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

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

**Radukic Snezana**
*Full Professor, Faculty of Economics, University of Nis, Trg kralja Aleksandra Ujedinitelja 11, Serbia,18000 Nis*
*snezana.radukic@eknfak.ni.ac.rs*

**Stankovic Zorana**
*Ass. Prof., University of Nis, Faculty of Mechanical Engineering, Department for Management in mechanical engineering, University of Niš, Aleksandra Medvedeva 14, Serbia,18000 Nis*
*zorana.kostic@masfak.ni.ac.rs*

**Sakıcı Şehnaz**
*Post-Doc. St., Gaziantep Universitesi, Universite Bulvari Sehitkamil, Türkiye, 27310 Gaziantep*
*sehnazsakici@gmail.com*

**Yaprak Burak**
*Ass. Prof., Faculty of Business, Istanbul Ticaret University, Örnektepe Mah., İmrahor Cad., Türkiye, 34445 Istanbul*
*brkyprk@gmail.com*

**Avdullahi Ajtene**
*Asoc. Prof., Faculty of Economics, University Isa Boletini, Mitovice, Ukshin Kovaçica, Kosovo*, 40000 Mitrovice*
*ajtene.avdullahi@umib.net*

**Dionizi Brikene**
*Project Manager, Faculty of Economics, University "Luigj Gurakuqi", Sheshi 2 Prilli, Shkoder, Albania, 4001 Shkoder*
*brikene.dionizi@unishk.edu.al*

**Espinosa Nieves**
*Ramon y Cajal researcher, Universidad de Murcia, Facultad de Química, Campus de Espinardo, Spain, 30100 Murcia*
*nieves.espinosa@um.es*

## *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 envornmental 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 enables (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 $CO_2e$, 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 $CO_2e$, 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 ($CO_2e$) 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:

- **$H_0$**: EU member states exhibit significantly higher levels of GGI and CCEI compared to non-EU countries (Western Balkan countries and Turkey).
- **$H_1$**: 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.
- **$H_2$: 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).
- **$H_3$: 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.

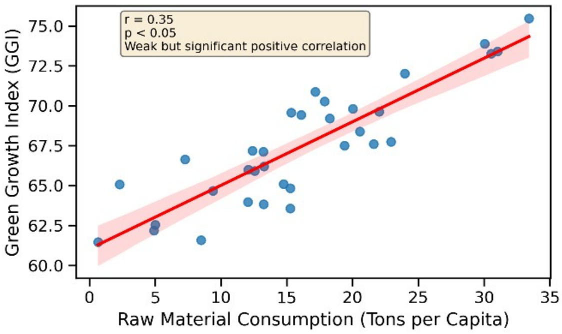

Figure 1. Correlation between RMC and GGI

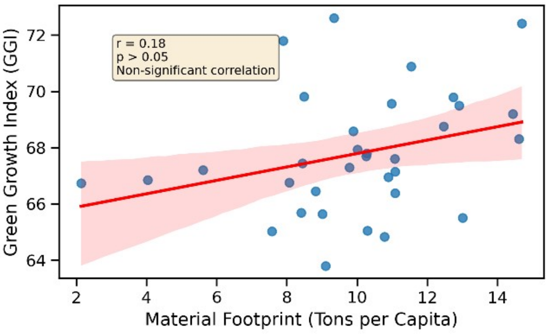

Figure 2. Correlation between Material Footprint and GGI

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 |
| *Dependent Variable: GGI / Model Summary = 0.38* | | | | | |

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.

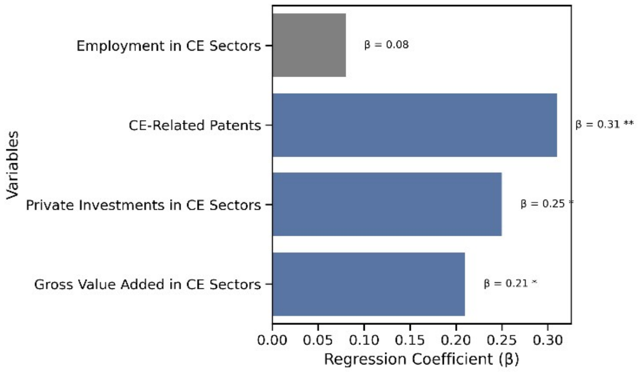

Figure 3. The regression results for the Green Growth Index (GGI) concerning circular economy drivers

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 ($\mathbf{H_{3a}}$) | 0.11 | 0.08 | 1.38 | 0.178 | 2.1 |
| CE Patents ($\mathbf{H_{3b}}$) | 0.45*** | 0.12 | 3.75 | <0.001 | 1.5 |
| Private Investments ($\mathbf{H_{3c}}$) | 0.38*** | 0.11 | 3.45 | 0.001 | 2.3 |
| GVA ($\mathbf{H_{3d}}$) | 0.16 | 0.10 | 1.60 | 0.120 | 1.9 |
| *Dependent Variable: CCEI / Model Summary=0.47* | | | | | |

Source: Authors

As shown in Table 8, the regression analysis for the Circular Carbon Economy Index (CCEI) reveals that $\mathbf{H_{3b}}$ and $\mathbf{H_{3c}}$ 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 (β=0.45, $p < 0.001$ β=0.45, $p<0.001$), while a 1 million euro increase in investments boosts CCEI by 0.38 points (β=0.38, $p<0.001$ β=0.38, $p<0.001$).

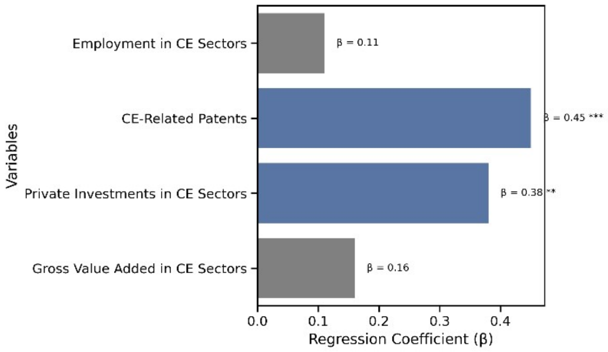

Figure 4. The regression results for the Circular Carbon Economy Index (CCEI) concerning circular economy drivers

The coefficient plot in Figure 4 illustrates the regression outcomes for the Circular Carbon Economy Index (CCEI) with circular economy variables. CE-related patents (β = 0.45, $p < 0.001$) and private investments (β = 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 (β = 0.11, $p = 0.178$) and gross value added (β = 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 |
|---|---|---|
| $\mathbf{H_0}$ | EU states outperform non-EU in GGI/CCEI | Supported |
| $\mathbf{H_{1a}}$ | RMC correlates with GGI/CCEI | Partially supported for GGI |
| $\mathbf{H_{1b}}$ | Material Footprint correlates with GGI/CCEI | Not supported |
| $\mathbf{H_{2a}}$ | CE employment → GGI | Not supported |
| $\mathbf{H_{2b}}$ | CE patents → GGI | Supported |
| $\mathbf{H_{2c}}$ | CE investments → GGI | Supported |
| $\mathbf{H_{2d}}$ | CE GVA → GGI | Supported |
| $\mathbf{H_{3a}}$ | CE employment → CCEI | Not supported |
| $\mathbf{H_{3b}}$ | CE patents → CCEI | Supported |
| $\mathbf{H_{3c}}$ | CE investments → CCEI | Supported |
| $\mathbf{H_{3d}}$ | CE GVA → 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 (β=0.11, p= 0.18 β=0.11, p=0.18) and Gross Value Added (β =0.16, p=0.12 β=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: β = 0.31; CCEI: β = 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 RandD 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 (β = 0.25) and CCEI (β = 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.

**Acknowledgment:** 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.

## References

Abbasi, K. R., Hussain, K., Radulescu, M., and Ozturk, I. (2021). Economic complexity, tourism, energy prices, and environmental degradation in the top economic complexity countries: fresh panel evidence. *Environmental Science and Pollution Research*, 28, 68717–68731. doi:10.1007/s11356-021-15312-4

Adebayo, O. P., Worlu, R. E., Moses, C. L., and Ogunnaike, O. O. (2020). An Integrated Organisational Culture for Sustainable Environmental Performance in the Nigerian Context. *Sustainability, 12*(20), 1-15. doi:10.3390/su12208323

Avdullahi, A., and Shala, B. (2023). Exploring the motivation and obstacles of the first entrant firm in the recycling industry. *Corporate Governance and Organizational Behavior Review, 7*(3), 277-290. doi:10.22495/cgobrv7i3sip5

Bherwani, H., Nair, M., Niwalkar, A., Balachandran, D., and Kumar, R. (2022). Application of circular economy framework for reducing the impacts of climate change: A case study from India on the evaluation of carbon and materials footprint nexus. *Energy Nexus*, 5, 100047. https://doi.org/10.1016/j.nexus.2022.100047

Circular Carbon Economy Index, Available at: https://cceindex.kapsarc.org/

David, P., Theochari, D., Nehls, T., Pedro, P., Patrizia, P., Korolova, A., . . . Schosseler, P. (2020). Enhancing the circular economy with nature-based solutions in the built urban environment: Green building materials, systems and sites. *Blue-Green Systems, 2*(1), 46 - 72. doi:10.2166/bgs.2019.928

Dionizi, B., Kërçini, D., and Ljarja, N. (2025). Community-Based Agroecosystem Management: Enhancing Sustainability for Food Security Through Local Initiatives. *Journal of Lifestyle and SDGs Review*, 5(3), e05045–e05045. https://doi.org/10.47172/2965-730X.SDGsReview.v5.n03.pe05045

Eurostat, Available at: https://ec.europa.eu/eurostat/data/database

Eurostat, Statistics Explained. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Carbon_dioxide_equivalent

Geissdoerfer, M., Savaget, P., M.P. Boc, N., and Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production, 143*, 757-768. doi:10.1016/j.jclepro.2016.12.048

Green Growth Index, Available at: https://ggindex-simtool.gggi.org/SimulationDashBoard/regional-outlouk

Huo, J., and Peng, C. (2023). Depletion of natural resources and environmental quality: Prospects of energy use, energy imports, and economic growth hindrances. *Resources Policy, 86, Part A*. doi:10.1016/j.resourpol.2023.104049

Hysa, E., Kruja, A., Rehman, N. U., and Laurenti, R. (2020). Circular Economy Innovation and Environmental Sustainability Impact on Economic Growth: An Integrated Model for Sustainable Development. *Sustainability*, 12(12), Article 12. https://doi.org/10.3390/su12124831

Jackson, T. (2009). *Prosperity without Growth. Economics for a Finite Planet.* London, New York: Earthscan.

Kafka, K. I. (2020). Economic theory and economic reality: A continuously dialectic relationship. In P. C. Kostis, *Bridging Microeconomics and Macroeconomics and the Effects on Economic Development and Growth.* United States: IGI Global.

Kirchherr, J., Reike, D., and Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221-232. doi:10.1016/j.resconrec.2017.09.005

Lenzen, M., Geschke, A., West, J., Fry, J., Malik, A., Giljum, S., Milà i Canals, L., Piñero, P., Lutter, S., Wiedmann, T., Li, M., Sevenster, M., Potočnik, J., Teixeira, I., Van Voore, M., Nansai, K., and Schandl, H. (2022). Implementing the material footprint to measure progress towards Sustainable Development Goals 8 and 12. *Nature Sustainability*, 5(2), 157–166. https://doi.org/10.1038/s41893-021-00811-6

Liu, H., Saleem, M. M., Al-Faryan, A. M., Khan, I., and Zafar, M. W. (2022). Impact of governance and globalization on natural resources volatility: The role of financial development in the Middle East North Africa countries. *Resources Policy, 78*. doi:10.1016/j.resourpol.2022.102881

Mishra, D. R., and Varshney, D. (2024). Consumer protection frameworks by enhancing market fairness, accountability and transparency (FAT) for ethical consumer decision-making: integrating circular economy principles and digital transformation in global consumer markets. *Asian Journal of Education and Social Studies*, *50*(7), 10-9734.

Munaro, M. R., and Tavares, S. F. (2023). A review on barriers, drivers, and stakeholders towards the circular economy: The construction sector perspective. *Cleaner and Responsible Consumption*, 8, 100107. https://doi.org/10.1016/j.clrc.2023.100107

García-Sánchez, I. M., Somohano-Rodríguez, F. M., Amor-Esteban, V., and Frías-Aceituno, J. V. (2021). Which region and which sector leads the circular economy? CEBIX, a multivariant index based on business actions. *Journal of Environmental Management*, *297*, 113299.

Najia, N., Taher, H., and Elkader, G. A. (2025). The Effect of Environmental Deterioration and Socio-cultural Factors on Economic Sustainability in Asia Pacific Selected Countries. *International Journal of Energy Economics and Policy, 15*(1), 8-14. doi:10.32479/ijeep.17472

OECD, Available at: https://www.oecd.org/en/data/indicators/population.html

Owojori, O. M., and Okoro, C. (2022). The Private Sector Role as a Key Supporting Stakeholder towards Circular Economy in the Built Environment: A Scientometric and Content Analysis. *Buildings*, 12(5), Article 5. https://doi.org/10.3390/buildings12050695

Paduszyńska, M., and Kozar, Ł. J. (2024). Consumer protection and sustainable development: key green research areas. *Ekonomia i Prawo*, *23*(2), 413-436).

Rosário, A. T., Lopes, P., and Rosário, F. S. (2024). Sustainability and the Circular Economy Business Development. *Sustainability*, *16*(14), 6092. https://doi.org/10.3390/su16146092.

Repp, L., Hekkert, M., and Kirchherr, J. (2021). Circular economy-induced global employment shifts in apparel value chains: Job reduction in apparel production activities, job growth in reuse and recycling activities. *Resources, Conservation and Recycling*, 171, 105621. https://doi.org/10.1016/j.resconrec.2021.105621

Smol, M., Marcinek, P., Duda, J., and Szołdrowska, D. (2020). Importance of Sustainable Mineral Resource Management in Implementing the Circular Economy (CE) Model and the European Green Deal Strategy. *Resources*, 9(5), Article 5. https://doi.org/10.3390/resources9050055

Sulich, A., and Sołoducho-Pelc, L. (2022). The circular economy and the Green Jobs creation. *Environmental Science and Pollution Research*, 29(10), 14231–14247. https://doi.org/10.1007/s11356-021-16562-y

Sverko Grdic, Z., Krstinic Nizic, M., and Rudan, E. (2020). Circular Economy Concept in the Context of Economic Development in EU Countries. *Sustainability*, 12(7), Article 7. https://doi.org/10.3390/su12073060

Tambovceva, T. T., Melnyk, L. H., Dehtyarova, I. B., and Nikolaev, S. O. (2021). Circular Economy: *Tendencies and Development Perspectives*. https://essuir.sumdu.edu.ua/handle/123456789/85156

The Green Growth Index, Available at: https://greengrowthindex.gggi.org/

Wang, J., and Azam, W. (2024). Natural resource scarcity, fossil fuel energy consumption, and total greenhouse gas emissions in top emitting countries. *Geoscience Frontiers, 15*(2), 1-15. doi:10.1016/j.gsf.2023.101757

Weiyang, F., and Yu, H. (2020). An empirical research on the relationship amongst renewable energy consumption, economic growth and foreign direct investment in China. *Renewable Energy, 146*, 598 - 609. doi:10.1016/j.renene.2019.06.170

World Bank, Open Data, Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG

Zaccone, M. C., Santhià, C., and Bosone, M. (2022). How hybrid organizations adopt circular economy models to foster sustainable development. *Sustainability*, *14*(5), 2679.