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## The impact of the circular economy on the sustainable development in the EU

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### Abstract

**Aim:** The goal of this research was to investigate the impact of the circular economy on the sustainable development of EU countries.

**Methodology:** The sample consisted of data from 27 EU countries, including eight selected circular economy indicators as independent variables and the Sustainable Development Goals Index (SDGI) as the dependent variable, covering the period from 2012 to 2021. Panel regression modelling was used to evaluate the impact of selected circular economy indicators on sustainable development.

**Results:** The findings of this research demonstrate that reducing greenhouse gas emissions, increasing the circular material use rate, raw material consumption, and the recycling rate of municipal waste have a positive impact on the SDGI of EU countries.

**Implications and recommendations:** CE serves as a tool for a long-term sustainability strategy, ensuring that all the countries, and by understanding its role, policymakers can implement more effective measures that foster economic resilience, environmental protection, and social equity.

**Originality/value:** Although the circular economy and sustainability are gaining popularity in research, they are often examined separately, with limited discourse connecting the two. The study addressed this gap by investigating the impact of the circular economy on the sustainable development of EU countries, offering new insights into their interrelation.

**Keywords:** circular economy, sustainable development, sustainable development goals

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## 1. Introduction

The rapid depletion of natural resources, driven by population growth, the intensification of globalisation, and the expansion of consumerism, is bringing into sharp focus the environmental and economic challenges confronting our planet. These issues underline the pressing need for immediate action to transition towards a more sustainable economic model. A crucial strategy in this shift is the adoption of the circular economy (CE) approach (Bianchi & Cordella, 2023). In late 2015, the European Union (EU) introduced an action plan aimed at advancing the implementation of the circular economy (European Environment Agency, 2015).

The EU has a longstanding commitment to fostering sustainable development (SD) and environmental protection, and in recent years the principles of the circular economy have increasingly taken centre stage in its policy agenda.

The Industrial Revolution at the end of the 18th century enabled the mass production of goods using new production methods, leading to a rapid increase in the supply of goods and a decrease in prices. The rapid growth of consumer society and industry led to an increase in emissions and the need for more landfill space (Lieder & Rashid, 2016). As time passes and consumption increases, concerns about resource depletion and environmental damage are growing. These concerns include pollution, deforestation, and greenhouse gas emissions (Dantas et al., 2021; Sadhukhan et al., 2020; Yang et al., 2023; Zhang et al., 2019). To address these challenges, governments and businesses are implementing a range of measures to achieve sustainable development, and one such measure is the circular economy.

Although the circular economy and sustainability are gaining popularity among researchers, they are often examined as two separate topics, and often differing perspectives among practitioners and policymakers are applied regarding the benefits of the circular economy for sustainable development. While some scholars assert that the circular economy supports the goals of sustainable development, others contend that the connection between them remains underexplored, as the circular economy is a relatively new area of research with limited discourse on its sustainability implications. Therefore, this study investigated the impact of the circular economy on the sustainable development of EU countries and addressed the research gap linking these two topics.

Examining the circular economy is crucial as it offers a solution to the environmental and economic challenges caused by resource depletion, pollution, and waste generation. By promoting resource efficiency, waste reduction, and recycling, circular economy aligns with Sustainable Development. Integrating circular principles can drive innovation and long-term economic resilience, helping to address global sustainability challenges while fostering more regenerative, closed-loop systems. Thus the circular economy is an essential tool in achieving sustainable development on a global scale.

## 2. Literature review

### 2.1. The circular economy concept and its relation to sustainability

The concept of the circular economy dates back to the late 1960s, yet there is no uniform definition of the circular economy. Among scientists the circular economy is often described as a regenerative system in which resource consumption, waste, emissions, and energy use are minimised by slowing, closing, and tightening material and energy use cycles (Corvellec et al., 2022; Geissdoerfer et al., 2017a). The circular economy promotes the responsible and circular use of resources and contributes to sustainable development (Moraga et al., 2019). Sverko Grdic et al. (2020) defined the circular economy as the reduction of waste through the development of new products and an industrial process that continuously circulates materials in a closed-loop system. Franklin-Johnson et al. (2016) emphasised that the circular economy focuses on the closed loop of raw materials and energy consumption. Piscicelli (2023) described the circular economy as an economic system in which the use of resources is minimised and material value is maximised. Geng et al. (2009) defined the circular economy as an economy that is based on a spiral loop – a system that minimises the use of raw materials, the flow of energy, and the degradation of the environment without compromising economic growth or socio-technical progress.

Although the circular economy has a wide range of definitions, which are constantly changing, most authors agree that its main objective is resource efficiency (De Pascale et al., 2021; Velenturf & Purnell, 2021). Hence, it can be seen that the circular economy can help address resource scarcity, reduce environmental pollution, reduce waste, increase energy productivity, and promote technological progress, thereby enhancing the overall well-being of society. Despite being often examined separately, the relationship between the circular economy and sustainability is undoubted.

Sustainability addresses topics relevant to economic science, such as the efficient use and conservation of scarce resources, risk mitigation, the creation of new sectors and jobs, stability, socio-economic well-being, and international cooperation (Kristensen & Mosgaard, 2020). Santillo (2007) emphasised that for sustainable development to be effective, sustainability should be placed above development. The definition of development should also be refined to mean societal growth rather than economic growth. One of the main topics of discussion regarding the link between the circular economy and sustainable development is the inclusion of the circular economy in the three dimensions of sustainability (Kristensen & Remmen, 2019; Pla-Julián & Guevara, 2019). The focus is usually on the economic and environmental benefits of the circular economy, while the social benefits are often overlooked (Kristensen & Mosgaard, 2020).

According to Johnston et al. (2007), the only sustainable development approach is one that simultaneously addresses the interrelated problems of economic, environmental, and social well-being, therefore equal attention should be paid to all three dimensions of sustainability. The economic dimension focuses on the cost of materials, products, or processes, as well as the price and economic value of circular economy strategies (Akmal & Jamil, 2021; Kristensen & Mosgaard, 2020; Mancini et al., 2019; Mujtaba et al., 2024; Tomazinakis et al., 2022). In terms of the environmental dimension, the most commonly discussed indicators are the environmental impact of different processes, measured in terms of CO<sub>2</sub> emissions, water pollution, ecosystem quality, SO<sub>2</sub> and particulate matter, acidification, depletion of natural resources, and the energy saved through recycling (Adebayo et al., 2021; Adebayo & Alola, 2023; Agaton et al., 2020; Akadiri et al., 2022; Rosenberg et al., 2021). There is also a focus on resource efficiency, longevity, and improving resource use (Geissdoerfer et al., 2017b; Rowse, 2022; Venhoeven et al., 2020). The social dimension is analysed through the following indicators: employee engagement, awareness and satisfaction, safe working environment, job creation, and adequate food and drinking water (Bekun, 2024). Sustainability and the circular economy are terms used to express concern about industrial production and consumption, where the depletion of resources and pollution of the environment are putting both future and present generations at risk.

Both concepts stress the importance of integrating environmental and social protection into economic progress. Some authors argued that the circular economy contributes to the concept of sustainable development (Murray et al., 2017), while others suggested that the link between the circular economy and sustainability has not been fully explored, as the circular economy is a new field of research and its relationship with sustainability has not been extensively discussed in peer-reviewed articles (Corvellec et al., 2022)

While both sustainability and the circular economy aim to address the challenges of resource depletion and environmental degradation, their interrelationship continues to be a subject of ongoing research. Integrating these concepts into economic practices is crucial for achieving long-term environmental and social well-being. Therefore, based on the theoretical aspects of both circular economy and sustainability, a research hypothesis was developed: applying circular economy practices positively contributes to achieving sustainable development goals.

## **2.2. Circular economy indicators**

Based on a literature review and the focus areas of the circular economy and sustainability, the main circular economy factors were identified. These factors are also needed to test the research hypotheses.

### **2.2.1. Recycling and circular material use**

As the population grows and urbanisation increases, so does waste, which is predicted to rise by 70% to 3.40 billion tonnes by 2050 (Akmal & Jamil, 2021; Mujtaba et al., 2024; Osman et al., 2022; The World Bank, 2023). Proper waste management is crucial for sustainable development. In the past decade, consumer awareness about sustainable production and reuse has significantly increased. The circular economy, once considered a utopia, is now a key strategy to reduce resource pressure and waste generation (Calvo-Porràl & Lévy-Mangin, 2020; Dumée, 2022).

However, much waste is still managed in unsustainable ways, such as incineration and illegal landfills. Improper waste management leads to environmental pollution, health risks, and economic losses (Akmal & Jamil, 2021; Mujtaba et al., 2024). Waste incineration releases harmful pollutants such as particulate matter, heavy metals, and toxic substances, causing diseases like lung, heart, and neurological conditions, and cancer, and residents close to incineration sites often complain about noise, bad smells, and air pollution (Agaton et al., 2020; Guillon, 2020; Rosenberg et al., 2021). In developing countries such as Pakistan, the accumulation of garbage in public spaces has led to an increase in disease-carrying insects and rodents, which contribute to the spread of diseases such as dengue fever and cholera (Akmal & Jamil, 2021).

Increasing waste is not the only challenge facing a growing population and rising consumption. Another challenge is the depletion of natural resources. Conserving natural resources such as forests, oil, gas, and minerals is crucial for the survival of future generations (Venhoeven et al., 2020). The circular economy addresses these issues and promotes the conservation of dwindling resources and sustainable waste management practices such as composting, recycling, reuse, landfill control, landfill gas collection, and waste-to-energy (Agaton et al., 2020; Mujtaba et al., 2024). One of the objectives of the circular economy is to decouple resource use from economic growth by using materials more efficiently, preserving their value through closed material cycles, and supporting the market for secondary raw materials (Bianchi & Cordella, 2023).

Recycling and reusing materials help to conserve natural resources and reduce negative environmental impacts. According to the US Environmental Protection Agency, recycling one tonne of paper saves as much energy as the average American home uses in half a year (Venhoeven et al., 2020). In a circular economy, waste becomes a resource, and some resources can be taken from one production system and used in another. In circular economies, products retain their added value for longer and generate

less waste (Donia et al., 2018). Material reuse helps to address resource scarcity (Forastero, 2023; Rossi et al., 2020), reduce the amount of waste generated, ensure environmental sustainability, save energy and reduce greenhouse gas emissions (Rowse, 2022), and reduce the cost of producing a product (Venhoeven et al., 2020). Recycling is, therefore, an important aspect of the circular economy, as it has a positive impact on the environment, the economy, and social well-being.

### **2.2.2. Renewable energy and energy efficiency**

Globalisation and urbanisation of production and consumption patterns have significant environmental impacts through increased consumption, energy demand, carbon emissions, habitat destruction, and pollution (Khiali-Miab et al., 2024). At the beginning of the 21st century, around 80% of the world's energy came from fossil fuels such as coal, oil, and natural gas (Su & Urban, 2021). Fossil fuel power plants and vehicles emit pollutants that cause health problems, e.g. heart disease and asthma, release carbon dioxide, a major greenhouse gas, and produce emissions that lead to acid rain, harming lakes, aquatic life, tree foliage, and creating smog in cities (Guillon, 2020; Khiali-Miab et al., 2024; Robaina et al., 2020; Rosenberg et al., 2021). Renewable resources are replacing fossil fuels, and energy efficiency is improving to reduce the greenhouse effect, as renewable energy sources like sun and wind do not emit greenhouse gases (Nunez, 2019). The circular economy promotes energy efficiency and renewable energy use in production, consumption, and transport, addressing resource depletion, reducing emissions, and mitigating the greenhouse effect (Rahman, 2020).

The benefits of renewable energy development extend beyond reducing climate warming – it creates jobs, strengthens electricity grid resilience, expands energy access in developing countries, and lowers energy bills, reducing dependence on fossil fuels (Donia et al., 2018). These factors have driven renewable energy growth, with wind and solar power reaching record levels. In 2019, over 100 cities generated at least 70% of their energy from renewable sources (Nunez, 2019). Energy efficiency must also be a major focus of sustainable development. Energy efficiency reflects the ability to maximise productivity while keeping energy consumption low (Roth & Rajagopal, 2018; Zhao et al., 2024). Energy efficiency helps to reduce overall energy consumption and emissions, conserve resources, and address the challenges of climate change (Wan et al., 2022). Energy efficiency is currently receiving considerable attention from policymakers around the world, recognising its important role in improving energy security and affordability and accelerating the transition to clean energy (IEA, 2024).

The use of renewable energy and energy efficiency improvements positively impact sustainable development by reducing greenhouse gas emissions, mitigating climate change, and protecting health. This transition aligns with Sustainable Development Goals, enhancing energy security, boosting economic growth, creating jobs, ensuring affordability, and addressing environmental, economic, and social challenges for a cleaner, more resilient future.

### **2.2.3. Greenhouse gas emissions**

The most popular topic in sustainable development is climate change and reducing greenhouse gases such as CO<sub>2</sub> and methane, primarily caused by burning fossil fuels, which release pollutants that cause warming, increase ozone, acidify oceans, and create smog and heat waves that threaten human health (Guillon, 2020; Rosenberg et al., 2021). Fossil fuels are being replaced by renewable resources and improved energy efficiency, with carbon taxes implemented to accelerate the switch and reduce GHG emissions to combat climate change.

However, climate change leads to rising average temperatures, extreme weather events, changing wildlife populations and habitats, rising sea levels, and other impacts that disrupt ecosystems, threaten food and water security, and increase poverty and inequality (Bekun, 2024). Reducing greenhouse gas emissions is important to mitigate the effects of climate change and achieve sustainable development.

### 3. Methodology

Panel regression modelling was used to evaluate the impact of selected circular economy indicators on sustainable development, as measured by the Sustainable Development Goals Index (SDGI). Data for the regression model were extracted from the Eurostat open database. The independent variables and its definitions, representing key areas of the circular economy as presented in the theoretical background, are listed in Table 1.

Table 1. Selected independent variables

Indicator	Definition
Circular material use rate ( $X_1$ )	Measures the proportion of material recovered and reintegrated into the economy, thereby reducing the demand for new material extraction.
Raw material consumption ( $X_2$ )	Refers to the total amount of natural resources extracted and used within an economy for production and consumption processes.
Greenhouse gas emissions per capita ( $X_3$ )	The average amount of greenhouse gases emitted by an individual within a specific country.
Share of energy from renewable sources ( $X_4$ )	Refers to the proportion of a country's total energy consumption that is generated from renewable resources.
Energy productivity ( $X_5$ )	Measure of how efficiently an economy generates economic output relative to its energy consumption.
Recycling rate of municipal waste ( $X_6$ )	Measures the percentage of municipal waste that is recycled.
Resource productivity ( $X_7$ )	Measure of how efficiently an economy uses natural resources to generate economic value.
Recycling rate of packaging waste ( $X_8$ )	Measures the percentage of packaging waste recycled.

Source: own work based on Eurostat (2023).

The regression model utilised ten years of panel data, covering the period from 2012 to 2021 (latest available data), for a sample of 27 EU countries. A unit-root test was employed to prevent spurious regression and ensure that the panels are stationary. The null hypothesis ( $H_0$ ) posits that panels contain unit roots, while the alternative hypothesis ( $H_a$ ) suggests that panels are stationary.

Table 2. Levin–Lin–Chu unit-root test results

Indicator	Unadjusted t	Adjusted t	p-value
Circular material use rate ( $X_1$ )	-9.1372	-5.0986	<0.05
Raw material consumption ( $X_2$ )	-7.2012	-3.6760	<0.05
Greenhouse gas emissions per capita ( $X_3$ )	-8.7267	-4.5188	<0.05
Share of energy from renewable sources ( $X_4$ )	-0.1103	3.5531	>0.05
Energy productivity ( $X_5$ )	-3.3655	-0.8610	>0.05
Recycling rate of municipal waste ( $X_6$ )	-7.7866	-6.1738	<0.05
Resource productivity ( $X_7$ )	-1.7635	3.9449	>0.05
Recycling rate of packaging waste ( $X_8$ )	-12.4239	-9.3905	<0.05

Source: authors' own.

The results presented in Table 2 indicate that five out of eight panels are stationary, allowing for further research to be conducted. Panels that are cointegrated were deducted from further research, which includes share of energy from renewable sources ( $X_4$ ), energy productivity ( $X_5$ ) and resource productivity ( $X_7$ ). All the remaining indicators (circular material use rate ( $X_1$ ), raw material consumption ( $X_2$ ), greenhouse gas emissions per capita ( $X_3$ ), recycling rate of municipal waste ( $X_6$ ) and recycling rate of packaging waste ( $X_8$ )) were used for panel analysis.

Before developing the model the author determine whether fixed or random effects were more appropriate, and the Hausman test was employed for this purpose. The null hypothesis ( $H_0$ ) is that the model has random effects, while the alternative hypothesis ( $H_a$ ) is that the model has fixed effects. The

Hausman test yielded  $\chi^2(5) = 2.24$ ,  $p=0.8145$  thus the null hypothesis was accepted. This implies that the random effects model is more appropriate for this analysis, therefore a research model was developed (1).

$$SDGI_{it} = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_6 X_{6it} + \beta_8 X_{8it} + u_{it} + \epsilon_i, \quad (1)$$

where

$\alpha$  – intercept,

$\beta_1, \beta_2, \beta_3, \beta_6, \beta_8$  – coefficients to be estimated for the independent variables,

$u_{it}$  – idiosyncratic error term for entity  $i$  at time  $t$ ,

$\epsilon_i$  – random error term.

#### 4. Results and discussion

In this study a panel regression model was developed. Based on unit root tests results, five indicators were included in the research. Three indicators were removed from the model, including share of energy from renewable sources, energy productivity and resource productivity. The results of the panel regression modelling are presented in Table 3.

Table 3. Panel regression results

Y	Coefficient	Std. err.	z	P> z	95% conf. interval	
Circular material use rate ( $X_1$ )	0.0619209	0.0258606	2.39	<0.05	0.0112351	0.1126067
Raw material consumption ( $X_2$ )	0.1714801	0.0236316	7.26	<0.05	0.125163	0.2177971
Greenhouse gas emissions per capita ( $X_3$ )	-0.4146514	0.0457202	-9.07	<0.05	-0.5042613	-0.3250414
Recycling rate of municipal waste ( $X_6$ )	0.0871016	0.008649	10.07	<0.05	0.0701498	0.1040535
Recycling rate of packaging waste ( $X_8$ )	0.0185794	0.0113487	1.64	>0.05	-0.0036637	0.0408225

Note: Coefficients correspond to  $\beta_1, \beta_2, \beta_3, \beta_6, \beta_8$  in equation (1)

Source: authors' own work.

As shown in Table 3, four out of five indicators were considered as statistically significant. Recycling rate of packaging waste was not considered as statistically significant based on the results. The circular material use rate, raw material consumption as well as the recycling rate of municipal waste had a positive effect on SDGI, while greenhouse gas emissions per capita had a negative effect on SDGI.

The results may seem contradictory, as both the circular economy and sustainable development promote the reduction of resource consumption. Therefore, it might appear that an increase in raw material consumption should lead to a decrease in the sustainable development goals index. However, academic literature highlights that, in the short term, an increase in raw material consumption can contribute to sustainable development (Mancini et al., 2019; Tomazakis et al., 2022). As modern economies grow, the demand for raw materials increases as they are necessary for developing new technologies across various sectors, including energy production, transport, strategic industries, and defence. Certain raw materials are essential for the deployment of low-carbon and green technologies, which are crucial for achieving sustainability, climate, and energy goals (Bekun, 2024; Bontempi et al., 2021; Mancini et al., 2019).

The raw materials used to build renewable energy plants contribute to sustainability by increasing renewable energy production and decreasing greenhouse gas emissions. For instance, materials technologies utilise raw materials to create lighter, more fuel-efficient cars, thereby contributing to the reduction of greenhouse gas emissions (Green et al., 2012). Raw materials are essential for the transition to a low-carbon and digital economy (European Commission, 2019), playing a crucial role in technological development and innovation across fields ranging from medicine to engineering, and from agriculture to artificial intelligence (Bontempi et al., 2021). They are vital for the well-being and prosperity of societies, as the raw materials industry contributes to economic development, creates

decent employment opportunities, adds value to supply chains, and improves the quality of life in local communities, thus contributing to the achievement of various sustainable development goals (Mancini et al., 2019). However, the use of raw materials can also have negative consequences for sustainable development, especially when inadequate environmental and social cohesion policies and measures are implemented (Tomazinakis et al., 2022). These potential negative effects of using raw materials are discussed in more detail in the theoretical background section.

The alternative to raw material, i.e. the circular material use rate which, according to the panel regression results, has a positive effect on SDGI. The circular material use rate directly reflects an economy's ability to retain materials within the economic system, effectively implementing circular economy practices. This approach minimises waste and reduces the need for raw material inputs by maintaining closed loops. According to (Walker et al., 2018), material circularity and efficiency are crucial aspects of a circular economy, contributing to lower environmental impacts. Moreover, circularity helps prevent resource scarcity and aligns with sustainable practices (Moraga et al., 2021). As stated by Yang et al. (2023) the rising volume of solid waste has led to a shortage of landfill space, further emphasising the need for effective waste management and resource conservation within a circular economy. The extraction of valuable metals from metal smelting slag, and the recycling of materials like paper, glass, metal, and plastic are key examples of how solid waste can be repurposed, contributing to the circular economy. Circular materials not only reduce waste that goes into landfill but also ensures that resources are used more effectively and are kept in use for longer periods, reducing environmental degradation which is one of the main goals in sustainability.

The panel regression results also showed that an increase in greenhouse gas emissions per capita leads to a decrease in the Sustainable Development Goals Index. Moreover, this indicator has the most considerable comparable effect among all indicators in this research based on given coefficient value. This finding confirms the theoretical approach outlined in the literature review. The accumulation of greenhouse gas emissions in the atmosphere is a key driver of climate change (Adebayo & Alola, 2023). Rising temperatures, extreme weather events, and sea-level rise are disrupting ecosystems, threatening the efficient provision of energy, food, and water security, and increasing poverty and inequality (Bekun, 2024). Climate change negatively impacts economic stability, particularly in vulnerable regions, as it severely affects agriculture, infrastructure, and industry. Reducing greenhouse gas emissions is one of the key challenges in mitigating the effects of climate change and achieving sustainable development, which is why the European Union aims to become climate-neutral by 2050 (European Commission, 2020).

The resulting effect of recycling rate of municipal waste is in line with the scientific literature analysed, namely that proper waste management contributes to sustainable development. Resource usage and waste generation are some of the most important economic and environmental problems of our time. Recycling of municipal waste contributes to addressing these problems through the reuse of resources as it reduces the amount of waste going to landfill or incineration, and helps to meet the demand for raw materials by using circular recycled materials in production. By turning waste into a resource and reducing the amount going to landfill or incineration, water and air pollution are reduced and the health of people and ecosystems is protected (Agaton et al., 2020; Guillon, 2020; Rosenberg et al., 2021). Based on these results, one can state that the research hypothesis was partly confirmed. While minimising raw material consumption is one of the goals of the circular economy, this research shows that it has a positive effect on achieving sustainable development goals. However, as explained earlier, this may only reflect a short-term effect since circular economy practices are not yet fully applied within economies.

## 5. Conclusions

The main goal of this research was to evaluate the impact of the circular economy on the sustainable development of EU countries. The panel regression results showed that reducing greenhouse gas emissions, increasing circular material use rate, raw material consumption and recycling rate of

municipal waste have a positive impact on the EU Sustainable Development Index. These observations were confirmed by the analysis of the scientific literature. Although the intensive use of natural resources has a negative impact on the environment and contributes to the problems that the circular economy and sustainable development aim to solve, it has been observed that in the short term, the use of raw materials can have a positive impact on sustainable development. This is because raw materials are used to develop advanced technologies that contribute to the achievement of sustainable development goals. In the long run countries should promote recycling of municipal waste leading to increase in circular material use rate and reduction of greenhouse gas emissions. This study showed that the circular economy and sustainability are highly related, and that the circular economy as a modern alternative to the linear economy can foster sustainable development. The circular economy touches on most of the Sustainable Development Goals through the reduction of pollution, the promotion of the use of circular material, the proper management of waste, the reuse of materials, the promotion of technological progress, the creation of new jobs, and the promotion of health and well-being, and thus contributes to addressing the challenges of the three dimensions of sustainability: social, economic and environmental.

This article offers several practical contributions, serving as a valuable resource for understanding the connection between the circular economy and sustainable development showing the impact of different circular economy indicators towards seeking sustainable development goals. Moreover, this research advances the academic field by addressing existing gaps in the understanding of how circular economy initiatives can directly impact sustainable development goals. It demonstrates that adopting circular economy practices can expedite the attainment of all sustainable development goals.

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