaravatti et al, 2024). At the international level, the UN Framework Convention on Climate Change was first concluded in 1992. Then, five years later, in 1997, the Kyoto Protocol was concluded. These agreements formed the basis for the international community to conclude the Paris Agreement in 2016. This was the first legally binding agreement on this topic, which prescribed clear parameters for monitoring the signatory states with clear goals and guidelines, such as limiting the increase in global temperature, etc. (Savaresi, 2016).

All of these efforts also had an impact on EU legislation, so the Paris Agreement was the basis for the adoption of the European Green Deal. It is a document that has similar goals as the Paris Agreement with the aim of preserving nature for future generations (Staudt et al, 2023). All of the above resulted in strong legislative activity of the EU, and in the following period a large number of documents were adopted regarding the standardization of environmental protection and the expansion of the focus and concept of business from financial to non-financial business. In this context, the content of corporate reporting began to be discussed more significantly because the focus of such reporting was no longer only on profit and financial sheets (Fornasari & Traversi, 2024, p. 117; Brondoni & Plata, 2022, p. 1-2).

Generally speaking, at the international level we find various forms of corporate non-financial reporting: voluntary, mandatory and hybrid. Nowadays, the voluntary model is mostly used, i.e. a model in which reporting is not legally binding, but it is an autonomous decision of the company whether or not to report. Despite such regulation, most companies report on their operations in order to avoid reputational damage and negative effects and effects on their operations due to bad publicity. For many years, a hybrid model was in force in the EU, which as a rule obligates large companies to report on non-financial aspects of business, but large undertakings can be released from such an obligation if they explain the reasons why they do not want to report on it (Lee et al, 2023).

Directive 2014/59/EU, i.e. the Non-Financial Reporting Directive (hereinafter: NFRD) from 2014, is among the first legally binding documents that introduced the obligation to report. The field of application of the NFRD referred to large undertakings that have more than 500 employees and which are public-interest entities (Art. 19a NFRD). The mentioned

undertaking was obliged to publish non-financial information from 2017 (Hummel and Jobst, 2024). NFRD tried to introduce transparency and comparative monitoring of non-financial statements among undertakings on the market. In this context, undertakings were obliged to report on various forms of non-financial business, such as a description of business methods and policies, which achieve ESG goals, then related risks and measurement of the success of such business (Koundouri et al, 2022). The main drawback when applying the NFRD was non-binding application in situations where undertakings explain the reasons why they want to hide the requested non-financial information. This led to the fact that many undertakings used the mentioned option and that the expected results of the NFRD were not realized (Cuomo et al, 2024).

The next step of the EU, in terms of non-financial reporting, was the adoption of Regulations 2019/2088 of the European Parliament and of the Council of 27 November 2019 on sustainability-related disclosures in the financial services sector (hereinafter: SFDR) which applied to participants in financial markets, including financial advisors. The SFDR introduced an obligation for the above-mentioned entities to report on non-financial risks. Also significant is Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019 (hereinafter: Taxonomy Regulation; Hummel and Jobst, 2024) which introduces “the criteria for determining whether an economic activity qualifies as environmentally sustainable for the purposes of establishing the degree to which an investment is environmentally sustainable” (Art. 1. of the Taxonomy Regulation).

The EU noted that the aforementioned legal framework and hybrid model of non-financial reporting did not meet the needs of the market, i.e. that it did not achieve its set goals and purpose. Therefore, the EU adopted Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU (hereinafter: CSRD) which switched to a mandatory model of reporting on non-financial sustainability (Staudt et al, 2023; CSRD; Krueger et al, 2024).

3. CORPORATE SUSTAINABILITY REPORTING DIRECTIVE (CSRD)

3.1. The most significant news and goals of CSRD

The increasing orientation of market participants and international organizations and countries towards environmental protection has led to the need to tighten the obligation of non-financial reporting and expand the field of application, i.e. the obligation to report also to other legal entities on the market and not only to large undertakings with public interest as prescribed in the NFRD (NFRD, Staudt et al, 2023). In other words, the NFRD referred to 11,700 undertakings, and with the adoption of the CSRD, the obligation to report was extended to 50,000 undertakings (Staudt et al, 2023; Zubović). In other words, with the new CSRD, redundant reporting is introduced and the possibility of hybrid reporting is abandoned, and instead of non-financial reporting, the term sustainable reporting is introduced (Lee et al, 2023).

The most important innovation brought by the CSRD is the concept of double materiality, which obliges undertakings to report on the effect of their operations on their business, but also on the effect of the undertaking's operations on the environment and society (Art. 19a (1) CSRD). A significant step forward is Art. 29b of the CSRD which introduces a standardized method on sustainable reporting so-called European Sustainability Reporting Standards (ESRS) developed and published by the European Financial Reporting Advisory Group (EFRAG) (Art. 29b CSRD). The aforementioned standards require detailed and clear

reporting on the environmental and social aspects of business undertakings (Staudt et al, 2023). In addition, the new CSRD introduces the obligation of external audit of the sustainable report, promotes digitization and facilitates access to data through the establishment of centralized databases, risks for end users, provisions on cyber security and data protection, etc. (CSRD; Boggini, 2024).

The main goal of CSRD is most often stated to be increasing transparency and standardizing sustainable reporting. All of the above aims to facilitate access to the capital market, facilitate access to information and relevant circumstances for interested stakeholders (Birkmann et al, 2024). The goal of CSRD is, among other things, to establish a balance between all participants and shift the focus from the financial aspect of business to the impact of enterprises on the environment and society (Freeman et al, 2021).

In addition to CSRD, the EU adopted the Directive on in-depth analysis of corporate sustainability (Directive (EU) 2024/1760 of the European Parliament and of the Council of 13 June 2024 on corporate sustainability due diligence and amending Directive (EU) 2019/1937 and Regulation (EU) 2023/2859, hereinafter: CSDDD) to achieve the goals of CSRD, which entered into force on 25 July 2024 (https://commission.europa.eu/business-economy-euro/doing-business-eu/sustainability-due-diligence-responsible-business/corporate-sustainability-due-diligence_en). Pursuant to Art. 4. of the CSDDD prescribes the obligation of member states that undertakings carry out an in-depth verification of whether the objectives in terms of conservation of ecclesiastes are achieved and whether the undertakings protect human rights. (Kent, 2023).

3.2. Deadlines and periodicity of reporting

The CSRD should be implemented into national legislation in 4 phases. The directive itself entered into force on 5.1.2023 (Zubović, 2024). The first phase concerned NFRD applicant who had to start reporting for the period from 1 January 2024 in 2025. The second phase affected all other large enterprises that were not NFRD applicant and who had to report from 1 January 2025 in 2026. The third phase concerns small and medium-sized enterprises that will have to report for the period from 1 January 2026 in 2027. The fourth phase concerns undertakings from third countries that will have to report for the period from 1 January 2028 in 2029. (CSRD; Art. 37 CSDDD, for Croatia see 70-73 Accounting Act).

4. IMPLEMENTATION IN NATIONAL LEGISLATION

4.1. General overview

The obligation to implement CSRD into national legislation was until July 6, 2024 (Zubović, 2024). Discrepancies in national legislation regarding sustainable reporting are the main obstacle to the implementation of CSRD and accompanying regulations. First of all, because the obligations of sustainable reporting in accordance with CSRD impose additional obligations and requirements for undertakings in terms of human resources, time and money (Romé and Renz, 2024). Germany stands out in the EU as one of the most advanced countries in terms of sustainable reporting (<https://www.twobirds.com/en/insights/2024/germany/neues-zur-csrd-und-deren-umsetzung-in-deutschland>). CSRD prescribes sanctions for non-compliance of sustainability reports in the form of fines or sanctions through negative market effects for non-disclosure of required information. The most severe penalties are in Germany, with the maximum sanction of 10 million euros, and in Italy they never exceed 150,000 euros. (Lee et al, 2023).

It is interesting that non-EU member states such as Norway have included CSRD provisions in their national regulations in order to harmonize them with European standards

on sustainable reporting (<https://wr.no/en/news/eu-corporate-sustainability-reporting-directive-csrd-implemented-into-norwegian-law>).

In addition, other non-EU countries operating in the EU single market are harmonizing their regulations with the CSRD regulation in order to be competitors on the EU market. It is worth noting that non-EU countries often complain that the EU has a selective "neo-colloquial approach" that relates negatively to (Sgaravatti et al, 2024).

4.2. Implementation of CSRD Directive in Croatian Legislation

CSRD and accompanying regulations were implemented in Croatian legislation through amendments to 3 laws: the Accounting Act, the Audit Act and the Capital Market Act (Accounting Act Narodne novine 85/2024, 145/24; Audit Act Narodne novine no. 127/2017, 27/2024, 85/2024, 145/2024 and the Capital Market Act, Narodne novine No. 65/2018, 17/2020, 83/2021, 151/2022, 85/2024).

In the Accounting Act, the term sustainability is mentioned in several places: SUCH AS "a sustainability report is a report on information related to sustainability issues" (Art. 3 (8) of the Accounting Act); "the report on the verification of the sustainability report is the report as regulated by the Audit Act" (Art. 3 (9) of the Accounting Act); "sustainability issues are environmental factors, social factors, factors in the field of human rights and management factors, including sustainability factors in the financial services sector" (Art. 3 (15) of the Accounting Act), and in chapter VIII that is titled as Sustainability Reporting (Art. 29 onwards of the Accounting Act). Art. 29 of the Accounting Act stipulates that large entrepreneurs, medium-sized entrepreneurs and small entrepreneurs are obliged to report on sustainability in accordance with the CSRD. (Art. 29 (2) of the Accounting Act). The sustainability report must be clearly published and contain a brief description of the implementation of the entrepreneur's sustainability strategy (Art. 29 (3) and (4) of the Accounting Act).

Furthermore, the law prescribes the criteria for exemption from submitting a sustainability report (Art. 31 of the Accounting Act), and what a consolidated sustainability report looks like (Art. 32 of the Accounting Act). and exemption from submitting a consolidated sustainability report (Art. 33 of the Accounting Act). Art. 33 of the Accounting Act stipulates that the members of the management, executive directors and the management board of the entrepreneur are obliged to report to the representatives of the workers on certain aspects of sustainability.

In Art. 35 of the Accounting Act prescribes the content of sustainability reports for non-EU countries.

In Art. 36 of the Accounting Act stipulates that the aforementioned sustainability reports are compiled and presented using the European sustainability reporting standards, as regulated by the implementing acts of the European Commission. Also, the Accounting Act in the Art 37 prescribes the obligation to verify, or draw a conclusion on the sustainability report by an independent auditor or an auditing company that performs a statutory audit of annual financial statements or annual consolidated financial statements.

Provisions 70-73 of the Accounting Act are also very important, which talk about the deadlines for mandatory submission of sustainability reports for large, medium and small enterprises and for enterprises from third countries (Art. 70-73 of the Accounting Act). The mentioned deadlines overlap with the deadlines from CSRD.

In the revision law, Art. 4. of the Audit Act stipulates that audit services include, among other things, verification of sustainability reports (Art. 4(1) of the Audit Act). Then it is prescribed that the verification of the sustainability report is actually the verification of the sustainability report and the consolidated sustainability report, which includes the

implementation of procedures resulting in the conclusion given by the audit company. in accordance with this Law and the law regulating the accounting of entrepreneurs (Art. 4(6) of the Audit Act).

5. ISSUES REKATED TO ESG POLICY IMPLEMENTATION AND TRENDS

Despite all the positive aspects of sustainable reporting, numerous authors and practitioners warn of the increasingly frequent false reporting of sustainability. In this context, the most mentioned is greenwashing, which represents the false presentation of action of undertakings as sustainable. Reasons for using greenwashing can be gaining a false green reputation and attracting customers, as well as deceiving business partners, financiers, etc. (Gatti et al, 2019; De Freitas Neto; Cornell and Damodaran, 2020).

In addition to the above, numerous authors criticize sustainable reporting, stating that orientation towards sustainability does not necessarily bring better business results. Namely, the authors warn that sustainability is manifested in long-term strategies and that large investments of money and resources are needed, and that the real results of the application of business viability and normative inconsistency (Johnson, 2021). New trends bring facilitation of reporting on sustainability through the use of AI softwares that facilitate the monitoring of sustainability indicators and parameters (Saxena et al, 2022; Sætra, 2023).

6. CONCLUSION

CSRD introduced major changes in the EU single market. The aforementioned Directive expanded the field of application from non-financial reporting to sustainability reporting, and expanded the scope of sustainability reporting obligations to include all other large, medium and small entrepreneurs, as well as entrepreneurs from third countries. Also, the concept of double materiality has been introduced, which must be reported not only on the impact of operations on undertakings, but also on the impact of undertakings on the environment and society in general.

All the mentioned provisions must be implemented in national legislation in four stages. The implementation this time affects not only EU member states, but also third countries operating in the EU. This has great implications for the day-to-day operations of undertakings, because now they have to calculate and measure sustainability parameters in their operations.

The Republic of Croatia also implemented CSRD. Implementation was carried out mostly through amendments to the Accounting Act, Audit Act and Act on Capital Market. All the mentioned regulations are harmonized with the EU legislation. At this moment, it is too early to assess whether the correct application has taken root properly in the Croatian business market. It can only be said that there are numerous dangers and negative effects of sustainable reporting. For example, greenwashing, excessive investments and weak investment returns, and the constant need for up-to-date compliance in order to facilitate the monitoring of sustainability parameters and indicators and at the same time facilitate ESG reporting.

It remains to be seen how sustainability policy and regulation will develop in the light of current global politics and international trade, and for now we can only hope that the pipe default CRSD will have a positive impact on the EU market.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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**INTEGRATING CIRCULAR ECONOMY IN TO SUSTAINABLE DEVELOPMENT
GOALS: INSIGHTS FROM LIFE CYCLE IMPACT ASSESSMENT**

DOI: 10.26341/issn.2241-4010-2025-16a-12-K02119

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Abstract

The integration of the circular economy into sustainable development goals offers an approach to sustainable resource management and economic growth, with Life Cycle Impact Assessment (LCIA) as a tool for evaluating environmental and socio-economic outcomes. This study investigates how LCIA methodologies can drive circular economy strategies within the textile industry, addressing sustainable development goals and targets such as responsible production and consumption and climate action. Textile production, which accounts for approximately 10% of global carbon emissions and 20% of industrial water pollution, presents significant opportunities for circular economy practices like recycling, reusing, and material innovation. Case studies from European textile manufacturers demonstrate the potential of LCIA in optimizing resource use, minimizing waste, and reducing greenhouse gas emissions by up to 50% when transitioning from virgin polyester production to closed-loop recycling systems. LCIA software tools such as OpenLCA and GaBi were employed to assess the environmental impacts across lifecycle stages, including raw material extraction, manufacturing, distribution, and end-of-life disposal. Results indicate that incorporating recycled fibers can lower energy consumption by 30–40%, while water usage can be reduced by as much as 70% compared to conventional production methods. Furthermore, the adoption of eco-design principles, supported by LCIA insights, showed a potential reduction in landfill waste by 25% through product lifecycle extension initiatives such as repair and reuse programs. This research highlights the socio-economic implications of circular economy adoption, including job creation in recycling and upcycling sectors, which could increase by 15% in regions implementing waste management systems. Policy recommendations emphasize the importance of regulatory frameworks that incentivize sustainable practices, such as extended producer responsibility and subsidies for green technologies. The findings show the value of cross-sector collaboration, combining insights

from LCIA with circular economy strategies to improve sustainable consumption patterns and support the transition towards a low-carbon textile industry.

Key words: *circular economy, life cycle impact assessment, resource management, recycling and reuse*

Introduction

The global textile industry is one of the most resource-intensive and environmentally damaging sectors, contributing to 10% of global carbon emissions and 20% of industrial water pollution (Ellen MacArthur Foundation, 2019). As concerns over environmental sustainability intensify, circular economy principles have gained momentum as a transformative approach to addressing the industry's environmental and socio-economic challenges. The circular economy promotes closed-loop systems that minimize resource extraction, optimize waste recovery, and extend product lifecycles. In the textile sector, this translates into strategies such as fiber-to-fiber recycling, eco-design, and sustainable material innovation. However, effectively integrating these principles into industry practices requires quantitative assessment methodologies to evaluate their environmental and economic benefits. This is where the Life Cycle Impact Assessment is most commonly used. LCIA represents an analytical tool used to quantify the environmental impacts of a product or process across its entire lifecycle, from raw material extraction and manufacturing to use and end-of-life disposal. With LCIA, industries can identify environmental hotspots, optimize resource efficiency, and compare the sustainability performance of different circular economy strategies. Despite the increasing relevance of LCIA, its integration with CE strategies within the textile industry remains underexplored, particularly in the context of achieving sustainable development goals. This paper aims to bridge this gap by analyzing the role of LCIA in driving circular economy transitions within the textile industry. By focusing on sustainable development goals targets such as responsible production and consumption (SDG 12), climate action (SDG 13), and sustainable industry innovation (SDG 9), this study analysis how LCIA methodologies can improve decision-making for sustainable textile production (Hales & Birdthistle, 2022), (Küfeoğlu, 2022). The United Nations Sustainable Development Goals (SDGs) provide a global framework for sustainable economic, social, and environmental progress. The textile and apparel industry, valued at approximately \$2.4 trillion, is a driver of economic growth and employment, yet it remains one of the largest contributors to pollution, carbon emissions, and resource depletion (UNEP, 2022). The integration of circular economy principles within the textile industry aligns directly with sustainable development goals, specifically: (1) SDG 12 - Responsible consumption and production, meaning reducing textile waste through recycling, reusing, and material recovery; (2) SDG 13 - Climate action, meaning that lowering carbon emissions through LCIA-informed eco-design and closed-loop production systems; (3) SDG 9 - Industry, innovation, and infrastructure, meaning encouraging sustainable industrialization through innovations in textile recycling technologies. However, the successful implementation of circular economy strategies requires a scientific, data-driven approach that goes beyond theoretical sustainability goals. LCIA enables a systematic evaluation of environmental trade-offs, ensuring that CE transitions lead to measurable sustainability benefits rather than unintended environmental consequences. LCIA provides quantitative insights into the sustainability impacts of different production methods, material choices, and waste management strategies. LCIA pinpoints high-impact processes within the textile lifecycle, such as dyeing (responsible for 20% of global industrial water pollution) and polyester production (generating 1.5 kg CO₂e/kg of fabric). It enables industry

stakeholders to prioritize mitigation strategies, such as adopting waterless dyeing techniques or shifting to recycled polyester. Conventional textile production follows a linear “take-make-waste” model, where raw materials are extracted, processed, and discarded. But on the other hand, LCIA allows for the comparison of linear and circular production models, demonstrating how closed-loop systems reduce carbon footprints by 40-60% and cut energy use by 30-50% (Hammar, Peñaloza, Hanning, 2024), (Lozano-Oviedo, Cortés, Rey, 2024). LCIA determines the most sustainable textile materials by assessing factors such as energy intensity, water use, and recyclability. LCIA studies show that mechanically recycled polyester emits 50% less CO₂ than virgin polyester while organic cotton consumes 91% less water than conventional cotton (Periyasamy, Militky, 2019), (Kamble, Behera, 2021).

The objectives of this paper are to analyze how LCIA methodologies influence circular textile decision-making and to quantify the environmental benefits of circular economy textile strategies using LCIA data.

Literature Review

LCIA evaluates environmental impacts associated with all stages of a product's life cycle, from raw material extraction to disposal. In textiles, LCIA identifies environmental hotspots and informs sustainable practices. A systematic review (Bianco, et al., 2023) analyses studies on LCIA applications in textiles, revealing that the production phase, particularly raw material extraction and manufacturing, contributes significantly to environmental impacts. Cotton cultivation accounts for approximately 90% of water consumption in the life cycle of cotton garments. Additionally, the dyeing and finishing processes are responsible for about 20% of industrial water pollution globally. The paper (Bicalho, et al., 2017) compared LCIA methodologies, highlighting discrepancies in data quality and system boundaries. It found that using site-specific data reduced uncertainty by approximately 10% compared to generic datasets. This shows the importance of accurate data collection in LCIA studies to improve reliability.

The circular economy model aims to minimize waste and maximize resource efficiency by creating closed-loop systems. In the textile industry, circular economy frameworks have been adopted to address sustainability challenges. The review (Ramírez-Escamilla, et al., 2024) analyzed articles on circular economy strategies in the textile sector, identifying reuse, recycling, repair, and reduction as primary strategies. The study emphasized that implementing these strategies could reduce greenhouse gas emissions by up to 30% and decrease water consumption by approximately 50% (Ramírez-Escamilla, et al., 2024). Moreover, the paper (Furferi, Volpe, Mantellassi, 2022) proposed guidelines for textile industries transitioning to circular economy practices, for efficient use of natural resources, adoption of renewable energies, waste reduction, and effective end-of-life product management. Implementing these guidelines could lead to a 20% reduction in production costs and a 25% decrease in environmental impact.

The paper (Edirisinghe, de Alwis, Wijayasundara, 2024) highlights that the textile sector is responsible for 8-10% of global greenhouse gas emissions and 20% of worldwide wastewater pollution. The authors analysed that the most significant environmental impacts occur during the fiber production and wet processing stages. For instance, cotton cultivation in countries like India and Turkey is associated with high water use, pesticide pollution, and soil degradation, scoring up to 10 in environmental significance. Wet processing, particularly dyeing and finishing, is water-intensive and contributes substantially to chemical pollution and energy consumption. Lifecycle thinking and hotspot mapping revealed stages, such as raw material extraction, fabric dyeing, and end-of-life disposal, where circular economy strategies like water recycling, renewable energy adoption, and sustainable farming can be

most effective. The paper's qualitative methodology, based on expert input from professionals and guided by UNEP's 2021 Eco-I Manual, offers a practical, low-cost alternative to conventional LCA software for identifying hotspots and proposing targeted circularity interventions across the product lifecycle.

It is important to emphasize that the textile and clothing industry is among the five most polluting and resource-intensive sectors globally, contributing significantly to water pollution and greenhouse gas emissions. While the concept of the circular economy offers a promising alternative to the traditional linear model, its practical implementation remains limited. The paper (Salmi & Kaipia, 2022) found that incumbent textile firms face path dependencies due to legacy product portfolios, product-oriented business cultures, and limited control over supply chains. In their case study of seven Finnish companies, only one was classified as a "circular incumbent," while others struggled to shift from selling low-cost, short-lived fashion items to service-based or recycled offerings. For example, a company specializing in affordably admitted that its product prices were too low to make rental models viable. Conversely, "born circular" companies successfully used waste materials like safety belts and cutting scraps to drive sustainable design. The paper highlights the importance of dynamic capabilities, such as sensing regulatory shifts, seizing design opportunities, and transforming supply chains, for enabling this transition. It emphasizes that firms with strong internal control and RFID-enabled tracking of garments were better positioned to implement circular business models and reduce waste through repair and reuse strategies.

Applying LCIA methodologies and circular economy frameworks is important for the textile industry, given its substantial environmental footprint. Textile production is responsible for about 20% of global clean water pollution from dyeing and finishing products.

Implementing zero-waste fashion strategies, such as zero-waste pattern design, can significantly reduce the average 15% textile waste generated during standard garment production. Furthermore, adopting circular fashion models, which emphasize designing for longevity, using sustainable materials, and promoting recycling, can contribute to a more sustainable and resilient textile industry.

Analysis of case studies

The following detailed analyses of case studies provide insights into the environmental footprints of different textile products. Bianco et al. (2023) conducted a cradle-to-gate LCA of a woollen undershirt produced in Italy, aiming to identify environmental hotspots in its production process. The study revealed that the total global warming potential of one undershirt is 11.7 kg CO_{2e}, with the sheep farming phase contributing 88% of these emissions. Energy consumption during the wool transformation process accounted for 11% of the total emissions, partially mitigated by the use of electricity from photovoltaic panels. Materials such as chemicals and transportation had negligible contributions to the overall environmental impact. The paper highlighted that user habits influence the environmental impact during the use phase of the undershirt.

Cotton Incorporated conducted a comprehensive LCA to evaluate the environmental impacts of cotton fiber and fabric production, covering stages from cultivation to finishing. The study found that producing 1,000 kg of woven cotton fabric requires approximately 8,000 cubic meters of water, with irrigation during cultivation being the primary contributor. The total energy consumption for producing the same amount of fabric was found to be significant, with notable contributions from both agricultural and textile processing stages. These findings underscore the importance of focusing on the cultivation stage to reduce water and energy consumption in cotton textile production (Barnes, et al., 2010).

The paper (Sandin et al., 2024) evaluated the environmental impacts of a garment made from chemically recycled fibers, considering stages from raw material extraction to end-of-life. The study demonstrated that using chemically recycled fibers resulted in a 60% reduction in energy consumption compared to virgin polyester production. Additionally, there was a 50% decrease in global warming potential, equating to a reduction of 2.5 kg CO₂e per garment. Water usage was also reduced by 70%, saving approximately 150 liters per garment. This case study highlights the environmental benefits of incorporating recycled materials into textile production.

Digital tools used for LCA analysis in the textile industry

LCA software tools are important for evaluating the environmental impacts of products within the textile industry. A comparative analysis of LCA software tools shows the features, strengths, and limitations of this sector (Table 1). SimaPro is the most frequently used LCA software in textile-related environmental assessments. In textile LCAs conducted with SimaPro, a wide range of system boundaries were applied, most notably cradle-to-gate and cradle-to-grave, enabling evaluations from raw material extraction to end-of-life stages. SimaPro supported assessments with standardized units (e.g., kg CO₂e/kg of material), allowing direct comparisons. For example, in the paper (Fonseca et al., 2023) wool yarn production evaluated using SimaPro revealed a remarkably high global warming potential of 95.70 kg CO₂e/kg, while silk fabric production showed a similarly high global warming potential of 80.9 kg CO₂e. Cotton fabric, by contrast, had lower emissions, averaging 14.9 kg CO₂e/kg of material. In cradle-to-grave analyses supported by SimaPro, polyester showed the highest impact, with an average global warming potential of 40.28 kg CO₂e/kg, compared to cotton (31 kg CO₂e/kg) and wool (30.94 kg CO₂e/kg). These values reflect the broader capabilities of SimaPro to integrate life cycle inventory data, including energy use, raw material extraction, use-phase activities (e.g., washing frequency), and end-of-life treatments such as reuse or incineration. SimaPro's compatibility with diverse impact assessment methods like IPCC, ReCiPe, CML, and TRACI further strengthens its versatility. For instance, TRACI was applied in studies using SimaPro 8.5.2, while ReCiPe and IPCC methods were applied in studies using versions ranging from 7.3 to 9.3. This flexibility enables detailed assessments of climate change impacts, energy demand, and water usage. Overall, SimaPro emerges as a validated tool for LCA in the textile sector, supporting evidence-based decision-making aligned with eco-design and circular economy principles.

The other software tool, GaBi is used in the textile industry to evaluate environmental impacts in different stages of textile production and recycling. In the paper (Sulochani et al., 2022) GaBi version 8 was used to model the environmental footprint of repurposing textile waste into composite materials. This application underscores GaBi's capability to handle complex recycling processes, offering insights into potential environmental benefits of innovative waste management strategies. The paper's findings, supported by GaBi's databases and modeling tools, highlight the software's role in promoting sustainable practices within the textile sector. However, specific quantitative impact values from this study are not provided in the available information. The paper (Dani and Shabiimam, 2024) aimed to evaluate the environmental impact of a textile company's operations. The GaBi 9.2.1 software was used in a gate-to-gate LCA of a Surat-based viscose textile company to evaluate its environmental performance across manufacturing stages, gray cloth production, dyeing, printing, and finishing. Using primary data collected directly from the facility and validated through mass and energy balances, the study revealed that the dyeing process accounted for the highest environmental impact. Dyeing alone contributed 38.04% of total energy demand and 28% of total water consumption, with a global warming potential of 5.37 kg CO₂-equivalents per kg

of product. The weaving and finishing stages followed closely, with global warming potential contributions of 5.382 kg and 5.535 kg CO₂-eq, respectively. Atmospheric impacts assessed using CML 2001 and Environmental Footprint 2.0 methods showed that the dyeing stage also had the highest ozone depletion potential (3.32×10^{-16} kg R11-eq) and acidification potential (0.0475 kg SO₂-eq). Power-intensive sub-processes like thermosetting and jet dyeing were identified as hotspots due to their high steam and electricity requirements. For photochemical ozone creation potential, dyeing contributed 0.0472 kg ethene-eq, followed by weaving at 0.0133 kg. GaBi's weak point analysis module enabled identification of these specific contributors, allowing targeted recommendations such as implementing cool pad dyeing to reduce energy use, installing zero-liquid discharge systems, and adopting renewable energy. Overall, this case study highlights GaBi's capability to model complex textile operations and support strategic environmental management through quantified, process-specific impact assessments.

OpenLCA, an open-source software, has been applied in the textile industry to evaluate environmental and social impacts throughout product life cycles. A case study of an organic cotton hooded sweatshirt produced in India and used in Germany (GreenDelta, 2025a), (GreenDelta, 2025b). The study conducted a cradle-to-grave assessment, encompassing raw material extraction, manufacturing, distribution, use, and end-of-life stages. The findings revealed that the use phase, specifically the washing process, contributed to environmental impacts such as climate change and freshwater eutrophication. Scenarios altering user behavior, like reducing washing frequency or washing at lower temperatures, demonstrated potential for impact reduction. Additionally, a Social Life Cycle Assessment (S-LCA) using OpenLCA highlighted social risks associated with labor practices in the Indian textile sector, emphasizing issues like low wages and extended working hours. These insights show OpenLCA's capability to integrate environmental and social dimensions, aiding stakeholders in making informed decisions to improve sustainability in textile production and consumption.

Ecochain Mobius represents an environmental intelligence platform that enables companies to conduct LCA and measure the environmental impact of their products and processes. In the textile industry, Ecochain Mobius has been employed to assess and improve sustainability practices (Khanna et al., 2022), (Koščáková et al., 2024), (Pamu & Alugubelli, 2023). Dutch textile company, Schijvens Corporate Fashion, used Ecochain Mobius to analyze the environmental footprint of their workwear production. By inputting data related to raw material sourcing, manufacturing processes, transportation, and end-of-life disposal, Schijvens was able to identify significant environmental hotspots within their supply chain. The LCA revealed that fabric production and dyeing processes were major contributors to carbon emissions and water consumption. Armed with these insights, Schijvens implemented strategies such as selecting more sustainable materials, optimizing dyeing techniques, and improving logistics to reduce their overall environmental impact. This case demonstrates how Ecochain Mobius facilitates data-driven decision-making, allowing textile companies to pinpoint areas for improvement and track the effectiveness of sustainability initiatives over time. Similarly, the Belgian textile manufacturer, Beaulieu International Group, applied Ecochain Mobius to evaluate the environmental performance of their flooring products. The platform enabled Beaulieu to conduct comprehensive LCAs, uncovering that the use phase of their carpets had a substantial environmental impact due to maintenance requirements. As a result, the company focused on designing products that required less frequent cleaning and utilized materials that extended the product's lifespan, thereby reducing the overall environmental footprint.

Table 1. Comparative table with features of LCA software tools

Feature	SimaPro	GaBi	OpenLCA	Ecochain Mobius	OneClick LCA
User-friendliness	Designed for LCA professionals; may have a steeper learning curve for beginners.	Comprehensive features suitable for detailed analyses; may require extensive training.	Open-source platform with a user-friendly interface; suitable for both beginners and experts.	Built for business users with an intuitive interface, facilitating quick and reliable footprint assessments.	User-friendly interface customized for the construction sector; may require adaptation for textile applications.
Database integration	Integrates with extensive databases like Ecoinvent and Agri-footprint, providing a wide range of data for various industries, including textiles.	Offers a comprehensive Life Cycle Inventory database, beneficial for detailed textile industry analyses.	Supports multiple databases, including Ecoinvent and ELCD, offering flexibility in data selection.	Provides access to extensive environmental impact databases, such as Ecoinvent and the Dutch Nationale Milieudatabase at no extra cost.	Contains a vast database of construction materials; may require additional data integration for comprehensive textile assessments.
Cost	Pricing starts at approximately €5,900 per year; offers a free demo version for evaluation.	Pricing details are not publicly available; interested users need to contact the provider for a quote.	Open-source and free to use, making it a cost-effective option for organizations.	Annual subscription at €3,120; offers a free trial for users to explore its features.	Annual subscription priced at €3,720; provides a free trial for potential users.
Textile industry suitability	Suitable for detailed LCA studies in the textile sector; widely used by professionals for in-depth analyses.	Well-suited for comprehensive LCA analyses in the textile industry; offers detailed modeling capabilities.	Versatile tool applicable to various industries, including textiles; supports comprehensive LCA studies.	Customized for product footprinting in industries like apparel, consumer goods, and electronics; facilitates sustainable product design in the textile sector.	Primarily designed for the construction industry; may require customization for effective application in textile-related LCA studies.
Accessibility	Desktop application; may have limited cloud-based features.	Primarily a desktop application; cloud-based features are limited.	Desktop application with capabilities for collaborative work; supports various operating systems.	Cloud-based platform, ensuring accessibility and ease of collaboration across teams.	Cloud-based solution, offering accessibility and real-time collaboration features.

The translation of these insights into actionable strategies requires a multi-level governance and market-oriented approach. In high-impact sectors such as textiles, which

contribute nearly 10% to global carbon emissions and over 20% to industrial water pollution, systemic change cannot be achieved through voluntary commitments alone. Therefore, a structured and enforceable policy framework is needed to scale circular practices, institutionalize sustainability metrics, and bridge the gap between assessment tools and industry-wide transformation. At the regulatory level, mandatory life cycle reporting and environmental product declarations should be introduced across textile value chains. Governments can require companies above a certain production threshold to disclose LCIA-based environmental performance indicators for lifecycle stages (e.g., raw material sourcing, dyeing, and end-of-life disposal). This aligns with the European Commission's Sustainable Products Regulation (2022), which mandates digital product passports and traceability, particularly for textiles. Such regulatory frameworks would improve transparency and comparability across supply chains, incentivizing lower-impact materials and processes. Extended producer responsibility schemes should also be expanded and refined to include LCIA-based benchmarks. For instance, producers could be taxed or subsidized based on their cradle-to-grave environmental footprint. This would encourage design for disassembly, modularity, and the use of recyclable or biodegradable fibres. The LCIA metrics, as outlined in this study, offer quantifiable thresholds for these performance-based incentives. For example, textiles emitting below 20 kg CO₂e/kg and using less than 4,000 Liters of water/kg during production could qualify for green-labelling or reduced compliance fees. Such economic instruments are vital in levelling the playing field and reducing the cost barriers to circular economy innovation. From an industry standpoint, LCIA provides companies with a strategic lens for eco-design, supply chain optimization, and innovation investment. Firms that integrate LCIA tools like SimaPro, GaBi, or OpenLCA into their R&D pipelines can prioritize raw materials with lower environmental intensity (e.g., mechanically recycled polyester, organic cotton) and identify high-impact production stages. The insights gained through LCIA can guide the development of closed-loop systems, such as take-back programs and fiber-to-fiber recycling, which not only reduce emissions but also open new revenue models (e.g., subscription-based clothing, resale, and remanufacturing). Case studies reviewed in this paper indicate that incorporating recycled fibers can cut GHG emissions by up to 50% and water usage by 70%, making a compelling business case for sustainable innovation. Capacity building and knowledge transfer must be prioritized, particularly for small and medium-sized enterprises in developing and transition economies, which often lack the technical and financial resources to implement LCIA tools. Governments, NGOs, and academic institutions should collaborate to establish LCIA training hubs and develop open-access circular economy toolkits. Policymakers and business leaders must act in concert to institutionalize lifecycle thinking and embed circularity across all levels of the textile ecosystem. This approach is needed for meeting international climate targets, decoupling growth from environmental degradation, and achieving long-term socio-economic resilience.

Conclusion

This paper provides a comprehensive assessment of how LCIA methodologies support the integration of circular economy principles within the textile industry, in alignment with the United Nations sustainable development goals. The findings demonstrate that LCIA is a critical decision-making tool that enables the identification of environmental hotspots across the textile lifecycle, from raw material extraction to end-of-life disposal, supporting evidence-based sustainability strategies. Quantitative insights from case studies show that transitioning from linear to circular models, specifically through fiber-to-fiber recycling and eco-design, can reduce greenhouse gas emissions by up to 50%, energy consumption by 30–40%, and water usage by as much as 70%. The use of LCIA tools such as SimaPro, GaBi, OpenLCA,

and Ecochain Mobius shows their effectiveness in modelling complex processes, validating impact reductions, and guiding product development aligned with circular economy strategies. In addition to environmental benefits, circular economy adoption has socio-economic implications, including the potential to increase employment by 15% in the recycling and upcycling sectors. However, the analysis also reveals challenges in practical implementation, especially among incumbent textile companies facing organizational inertia, technological limitations, and supply chain fragmentation. These findings underscore the need for policy frameworks that incentivize sustainable practices, foster innovation, and enforce extended producer responsibility. LCIA, when coupled with circular economy, offers a scientifically grounded pathway for the textile industry to transition toward low-carbon, resource-efficient, and inclusive production systems that support the 2030 Agenda for Sustainable Development.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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ANALYSIS OF POLICY FRAMEWORKS RELATED TO CIRCULAR ECONOMY IMPACT IN AGRICULTURE, ALBANIAN CASE

DOI: 10.26341/issn.2241-4010-2025-16a-13-K02206

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Abstract

The transition to a circular economy (CE) is a critical pathway for achieving sustainable development, particularly in developing countries like Albania, where resource efficiency and waste management are pressing concerns. This study examines the interplay between regional development policy frameworks and the adoption of circular economy principles in Albania, analyzing it through agriculture sector. Agriculture is a vital sector in Albania, contributing significantly to GDP more than 18.5 % (INSTAT, 2023). However, the sector faces challenges such as low productivity, resource inefficiency, and environmental degradation. These issues present opportunities for circular economy (CE) practices, which focus on reducing waste, improving resource efficiency, and enhancing sustainability.

The study explores how existing policies focus subsidies to agriculture sector, institutional capacities, and economic strategies influence the implementation of CE practices. The paper highlights key barriers, including regulatory gaps, limited awareness, and infrastructure deficiencies, while also identifying opportunities such as EU integration incentives, access to green funding, and community-level initiatives. By analyzing case studies and policy approaches, the research provides actionable recommendations for aligning regional development goals with CE principles. It concludes that a more integrated policy framework, supported by robust governance and stakeholder engagement, can accelerate Albania's transition to a circular economy, fostering economic resilience, environmental agriculture sustainability, and regional equity.

Key words: *circular economy, legal framework, agriculture subsidies, impact assessment*

INTRODUCTION

In Albania, the integration of circular economy principles into agricultural subsidy schemes is gradually taking shape, driven by national goals for sustainability and alignment with the European Green Deal. Policy Framework has been incorporating circular economic goals into its legislative framework, focusing on waste management and sustainable energy. The National Plan for Integrated Waste Management outlines mechanisms and actors involved in transitioning from linear to circular production systems. This includes reducing waste and environmental impacts in agriculture , Various EU-funded initiatives are supporting Albania's transition to circular practices. The livestock sector, a significant part of Albanian agriculture, faces challenges like inefficient resource use and environmental impacts. Efforts to incorporate circular economy principles involve reducing waste, recycling nutrients, and improving sustainability in farming practices. These measures are still in the early stages but are crucial for Albania's broader agricultural transformation . Awareness campaigns and technical training for farmers and stakeholders are being prioritized. These efforts aim to address barriers such as limited understanding of circular practices, insufficient infrastructure, and a lack of financial and institutional resources

In Albania, subsidies in the agriculture sector funded by the national budget include efforts to incorporate circular economy principles, particularly through environmental protection and sustainable development initiatives. The legal frameworks supporting these

actions aim to align with EU standards for sustainable production and waste management, as part of Albania's broader European integration strategy.

Despite early-stage implementation, several initiatives target resource inefficiencies in sectors like livestock farming (Ministry of Agriculture and Rural Development [MARD], 2023).

Awareness campaigns and technical training are essential to overcoming knowledge gaps and infrastructural limitations. In 2024, MARD allocated 3.9 billion ALL in direct subsidies, supporting sustainable farming practices, eco-technologies, and compliance with EU standards (MARD, 2024).

In 2024, the Ministry of Agriculture and Rural Development in Albania introduced several subsidy schemes aimed at enhancing sustainability and aligning with circular economy principles. The key aspects include:

Meanwhile Efforts to integrate circular practices are visible in programs supporting waste reduction, sustainable resource management, and the promotion of eco-friendly technologies in farming. The initiatives are supported by Albania’s National Strategy for Development and Integration and European Union standards. The government’s focus on aligning subsidies with sustainable practices ensures compliance with international commitments, such as the European Green Deal and climate action goals.

METHODOLOGY

A mixed-methods approach was adopted to assess CE integration in Albania’s agricultural subsidy system.

Objectives:

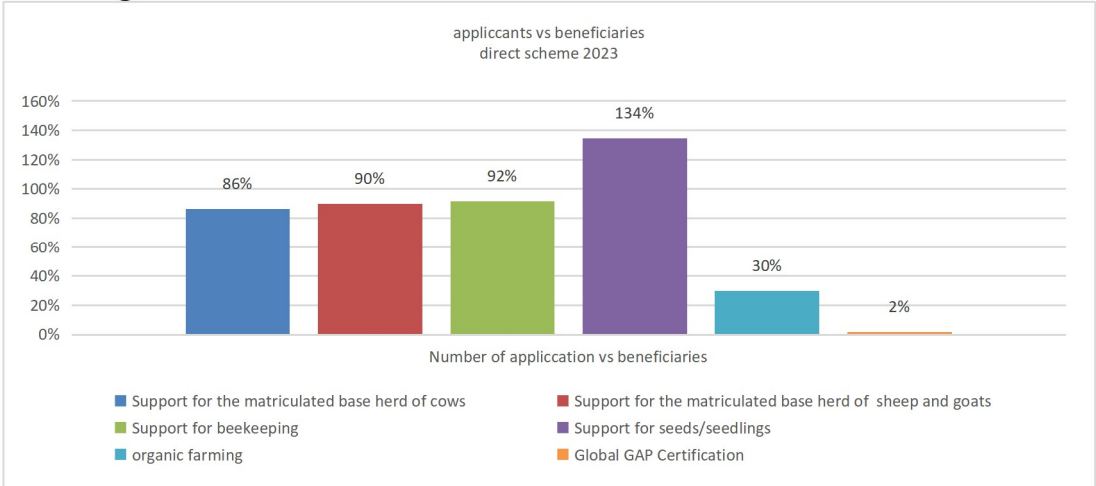
- 1. Analyze secondary data on agriculture subsidies and their support for CE.
- 2. Measure impact indicators linked to CE-related practices.

Data sources include MARD, INSTAT, UNSTAT, and national policy documents. A literature review and policy analysis were also conducted, focusing on CE-related incentives in national agricultural programs.

STATISTICAL DATA RESULTS ANALYSIS

Based on statistical data it results the direct schemes financed through national budget program for rural development.

Chart 1, Applicants vs beneficiaries by measures direct schemes financed through national budget 2023.

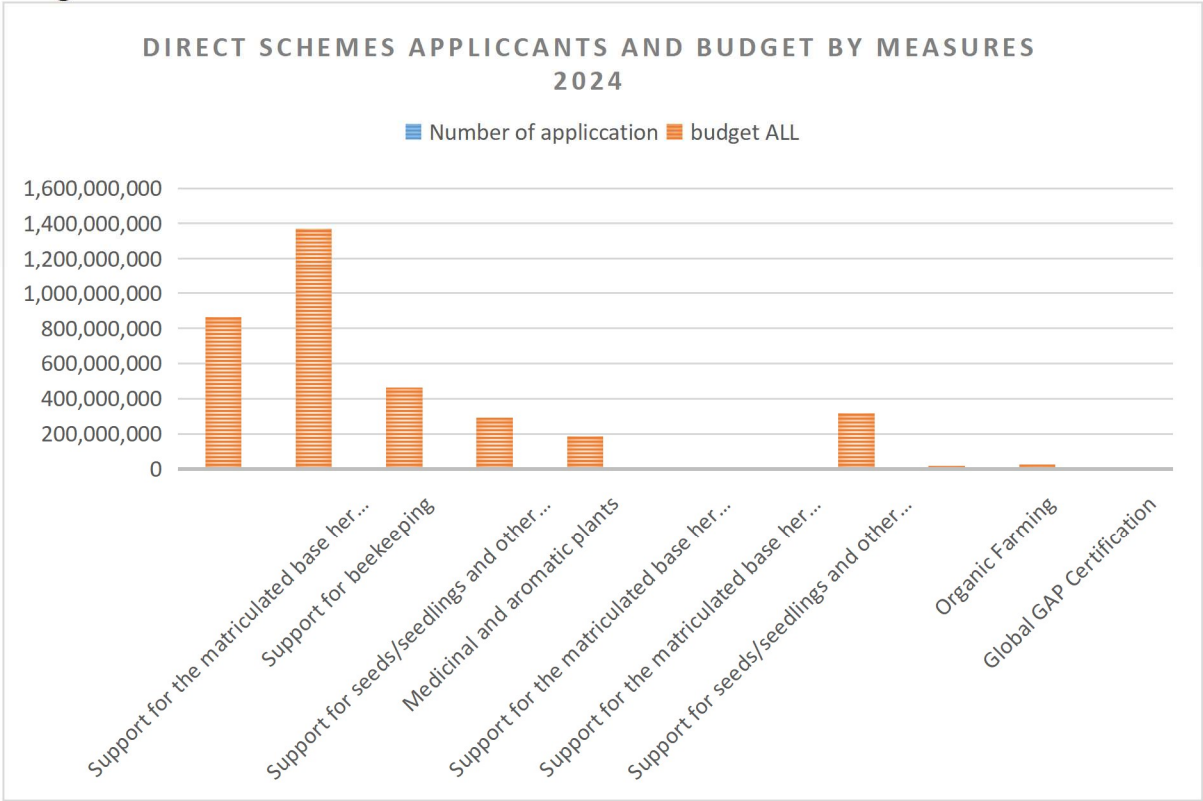


Source: Ministry of Agriculture and Rural Development, annual report 2023.

An analysis of the statistical data from the national rural development program indicates notable disparities in the distribution of direct subsidies across agricultural measures.

Chart 1 presents a comparison between the number of applicants and beneficiaries across selected subsidy schemes in 2023. The data demonstrate that the highest beneficiary rates were observed in the livestock sector, specifically for the matriculated base herd of sheep and goats, as well as in seed and seedling support programs. Conversely, organic farming exhibited a substantially lower absorption capacity, with only 30% of applicants successfully securing subsidies. This pronounced gap underscores systemic challenges in promoting environmentally sustainable practices, suggesting that organic agriculture may face structural constraints such as limited institutional support, insufficient awareness, or more stringent eligibility criteria compared to conventional agricultural activities.

Chart 2: Applicants and budgeted by measures. direct schemes financed through national budget 2024



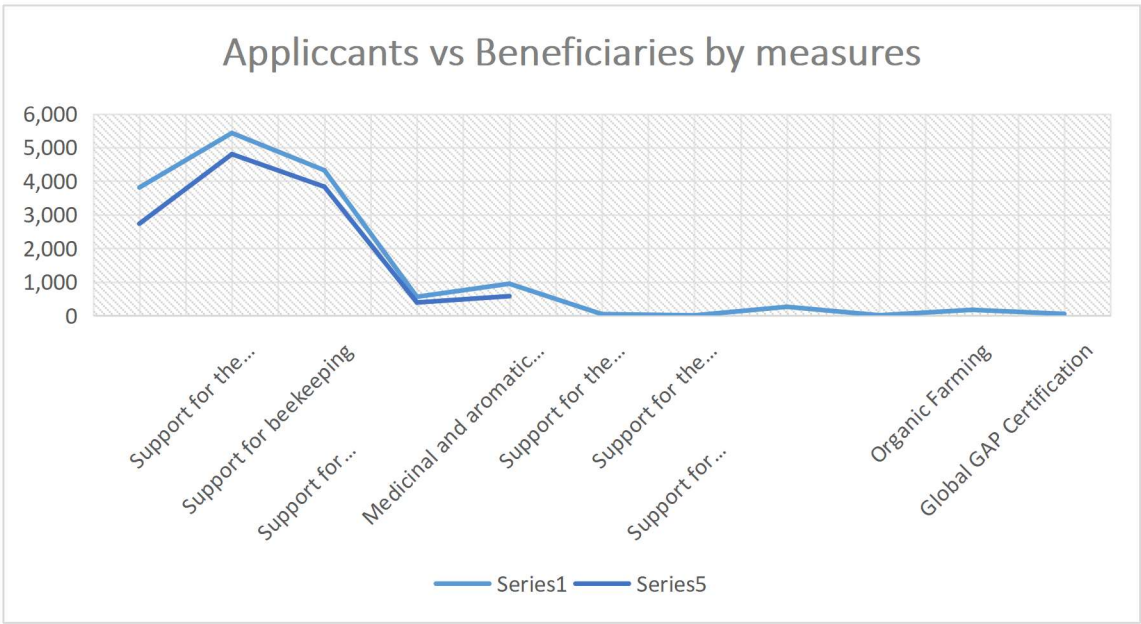
Source: Ministry of Agriculture and Rural Development, 2024

The analyzed data provide a comparative overview of both the number of applicants and the allocated budget across various measures under the direct schemes financed by the national budget for rural development as of 2024.

The data reveals a divergence between the volume of applicants and the distribution of financial resources across measures. While certain schemes, such as livestock herd support and seed/seedling programs, continue to attract the majority of applicants, the corresponding budget allocation is not always proportional to applicant demand. Some measures with fewer applicants, such as mechanization or eco-technology investments, receive relatively higher budget shares, reflecting policy priorities aimed at promoting modernization and circular economy principles.

This trend may indicate a deliberate policy shift to encourage capital-intensive investments aligned with sustainable agricultural practices, despite traditionally lower application rates. Additionally, the observed imbalance between applications and budgetary commitment highlights the need for further refinement in aligning subsidy distribution with sectoral demand, particularly in the context of advancing Albania’s transition towards more resource-efficient and circular agricultural systems.

Chart 3: Applicants vs beneficiaries by measures. direct schemes financed through national budget 2024



Source: Ministry of Agriculture and Rural Development, 2024

Chart 3 presents a comparative analysis of applicants and beneficiaries across multiple subsidy measures under the national rural development program.

The data highlights a clear concentration of both applications and successful disbursements in a few key areas. The highest number of applicants and beneficiaries is observed in schemes supporting livestock herds and beekeeping, indicating these as the most sought-after and accessible funding categories. The notable gap between applicants and beneficiaries across these two measures, while present, is relatively moderate, suggesting efficient fund disbursement relative to demand.

Conversely, measures such as support for medicinal and aromatic plants, organic farming, and Global GAP certification exhibit significantly lower figures for both applicants and beneficiaries. This trend reveals two critical issues: first, a lack of widespread farmer engagement with specialized or sustainability-oriented schemes; second, a substantial implementation gap in promoting value-chain upgrades (e.g., certifications) and environmentally sustainable practices like organic farming.

The sharp drop-off in applicant and beneficiary numbers beyond the top two measures reflects a structural imbalance in the national program's appeal and possibly in its administrative complexity or eligibility criteria for niche sectors.

Policy Implications:

- The over-reliance on traditional subsidy categories (livestock and beekeeping) highlights the need for diversification and stronger incentives for underutilized programs like organic farming and certification schemes.
- The persistent gap between applicants and beneficiaries across all measure's points to procedural bottlenecks, budgetary constraints, or challenges related to compliance with technical criteria, especially for measures aligned with circular economy objectives.

CONCLUSIONS

- During the design of policy making in agriculture sector Subsidies in Albania should improve Policy Integration Develop targeted policies that encourage Circular Economy in agriculture, supported by clear incentives and regulatory frameworks.
- Improve of Capacity Building: Train farmers and agribusinesses on CE practices and their economic and environmental benefits.
- Investment in Infrastructure: Establish composting facilities, biogas plants, and water recycling systems in agricultural regions.
- Market Development: Create demand for recycled and bio-based agricultural products through subsidies, awareness campaigns, and public procurement.
- Research and Innovation: Support R&D for CE technologies and practices tailored to Albania's agricultural context.

RECOMMENDATIONS

1. Diversify and Promote Underutilized Measures

Strengthen awareness campaigns and technical assistance for less popular schemes, particularly those related to sustainable agriculture (e.g., organic farming and certification programs). Tailored outreach could enhance farmer engagement and improve uptake.

2. Streamline Administrative Processes

Review and simplify application and approval procedures to reduce the gap between applicants and beneficiaries. This may include clearer guidelines, faster review timelines, and reducing bureaucratic hurdles, especially for measures that currently show low conversion rates.

3. Enhance Advisory and Extension Services

Establish or strengthen advisory services focusing on niche and high-value sectors such as medicinal plants, organic farming, and eco-certifications. Improved access to technical knowledge will increase farmers' confidence and capability to apply for and meet the requirements of these schemes.

4. Rebalancing Budget Allocations

Consider reallocating or increasing budgetary provisions for measures that are crucial to supporting the circular economy and climate-resilient agriculture. This rebalancing could encourage farmers to adopt more sustainable and innovative agricultural practices.

5. Monitor and Evaluate Impact

MARD in the function of policy design should implement continuous monitoring and evaluation mechanisms to assess the effectiveness of each measure and adjust program design based on data-driven insights. Feedback loops between policymakers and farmers could further refine future rural development initiatives.

Acknowledgments

This publication is based upon work from COST Action CA22124 supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation. <http://www.cost.eu>.

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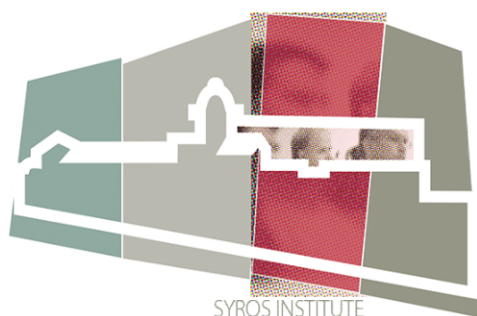
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INTERNATIONAL
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GREECE

ISSN: 2241-4010

Sustainable Development, Culture, Traditions Journal

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