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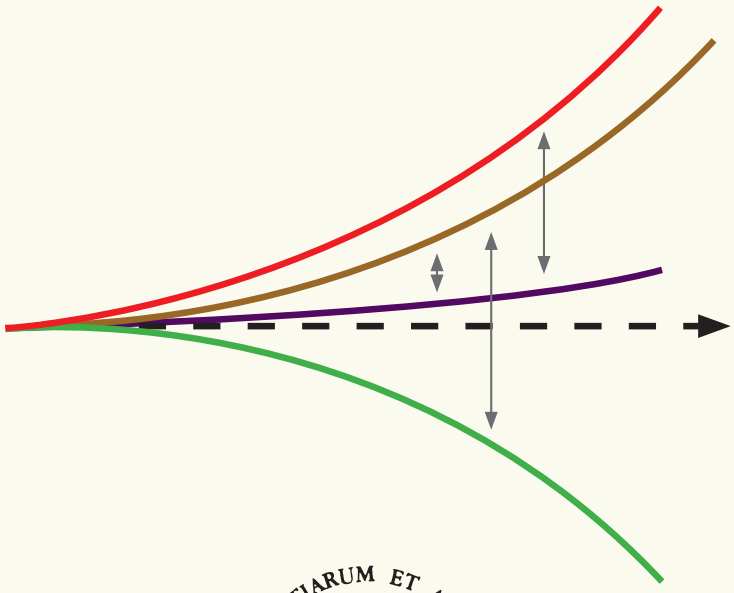

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ECONOMIC GROWTH
and SUSTAINABLE DEVELOPMENT

DIGITAL TRANSFORMATION AS A DETERMINANT OF SUSTAINABLE DEVELOPMENT

Erna HERIĆ[*], Amra NUHANOVIĆ[**], Amra GADŽO[***]

This paper examines the impact of digital transformation on the achievement of Sustainable Development Goals (SDGs) in Bosnia and Herzegovina. The research aims to identify the nature and intensity of the relationships between the key dimensions of digital transformation (human capital and skills, infrastructure and connectivity, digital integration in business, and innovation and sustainability) and selected SDG indicators (SDG4, SDG7, SDG8, SDG9, SDG13). A composite index of digital transformation was constructed based on secondary data for the period 2019-2023, while correlation and regression analyses were employed to explore the research propositions. The results suggest that infrastructure and connectivity (r = 0.9878) and digital integration in business (r = 0.9808) show strong positive associations with SDG9. Furthermore, digital integration in business appears to be negatively associated with SDG8 (Decent Work and Economic Growth), suggesting short-term labor market disruptions caused by digitalization. The relationships between human capital and SDG4, SDG8, as well as between innovation and SDG13, show marginally significant tendencies requiring further verification. These preliminary findings suggest that digital transformation exhibits differentiated association patterns with sustainable development indicators: it is associated with strong positive trends in certain goals while coinciding with negative patterns in others. Additionally, a comparative analysis across seven Western Balkan countries reveals a striking paradox: Bosnia

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and Herzegovina ranks first in digital skills (62%), yet last in e-commerce adoption (17.5%), suggesting that institutional barriers, rather than human capital constraints, impede digital transformation. This exploratory research provides initial insights into the digitalization-sustainability nexus in developing and transition economies, and establishes a foundation for future empirical investigations with larger datasets.

Keywords: *Digital transformation, sustainable development, composite index, Western Balkans, comparative analysis*

1. INTRODUCTION

In order to elaborate the research problem presented in this paper, it is essential to first define what is meant by *sustainable development* and *digital transformation*. Sustainable development refers to the balancing of environmental, economic, and social goals to ensure long-term progress without compromising the resources available to future generations. It is defined through the 17 United Nations Sustainable Development Goals (Agenda 2030). Digital transformation refers to the integration of digital technologies across all areas of society and the economy, from industry to education, healthcare, and government. In this context, it is highly important to consider how these changes can contribute to sustainable development.

Previous research (UN, 2015; WEF, 2020; OECD, 2021; among others) has confirmed that digital transformation and sustainable development are increasingly interconnected, as digital technologies can play a key role in achieving sustainability goals. Digital technologies can, for example, significantly contribute to: a) more efficient resource use (precise monitoring of energy and water consumption), b) increased transparency and/or accountability in tracing product origins and maintaining environmental and social standards, c) the development of smart cities, d) improved access to education and healthcare, and e) the advancement of the circular economy. What all these perspectives have in common is the view that digital transformation can meaningfully support sustainable development by promoting efficiency, reducing environmental impacts, and enhancing quality of life. However, uncertainties remain regarding the ways and extent to which digital technologies can affect the economic, social, and environmental dimensions of sustainability. Therefore, it is important to explore in detail how and to what extent digital transformation can act as a determinant of sustainable development, identifying key factors that either support or limit this process.

This paper focuses on understanding the mechanisms through which digital transformation impacts sustainable development in Bosnia and Herzegovina. The country is currently at a developmental crossroads where digital transformation could have a substantial influence on achieving sustainability goals. However, numerous challenges hinder or limit the effective implementation of digital technologies across different sectors of society and the economy. Issues such as underdeveloped digital infrastructure, a significant digital divide among citizens, lack of strategic policy frameworks, and limited innovation capacities present serious obstacles. On the other hand, the potential of digital transformation to enhance economic performance, increase social inclusion, and promote environmental protection remains largely untapped. Therefore, it is crucial to investigate how digital transformation can become a determinant of sustainable development in Bosnia and Herzegovina, and to identify the key factors and barriers shaping this process. This paper seeks to answer the following question: How can digital transformation contribute to sustainable development within the specific socio-economic and infrastructural context of Bosnia and Herzegovina?

Given the limited availability of longitudinal data for Bosnia and Herzegovina, this study adopts an exploratory research design aimed at identifying preliminary patterns and trends rather than establishing definitive causal relationships. The findings should be interpreted as indicative rather than conclusive, providing a foundation for future research with extended time series or cross-country panel data.

2. LITERATURE REVIEW

The relationship between digital transformation and sustainable development has attracted considerable scholarly attention over the past decade. Empirical evidence suggests that digital transformation promotes sustainable development, with studies identifying a linear relationship in which the positive impact of digitalization on SDG achievement remains constant after reaching a certain threshold (El Awady et al., 2025). A study based on data from 63 middle- and high-income countries over the period 2017–2023 confirmed that the technological dimension of the digital transformation index exerts a significant positive effect on SDG performance, whereas the knowledge and future readiness dimensions do not exhibit statistically significant effects (El Awady et al., 2025). Nosratabadi et al. (2023) provided quantitative empirical evidence that digital transformation in Finland, the Netherlands, and Denmark is the

most socially sustainable, and that social sustainability of digital transformation leads countries to higher performance in achieving the SDGs. ElMassah and Mohieldin (2020) emphasized that localization enables governments to tailor sustainable development strategies more effectively at the local level, a process that can be further strengthened through digital transformation. Nevertheless, substantial barriers have been identified, including the digital divide, high implementation costs, data privacy concerns, and skills shortages.

Regarding the impact of digitalization on labor markets, the literature indicates complex and non-linear effects. Multiple studies have confirmed that digital transformation initially exerts a negative effect on employment quality, which gradually reverses as transformation deepens, displaying a U-shaped pattern (Zhao et al., 2024), with adverse employment effects being particularly pronounced among women and less-educated workers (Aum & Shin, 2025; Autor & Dorn, 2013). The World Economic Forum (2023) projects that by 2027, digitalization and automation will lead to the elimination of 26 million administrative jobs while simultaneously creating approximately 4 million new digitally enabled roles. In the context of SDG 9 (Industry, Innovation, and Infrastructure), the literature confirms that investments in digital infrastructure significantly contribute to industrial development, with UNCTAD (2017) emphasizing the need for targeted investment policies in developing countries aimed at building connectivity infrastructure and supporting the digitalization of the broader economy. By the end of 2022, 4.5 billion people (57% of the global population) were using mobile internet, although 5% of the world's population still lives in areas without mobile broadband coverage (GSMA, 2023).

With regard to the relationship between digital transformation and environmental sustainability, the literature reports mixed findings. While digital technologies in energy grids can enhance energy efficiency and contribute to reductions in greenhouse gas emissions, rapid technological development may simultaneously lead to increased electronic waste, energy consumption of digital infrastructure, and cybersecurity vulnerabilities that partially offset positive contributions to SDG achievement.

According to Truong (2022), the results highlight the transformations that preserve the environment in three main areas: waste management and handling, pollution prevention and control, and sustainable resource management. On the other hand, the study highlights several challenges: the extraction of mineral resources for ICT goods production causes numerous negative environmental impacts, the volume of e-waste proliferates year by year and is becoming an emerging threat to the environment, and digital transformation requires a large amount of physical hardware that demands resources and energy throughout its life cycle (Truong,

2022). The OECD (2021), in its Development Co-operation Report, stressed that digital transformation represents a strategic opportunity to accelerate progress toward development objectives, provided that policies foster an inclusive digital future and align digital financing with sustainability goals. Secundo et al. (2020) emphasized that governments can promote sustainability-oriented digital transformation through subsidies for green technologies, legislative frameworks for CO_2 reduction, and incentives for sustainable infrastructure investment.

Despite the growing body of research, empirical evidence on the digitalization–sustainability nexus in developing and transition economies remains limited (Varriale et al., 2025). A comprehensive analysis linking digital technologies, industrial sectors, and SDGs is still largely absent from the existing scholarly literature, particularly for countries in the Western Balkans. This study is grounded in two complementary theoretical perspectives that provide a robust analytical lens for examining the relationship between digital transformation and sustainable development: the Technology–Organization–Environment (TOE) framework and Institutional Theory.

3. RESEARCH METHODOLOGY

3.1. RESEARCH OBJECTIVES

The primary objective of this study is to explore the potential associations between digital transformation and the achievement of the Sustainable Development Goals (SDGs) in Bosnia and Herzegovina by analyzing the relationships between the key dimensions of digital transformation (D1 = human capital and skills, D2 = infrastructure and connectivity, D3 = digital integration in business, and D4 = innovation) and selected SDG indicators (SDG 4, SDG 7, SDG 8, SDG 9, and SDG 13).

In order to achieve the main research objective, the following operational objectives were defined:

1. To construct a composite digital transformation index tailored to the context of Bosnia and Herzegovina.
2. To determine the nature and intensity of the relationships between individual dimensions of digital transformation and the Sustainable Development Goals.
3. To identify which dimensions of digital transformation exert positive effects, and which potentially generate negative effects on sustainable development outcomes.

4. To formulate policy recommendations aimed at steering digital transformation toward sustainable development.
5. To position Bosnia and Herzegovina within the regional context by conducting a comparative analysis of digital transformation indicators across the Western Balkan countries.

Given the exploratory nature of this study and the limited sample size, the following research question – rather than formal hypotheses – guided the analysis:

RQ0: Are there observable associations between digital transformation dimensions and SDG achievement in Bosnia and Herzegovina?

The following propositions were examined:

P1: Infrastructure and connectivity (D2) are expected to show a positive association with SDG 9 (Industry, Innovation, and Infrastructure).

P2: Digital integration in business (D3) is expected to show a positive association with SDG 9 (Industry, Innovation, and Infrastructure).

P3: Digital integration in business (D3) is expected to show a negative association with SDG 8 (Decent Work and Economic Growth), reflecting potential short-term labor market disruptions.

P4: Human capital and digital skills (D1) are expected to show associations with SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth).

P5: Innovation (D4) is expected to show associations with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action).

3.2. CONCEPTUAL RESEARCH MODEL

Digital transformation in Bosnia and Herzegovina during the period 2019–2023 functioned as a multi-layered catalyst for development through four key dimensions (Table 1). First, the human capital dimension (D1) links digital skills with educational attainment and labor market employability. Growth in SDG 4 indicators, such as participation in pre-primary and primary education, reflects long-term strengthening of digital literacy, which indirectly contributes to SDG 8 by increasing employment and reducing workforce vulnerability. Second, the infrastructure and connectivity dimension (D2) directly supports SDG 9 and extends its effects to SDG 11, SDG 16, and SDG 17. Rising internet penetration and mobile connectivity enable greater inclusion of citizens in financial, administrative, and educational services, thereby enhancing institutional transparency and social participation. Third, digital integration in busi-

ness (D3) supports productivity and innovation among economic entities. The adoption of e-commerce platforms and digital business processes facilitates reductions in operational costs, resource optimization, and improved market access, which is reflected in lower unemployment and more stable economic growth within the scope of SDG 8 and SDG 9. Finally, the innovation dimension (D4) links research and development activities with green technologies. Although Bosnia and Herzegovina has achieved universal access to electricity, challenges related to clean fuel usage and CO_2 emissions indicate substantial room for improvement. Nevertheless, the gradual reduction in emission intensity suggests that digital innovation, energy efficiency, and automation contribute to the achievement of SDG 7 and SDG 13. This cross-sectoral model demonstrates that digital transformation does not operate in isolation, but rather through integrated mechanisms that simultaneously advance education, economic performance, infrastructure development, and climate policies.

Table 1. Conceptual framework of the study

Dimension (DT)	Primary SDG	Secondary SDG	Key Mechanism
D1: Human Capital and Skills	SDG 4, SDG 8	SDG 1, SDG 5, SDG 10	Digital Literacy → Employability → Income
D2: Infrastructure and Connectivity	SDG 9	SDG 11, SDG 16, SDG 17	Internet Access → Inclusion → Participation
D3: Digital Integration in Business	SDG 8, SDG 9	SDG 1, SDG 12	E-commerce → Productivity → Economic Growth
D4: Innovation	SDG 7, SDG 13	SDG 9, SDG 11, SDG 12	R&D → Green Technologies → Decarbonization

Source: Authors' elaboration

Although the SDG goals comprise a larger number of indicators, only those indicators for which data were available for Bosnia and Herzegovina for the period 2019–2023 were included in the analysis. The limited number of indicators reflects systemic shortcomings in the available statistical sources, rather than a weakness of the analytical model. Therefore, the composite index provides a realistic representation of what could be empirically measured in Bosnia and Herzegovina during the specified period.

3.3. DATA SOURCES FOR EMPIRICAL ANALYSIS

Digital transformation served as the independent variable in this study. The analysis utilized secondary data on various digital transformation indicators for Bosnia and Herzegovina. This includes a review of the existing reports and data from relevant sources such as the Agency for Statistics of Bosnia and Herzegovina, the Ministry of Finance of BiH, as well as reports from Eurostat, the World Bank, the United Nations, the OECD, and the World Economic Forum. The analysis covered the period from 2019 to 2023, aiming to identify trends in digital transformation and sustainable development. Descriptive data on the available digital transformation indicators for Bosnia and Herzegovina are presented in Table 2.

Table 2. Digital transformation indicators for the period 2019–2023

Indicator	**2019**	**2020**	**2021**	**2022**	**2023**
Adoption of Digital Technologies (Internet usage)	71.50%	75.00%	77.00%	79.00%	80.00%
Automation and Process Optimization (proportion of automated industries)	12.50%	17.50%	20.00%	22.50%	25.00%
Increase in Online Presence (E-commerce: % of total retail sales)	7.50%	12.50%	15.00%	17.50%	17.50%
Cybersecurity (cybersecurity resilience)	99.80%	87.50%	82.50%	78.50%	77.50%
Education and Competencies (digital literacy)	52.55%	59.00%	61.00%	62.00%	62.00%
Speed of Innovation (R&D investment - % of GDP)	0.30%	0.35%	0.40%	0.45%	0.50%
Digital Transformation in Public Services (E-government - % of services online)	12.50%	22.50%	27.50%	30.00%	30.00%
Climate Adaptation and Resilience (share of renewable energy sources)	35.00%	36.50%	38.00%	40.00%	40.00%
Green Transport (electric vehicles - % of total vehicles)	0.50%	0.70%	1.00%	1.20%	1.75%
ICT specialists (% of total employment)	2.10%	2.30%	2.40%	2.50%	2.60%
STEM graduates (% of all graduates)	22.00%	23.00%	24.00%	25.00%	26.00%
Percentage of researchers per million inhabitants	0.069%	0.062%	0.065%	0.067%	0.067%

Indicator	2019	2020	2021	2022	2023
High-tech exports (% of manufactured exports)	2.30%	2.50%	2.80%	3.00%	3.20%
ICT sector: contribution to GDP (%)	4.50%	4.80%	5.00%	5.20%	5.50%
Enterprises with a website (%)	65.00%	68.00%	70.00%	72.00%	75.00%
Enterprises with e-sales (%)	15.00%	18.00%	20.00%	22.00%	25.00%
Telecom Infrastructure	49.45%	52.80%	56.20%	59.60%	59.50%

Data Sources: Agency for Statistics of Bosnia and Herzegovina (2023); Eurostat (2023); United Nations Department of Economic and Social Affairs (2024); World Bank (2023); UNESCO Institute for Statistics (2023); Carrington (2020)

The dependent variable in this study was sustainable development. From the 17 SDGs defined in the UN 2030 Agenda, five goals were selected for the analysis: SDG 4 (Quality Education), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action). The selection was guided by two criteria: (1) theoretical relevance to digital transformation based on the conceptual framework presented in Table 1, and (2) data availability for Bosnia and Herzegovina for the complete period 2019-2023. Several SDGs theoretically relevant to digitalization (e.g. SDG 11 - Sustainable Cities, SDG 16 - Strong Institutions) could not be included due to incomplete time series data for BiH in the source database. The sustainable development indicators used in the research are presented in Table 3.

Table 3. Descriptive statistics for the selected SDG indicators

Country	Year	SDG4			SDG 7			SDG 8		SDG 9		SDG 13	
		sdg4_preprim	sdg4_primary	sdg4_second	sdg7_elecac	sdg7_cleanfuel	sdg7_co2twh	sdg8_unemp	sdg8_rights	sdg9_intuse	sdg9_mobuse	sdg13_co2gcp	sdg13_ghgimport
BiH	2019	31.29	98.73	91.05	100.00	42.05	1.19	15.69	0.65	69.95	46.64	6.16	1.61
BiH	2020	33.15	98.16	90.14	100.00	40.85	1.23	15.87	0.63	73.21	49.21	6.24	1.70
BiH	2021	31.59	98.45	88.28	100.00	40.90	1.14	14.90	0.63	75.68	56.51	6.45	1.78
BiH	2022	35.28	98.50	87.02	100.00	41.10	1.25	12.66	0.62	78.85	65.48	6.46	1.84
BiH	2023	37.50	97.90	87.82	100.00	41.10	1.14	10.67	0.61	83.38	69.91	6.27	1.91

Data Source: Sachs, J.D., Lafortune, G., Fuller, G., Iablonovski, G. (2025). Financing Sustainable Development to 2030 and Mid-Century. Sustainable Development Report 2025. Paris: SDSN, Dublin: Dublin University Press. DOI: https://doi.org/10.25546/111909

The Sustainable Development Report database contains multiple indicators for each SDG. For Bosnia and Herzegovina, data availability was the pri-

mary constraint, as many indicators tracked for EU and OECD countries are not systematically reported for Western Balkan states. The twelve indicators presented above represent the complete set of SDG 4, 7, 8, 9, and 13 metrics available for BiH across all five years of the observation period (2019-2023). This data limitation should be considered when comparing results with studies conducted in data-rich environments.

The selected indicators align with the metrics used in comparative studies of digital transformation and sustainability (El Awady et al., 2025). The SDG 9 indicators (internet use and mobile broadband) directly overlap with connectivity metrics in the Digital Economy and Society Index (DESI), facilitating cross-referencing with EU benchmarks (European Commission, 2022). Similarly, the SDG 8 unemployment indicator corresponds to standard labor market metrics used by Eurostat.

3.4. DATA PREPARATION FOR ANALYSIS

For the independent variable, a min–max normalization of the data was performed on a scale from 0 to 100. Min–max normalization was used to transform the original values of the digital transformation indicators into comparable values on a 0–100 scale. The normalization formula applied is as follows:

$$X_{\text{norm}} = \frac{X - X_{min}}{X_{\text{max}} - X_{\text{min}}} \times 100$$

Where:

- X_{norm} = normalized value on a 0–100 scale
- X = original indicator value
- X_{min} = minimum value of the indicator during the period 2019–2023
- X_{max} = maximum value of the indicator during the period 2019–2023

The min-max normalization using the sample's own range (2019-2023) should be interpreted with caution, as this approach may amplify apparent trends. Additionally, the small sample size (n=5) limits the statistical power of subsequent analyses. Therefore, the correlation and regression results presented in this study should be considered as exploratory indicators of potential relationships rather than statistically robust estimates.

After normalization, the digital transformation indicators for Bosnia and Herzegovina are presented in Table 4.

Table 4. Digital transformation indicators for Bosnia and Herzegovina after data normalization

Indicators	2019	2020	2021	2022	2023
Adoption of Digital Technologies (Internet usage)	0.00	41.18	64.71	88.24	100.00
Automation and Process Optimization (proportion of automated industries)	0.00	40.00	60.00	80.00	100.00
Increase in Online Presence (E-commerce: % of total retail sales)	0.00	50.00	75.00	100.00	100.00
Cybersecurity (cybersecurity resilience)	100.00	44.84	22.42	4.48	0.00
Education and Competencies (digital literacy)	0.00	68.25	89.42	100.00	100.00
Speed of Innovation (R&D investment - % of GDP)	0.00	25.00	50.00	75.00	100.00
Digital Transformation in Public Services (E-government - % of services online)	0.00	57.14	85.71	100.00	100.00
Climate Adaptation and Resilience (share of renewable energy sources)	0.00	30.00	60.00	100.00	100.00
Green Transport (electric vehicles - % of total vehicles)	0.00	16.00	40.00	56.00	100.00
ICT specialists (% of total employment)	0.00	40.00	60.00	80.00	100.00
STEM graduates (% of all graduates)	0.00	25.00	50.00	75.00	100.00
Percentage of researchers per million inhabitants	100.00	0.00	100.00	100.00	100.00
High-tech exports (% of manufactured exports)	0.00	22.22	55.56	77.78	100.00
ICT sector: contribution to GDP (%)	0.00	30.00	50.00	70.00	100.00
Enterprises with a website (%)	0.00	30.00	50.00	70.00	100.00
Enterprises with e-sales (%)	0.00	30.00	50.00	70.00	100.00
Telecom Infrastructure	0.00	33.00	66.50	100.00	99.01

After data normalization, the indicators were grouped, and a composite index for each group was calculated using the procedure presented in Table 5. The construction of the composite digital transformation index follows established methodological practices used in internationally recognized indices. Equal weights were applied to all indicators within each dimension and to

all four dimensions in the overall index. This approach is consistent with the methodology of the Digital Economy and Society Index (DESI) developed by the European Commission, which assigns equal weights of 25% to each of its four main dimensions: Human Capital, Connectivity, Integration of Digital Technology, and Digital Public Services (European Commission, 2022). The four dimensions of the digital transformation index (D1-D4) were conceptualized based on established theoretical frameworks in the digital transformation literature. The dimensional structure aligns with the European Commission's Digital Economy and Society Index (DESI), which organizes digital development into Human Capital, Connectivity, Integration of Digital Technology, and Digital Public Services (European Commission, 2022). Similarly, the IMD World Digital Competitiveness Ranking structures digital competitiveness around Knowledge, Technology, and Future Readiness (IMD, 2024). Our framework adapts these established approaches to the specific context of Bosnia and Herzegovina, focusing on: (D1) human capital and digital skills as enablers of digital adoption; (D2) infrastructure and connectivity as foundational prerequisites; (D3) digital integration in business as a measure of economic digitalization; and (D4) innovation as a driver of technological advancement and sustainability orientation.

Table 5. Calculation of the composite index for each dimension

D1: HUMAN CAPITAL AND SKILLS						
Indicator	**Weighted**	**2019**	**2020**	**2021**	**2022**	**2023**
Education and Competencies (digital literacy)	33.33%	0.00	68.25	89.42	100.00	100.00
ICT specialists (% of total employment)	33.33%	0.00	40.00	60.00	80.00	100.00
STEM graduates (% of all graduates)	33.33%	0.00	25.00	50.00	75.00	100.00
Average D1	**25%**	**0.00**	**44.42**	**66.47**	**85.00**	**100.00**
D2: INFRASTRUCTURE AND CONNECTIVITY						
Indicator	**Weighted**	**2019**	**2020**	**2021**	**2022**	**2023**
Adoption of Digital Technologies (Internet usage)	33.33%	0.00	41.18	64.71	88.24	100.00
Telecom Infrastructure	33.33%	0.00	33.00	66.50	100.00	99.01
Cybersecurity (cybersecurity resilience)	33.33%	100.00	44.84	22.42	4.48	0.00
Average D2	**25%**	**33.33**	**39.67**	**51.21**	**64.24**	**66.34**

D3: DIGITAL INTEGRATION IN BUSINESS						
Indicator	**Weighted**	**2019**	**2020**	**2021**	**2022**	**2023**
Automation and Process Optimization (proportion of automated industries)	20.00%	0.00	40.00	60.00	80.00	100.00
Increase in Online Presence (E-commerce: % of total retail sales)	20.00%	0.00	50.00	75.00	100.00	100.00
Enterprises with a website (%)	20.00%	0.00	30.00	50.00	70.00	100.00
Enterprises with e-sales (%)	20.00%	0.00	30.00	50.00	70.00	100.00
High-tech exports (% of manufactured exports)	20.00%	0.00	22.22	55.56	77.78	100.00
Average D3	**25%**	**0.00**	**34.44**	**58.11**	**79.56**	**100.00**
D4: INNOVATIONS FOR SUSTAINABILITY						
Indicator	**Weighted**	**2019**	**2020**	**2021**	**2022**	**2023**
Speed of Innovation (R&D investment - % of GDP)	16.67%	0.00	25.00	50.00	75.00	100.00
Digital Transformation in Public Services (E-government - % of services online)	16.67%	0.00	57.14	85.71	100.00	100.00
ICT sector: contribution to GDP (%)	16.67%	0.00	30.00	50.00	70.00	100.00
Percentage of researchers per million inhabitants	16.67%	100.00	0.00	100.00	100.00	100.00
Climate Adaptation and Resilience (share of renewable energy sources)	16.67%	0.00	30.00	60.00	100.00	100.00
Green Transport (electric vehicles - % of total vehicles)	16.67%	0.00	16.00	40.00	56.00	100.00
Average D4	**25%**	**16.67**	**26.36**	**64.29**	**83.50**	**100.00**

Source: Authors' elaboration

Regarding the data preparation for the dependent variable, it was first necessary to identify the negative indicators from Table 3. These are indicators for which higher values represent worse outcomes in achieving the SDG targets. These indicators are presented in Table 6.

Table 6. Negative indicators

SDG	Label	Description
SDG 7	sdg7_co2twh	Emissions per TWh
SDG 8	sdg8_unemp	Unemployment
SDG 13	sdg13_co2gcp	CO_2 per Capita

These indicators were converted into a positive metric, so that higher values correspond to better achievement of the goal, using the following formula:

$$X_{inv} = \max(X) - X$$

Subsequently, min–max normalization of the dependent variable data on a 0–100 scale was performed using the following formulas:

$$\text{Positive Indicators: } X' = \frac{X - \min(X)}{\max(X) - \min(X)} \times 100$$

$$\text{Negative Indicators (Already Inverted): } X' = \frac{X_{inv} - \min(X_{inv})}{\max(X_{inv}) - \min(X_{inv})} \times 100$$

Table 7 presents the data for the sustainable development sub-indicators after their normalization.

Table 7. Data for sustainable development sub-indicators after data normalization

Year	sdg4 _preprim	sdg4 _primary	sdg4 _second	sdg7 _elecac	sdg7 _clean-fuel	sdg7 _co2twh	sdg8 _unemp	sdg8 _rights	sdg9 _intuse	sdg9 _mobuse	sdg13 _co2gcp	sdg13 _ghgim-port
2019	0	100	100	0	100	42.9	34.4	100	0	0	77.6	100
2020	28.8	52.4	76.2	0	0	0	31.6	50	28.1	28.1	51.7	57.1
2021	13.3	76.2	28.9	0	14	57.1	50	50	51.8	60.8	0	28.6
2022	79.4	81	0	0	57.7	0	86.5	25	79.7	87.7	0	7.1
2023	100	0	10	0	57.7	57.1	100	0	100	100	41.4	0

Source: Authors' elaboration

The dependent variable in this study is a composite index measuring the achievement of selected Sustainable Development Goals (SDGs). All SDG in-

dicators were obtained from the Sustainable Development Report 2025 (Sachs et al., 2025), which provides standardized, internationally comparable metrics for tracking SDG progress across countries.

The composite index for each SDG was calculated by applying a simple arithmetic mean of the normalized sub-indicators, in the same manner as presented in Table 5. The results are shown in Table 8. The findings indicate that SDG 4 experienced stable growth, primarily driven by increased participation in pre-primary education and high levels of primary education. SDG 7 remained nearly unchanged due to the already high electrification rates and modest improvements in access to clean fuels. SDG 8 shows gradual growth, predominantly driven by reductions in unemployment, while SDG 9 achieved the strongest progress due to accelerated digitalization, reflected in increased internet and mobile access. SDG 13 demonstrates continuous, but moderate advancement through the decarbonization of the economy, although increases in GHG emissions from imports partially offset the overall effect.

Table 8. Composite indicator of sustainable development goal achievement

Year	SDG 4	SDG 7	SDG 8	SDG 9	SDG 13
2019	66.67	47.63	67.20	23.32	88.79
2020	52.47	33.36	60.53	38.08	54.40
2021	39.46	23.70	61.84	56.25	9.52
2022	53.47	30.26	53.23	83.67	2.35
2023	35.97	38.16	36.90	100.00	20.71

Source: Authors' elaboration

3.5 COMPARATIVE REGIONAL FRAMEWORK

In order to address the limitations inherent in the single-country analysis and to respond to the need for cross-country comparison, this study incorporates a regional dimension encompassing seven Western Balkan economies: Bosnia and Herzegovina, Croatia, Serbia, Montenegro, North Macedonia, Kosovo, and Albania. Regional data on digital transformation indicators were obtained from the OECD Economic Convergence Scoreboard for the Western Balkans (OECD, 2024; 2025). Due to data availability constraints, the comparative analysis focuses on seven indicators for which consistent data exist across all countries and years: (1) internet usage, (2) e-commerce adoption, (3) digital skills, (4) e-government services, (5) ICT specialists as

percentage of employment, (6) enterprises with a website, and (7) enterprises with e-sales.

This comparative framework serves three analytical purposes: first, to contextualize BiH's digital transformation performance relative to regional peers; second, to identify convergence or divergence patterns across the Western Balkans; and third, to assess whether findings from the BiH-specific analysis are consistent with broader regional trends. The regional comparison is primarily descriptive, given that harmonized SDG data for panel regression were not available for all countries.

4. RESEARCH RESULTS AND DISCUSSION

4.1. RESULTS FOR BOSNIA AND HERZEGOVINA

The study explored potential associations between the digital transformation dimensions, human capital (D1), digital infrastructure (D2), digital integration in business (D3), and innovation (D4), in the achievement of SDGs in Bosnia and Herzegovina during the period 2019–2023. The exploratory analysis suggests that digital infrastructure and digital integration show the strongest and most consistent associations with SDG 9 (Industry, Innovation, and Infrastructure), whereas digital integration has a short-term negative impact on SDG 8 (Decent Work and Economic Growth), as shown in Table 9. Marginally significant and uncertain relationships highlight the challenges in human capital and innovation, particularly in the areas of education, employment, and environmental sustainability, as presented in Table 10. Relationships that are not statistically significant are summarized in Table 11.

Table 9. Exploratory results: strong associations ($p < 0.05$)

Relationship between variables	r	R^2	β^1	p-value	Regression equation
D2 → SDG9	0.9878	97.58%	2.1413	0.0016	SDG9 = -48.85 + 2.1413 × D2
D3 → SDG9	0.9808	96.20%	+0.7953	0.0032	SDG9 = 16.98 + 0.7953 × D3
D3 → SDG8	-0.8829	77.94%	-0.2661	0.0473	SDG8 = 70.42 - 0.2661 × D3

Note: Given the small sample size (n=5), p-values should be interpreted with caution as indicators of association strength rather than definitive statistical significance.

Table 10. Research results for marginally significant relationships (0.05 < p < 0.10)

Relationship between variables	r	R^2	β^1	p-value
D1 → SDG4	-0.8248	68.03%	-0.2592	0.0857
D1 → SDG8	-0.8375	70.14%	-0.2519	0.0767
D4 → SDG13	-0.8559	73.25%	-0.8580	0.0643

Table 11. Research results for relationships with no statistical significance (p ≥ 0.10)

Relationship between variables	r	R^2	β^1	p-value
D4 → SDG7	-0.4105	16.85%	-0.1024	0.4925

The results suggest that digital infrastructure (D2) and digital integration in business (D3) show the strongest and most consistent associations with sustainable development indicators in Bosnia and Herzegovina during the period 2019–2023.

Proposition P1, which anticipated a positive association between infrastructure and connectivity (D2) and SDG 9, is supported by the observed data patterns. The relationship is extremely strong and positive ($r = 0.9878$; $R^2 = 97.58\%$; $p = 0.0016$), suggesting that SDG 9 trends closely mirror digital infrastructure development, though the small sample size (n=5) warrants caution in interpreting this association as causal. Proposition P2 is similarly supported: digital integration in business (D3) exhibits a strong positive association with SDG 9 ($r = 0.9808$; $p = 0.0032$), suggesting that business digitalization trends closely align with industrial development indicators during the observed period.

Proposition P3, which anticipated a negative association between D3 and SDG 8, is also supported. The negative correlation ($r = –0.8829$; $p = 0.0473$) suggests that increased digital integration may be accompanied, in the short term, by digital disruption processes: automation, digital commerce, and workforce restructuring reduce traditional forms of employment, particularly in economies where workforce adaptation is slower. This pattern is consistent with theoretical expectations of short-term labor market disruptions during digital transition.

Propositions P4 and P5 show weaker patterns. The negative correlations between human capital (D1) and both SDG 4 ($r = –0.8248$; $p = 0.0857$) and SDG 8 ($r = –0.8375$; $p = 0.0767$) suggest that structural shifts in education and the labor market are not occurring rapidly enough to keep pace with the digital changes. Innovation (D4) shows a marginally significant negative relationship with SDG 13 ($r = –0.8559$; $p = 0.0643$), indicating that technological innova-

tions in BiH are still primarily focused on industrial modernization rather than emissions reduction. The only non-significant relationship (D4 → SDG 7; p = 0.4925) suggests that digital innovations during the observed period were not directed toward energy transition.

In summary, of the five exploratory propositions, three show strong supporting patterns (P1, P2, P3), while two show weaker patterns (P4, P5) that require verification with larger datasets.

Based on these preliminary patterns, several tentative policy considerations emerge. Priority should be placed on continuous investment in digital infrastructure, particularly in rural areas, to ensure balanced regional development. The observed negative relationship between digital integration and decent work highlights the necessity of complementary social protection measures and workforce reskilling programs. Special attention should be devoted to integrating environmental considerations into innovation policy through financial instruments and tax incentives that favor green solutions. Finally, educational system reform is essential to strengthen digital competencies while maintaining a focus on lifelong learning and workforce adaptability.

4.2 COMPARATIVE REGIONAL ANALYSIS: BOSNIA AND HERZEGOVINA IN THE WESTERN BALKANS CONTEXT

In order to address the limitations of single-country analysis, this section presents a comparative overview of digital transformation trends across seven Western Balkan economies. Data were obtained from the OECD Economic Convergence Scoreboard (OECD, 2024; 2025), enabling cross-country comparison during the period 2019–2023.

Table 12. Digital transformation indicators across Western Balkans (2023)

Indicator	BiH	Croatia	Serbia	Montenegro	N. Macedonia	Kosovo	Albania
Internet usage (%)	80.0	86.0	84.0	86.0	80.0	90.0	83.0
E-commerce adoption (%)	17.5	40.0	45.0	32.0	30.0	40.0	25.0
Digital skills (%)	62.0	59.0	48.0	45.0	40.0	45.0	45.0
E-government services (%)	30.0	50.0	35.0	30.0	24.0	25.0	28.0
ICT specialists (% employment)	2.6	4.3	2.8	2.3	2.0	1.7	1.8
Enterprises with a website (%)	75.0	78.0	76.0	70.0	66.0	65.0	66.0
Enterprises with e-sales (%)	25.0	38.0	35.0	30.0	25.0	28.0	28.0

Source: OECD (2024; 2025); BiH data from Table 2

The comparative analysis reveals several notable patterns (Table 12). Internet connectivity has largely converged across the region (80–90% by 2023), suggesting that basic infrastructure gaps are narrowing. However, substantial disparities persist in e-commerce adoption, where BiH (17.5%) significantly lags behind the regional average (32.8%) and the leader Serbia (45%). Conversely, BiH demonstrates a comparative advantage in digital skills (62%), ranking first among the Western Balkan countries and surpassing even Croatia (59%). E-government development shows significant variation, with Croatia leading decisively (50%), while BiH (30%) ranks in the middle tier.

Table 13 presents the growth dynamics in internet usage across the region, illustrating differential rates of digital transformation progress.

Table 13. Internet usage growth across the Western Balkans (2019-2023)

Country	2019	2023	Change (p.p.)	Annual growth rate
Kosovo	60.0%	90.0%	+30.0	10.7%
Montenegro	70.0%	86.0%	+16.0	5.3%
North Macedonia	65.0%	80.0%	+15.0	5.3%
Serbia	72.0%	84.0%	+12.0	3.9%
BiH	71.5%	80.0%	+8.5	2.8%
Croatia	78.0%	86.0%	+8.0	2.5%
Albania	75.0%	83.0%	+8.0	2.5%

Source: Authors' calculations

The growth trajectory analysis (Table 13) reveals that countries with lower initial connectivity experienced faster growth, consistent with the technological catch-up dynamics. BiH recorded one of the slowest growth rates (2.8% annually), suggesting that accelerating connectivity expansion should be a policy priority. Three distinct country clusters emerged: a leading cluster (Croatia, benefiting from EU membership and structural funds), a converging cluster (Serbia, Montenegro, Kosovo), and a lagging cluster (BiH, North Macedonia, Albania), though with differentiated profiles.

Table 14. BiH digital transformation position in the Western Balkans (2023)

Indicator	BiH value	WB average	BiH rank (from 7)	Gap vs. Leader
Internet usage	80.0%	84.1%	6.	-10 p.p. (Kosovo 90%)
E-commerce	17.5%	32.8%	**7.**	-27.5 p.p. (Serbia 45%)
Digital skills	62.0%	49.1%	**1.**	+3 p.p. (above Croatia)
E-government	30.0%	31.7%	4.	-20 p.p. (Croatia 50%)
ICT specialists	2.6%	2.50%	3.	-1.7 p.p. (Croatia 4.3%)
Enterprises with a website	75.0%	70.9%	3.	-3 p.p. (Croatia 78%)
Enterprises with e-sales	25.0%	29.9%	6.	-13 p.p. (Croatia 38%)

Source: Authors' calculations

The most striking finding is the BiH digital paradox: the country ranks first in digital skills, yet last in e-commerce adoption (Table 14). This suggests that human capital is not the binding constraint on digital transformation. Rather, institutional factors such as regulatory fragmentation, underdeveloped payment infrastructure, complex governance structures, and limited coordination capacity, appear to prevent the translation of digital competencies into economic outcomes. This interpretation aligns with the marginally significant negative relationships between human capital (D1) and both SDG 4 and SDG 8 observed in Section 4.1, suggesting that institutional bottlenecks may be preventing human capital from generating expected developmental returns.

Croatia consistently leads in four of the seven indicators, benefiting from EU membership since 2013, the access to structural funds, and regulatory harmonization with the EU digital acquis. This positions Croatia as the natural benchmark for Western Balkan EU aspirants.

CONCLUSION

This exploratory study investigated the potential associations between digital transformation and the achievement of Sustainable Development Goals (SDGs) in Bosnia and Herzegovina during the period 2019–2023, complemented by a comparative analysis across seven Western Balkan countries. The results suggest that digital transformation shows differentiated association patterns with specific SDGs. Of the five exploratory propositions examined, three showed strong supporting patterns. Digital infrastructure and connectivity

(D2) and digital integration in business (D3) demonstrated the strongest positive associations with SDG 9 (Industry, Innovation, and Infrastructure), with correlation coefficients exceeding 0.98. Conversely, digital integration showed a statistically significant negative association with SDG 8 (Decent Work and Economic Growth), consistent with theoretical expectations of short-term labor market disruptions during digital transition. Marginally significant relationships between human capital and educational/economic objectives, as well as between innovation and climate action, suggest structural challenges in aligning institutional frameworks with the pace of digital transformation.

The comparative analysis across the Western Balkans revealed a striking paradox: Bosnia and Herzegovina ranks first in the region in digital skills (62%), yet simultaneously ranks last in e-commerce adoption (17.5%). This finding fundamentally reframes the interpretation of BiH's digital transformation challenges. Rather than human capital deficits, institutional factors, including regulatory fragmentation, underdeveloped payment infrastructure, complex governance structures, and limited coordination capacity, appear to be the main barriers to progress. This interpretation aligns with and reinforces the marginally significant negative relationships between human capital (D1) and both SDG 4 and SDG 8 observed in the primary analysis, suggesting that institutional bottlenecks prevent human capital from generating expected developmental returns.

The convergence of evidence from both analytical approaches suggests three priority areas. First, policy focus should shift from basic digital literacy programs toward removing institutional barriers to digital commerce, including payment infrastructure modernization, consumer protection frameworks, and regulatory simplification. Second, the substantial gap in e-government services between BiH (30%) and regional leader Croatia (50%) highlights the need for accelerated public sector digitalization. Third, BiH's complex governance structure, with multiple levels of government and fragmented regulatory competencies, constitutes a unique structural barrier requiring coordination mechanisms that transcend entity and cantonal boundaries.

The study has several important limitations. The primary analysis is based on only five annual observations (2019-2023), fundamentally constraining statistical inference. The high R^2 values reflect trend similarities over a short period and should be interpreted as preliminary indicators rather than definitive measures of explained variance. It is important to acknowledge that the observed correlations may reflect common trends driven by broader structural factors rather than direct causal pathways from digital transformation to SDG achievement. Both digital transformation indicators and SDG measures exhib-

it upward trends, raising the possibility of spurious correlation. Future research should prioritize extending the sample through longer time series (ideally 15-20 years) or panel data approaches incorporating multiple countries, if data for such research become available in the future. Such extensions would enable more robust statistical inference, including tests for Granger causality and cointegration analysis. The preliminary patterns identified in this exploratory study, particularly the BiH digital paradox, can serve as hypotheses for testing in more comprehensive research designs.

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HETEROGENEITY IN GREEN DECOUPLING ACROSS THE EUROPEAN UNION: A CLUSTER ANALYSIS OF EU-27, 2013-2023

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Over the past decade, the European Union (EU) has faced a growing challenge of aligning economic expansion with environmental sustainability, as rising concerns over climate change, resource scarcity, and greenhouse gas (GHG) emissions have intensified the demand for low-carbon development. Within this context, green decoupling – the capacity of an economy to grow while stabilizing or reducing environmental pressures – has emerged as a central policy and research objective. Despite ambitious EU-wide initiatives such as the European Green Deal and the Fit for 55 package, significant uncertainty remains regarding the degree to which Member States have succeeded in reducing the environmental intensity of growth, and how structural differences shape these outcomes. This study contributes to the literature by providing a systematic assessment of decoupling dynamics across the EU-27 during the 2013-2023 period, offering empirical insights into the heterogeneity of national performance and the persistence of differences in decoupling intensity across Member States in Europe's green transition. The main objective of the paper is to quantify the intensity and structure of green decoupling across EU Member States, and to identify distinct country groupings based on their decoupling performance. Specifically, the study investigates how variations in industrial composition, technological capability, energy efficiency, and institutional capacity contribute to differences in environmental outcomes. By combining econometric estimation with multivariate statistical techniques, the analysis seeks to provide a replicable framework for assessing sus-

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tainability transitions and to generate policy-relevant evidence that supports differentiated strategies for achieving EU climate objectives. The empirical analysis employed a balanced panel of annual Eurostat data for the EU-27, covering the 2013-2023 period. Three key variables were examined: gross domestic product (GDP), total greenhouse gas emissions (GHG), and primary energy consumption (PEC). Country-specific log-log regressions of GDP against GHG and PEC were estimated so as to derive elasticity coefficients (β), which measure the responsiveness of environmental pressures to economic growth. Values of β below one indicate relative decoupling, negative coefficients signify absolute decoupling, and coefficients equal to or above one reflect persistent coupling between growth and environmental pressures. The estimated elasticities were subjected to hierarchical and k-means clustering to identify the groups of countries exhibiting similar decoupling trajectories. In order to assess the robustness of the classification, discriminant analysis was applied, verifying that the resulting clusters represent statistically significant structural differences rather than methodological artefacts. The results provide clear evidence of structural heterogeneity across the European Union. Most Western and Northern European economies have achieved strong or even absolute decoupling between GDP and environmental indicators, reflecting advanced technological capabilities, mature energy systems, and effective policy frameworks. In contrast, many Central and Eastern European countries remain characterized by energy-intensive growth patterns and weaker decoupling performance, driven by structural and institutional constraints. Cluster analysis confirms this divide, identifying a high-decoupling cluster of advanced, energy-efficient economies, and a low-decoupling cluster with persistent coupling between growth and environmental impact. Discriminant validation reinforces the empirical credibility of this two-tier model, indicating that differences in decoupling intensity correspond to genuine underlying economic and structural disparities. From a policy perspective, the findings highlight that although the EU as a whole is progressing toward reduced emissions and improved energy efficiency, convergence among the Member States remains incomplete. The persistence of differences between high- and low-decoupling clusters implies that the benefits of the green transition remain unevenly distributed. Achieving the objectives of the European Green Deal will thus depend on region-specific measures that combine investments in clean technologies and industrial modernization with enhanced institutional capacity and coordination at the EU level. Methodologically, the study demonstrates the analytical

value of integrating elasticity estimation with multivariate clustering and discriminant validation, offering a replicable framework for monitoring and comparing sustainability transitions. By revealing both the structural and spatial dimensions of decoupling, the study contributes to understanding how technological, institutional, and policy factors jointly shape sustainable growth trajectories within the European Union. This study adds value by combining econometric and multivariate techniques in a novel way, generating robust empirical evidence on heterogeneity in EU decoupling performance and providing policy-relevant insights for a differentiated implementation of the European Green Deal. While the study offers robust evidence, its scope is limited to aggregate national data and two environmental indicators, suggesting avenues for future research.

Keywords: *green decoupling, economic growth, energy consumption, greenhouse gas emissions, cluster analysis*

JEL classification: *Q43, Q56, O44, C33, C38*

INTRODUCTION

Over the past decade, the European Union (EU) has faced increasing pressure to reconcile economic growth with environmental sustainability (European Environment Agency [EEA], 2020). Mounting concerns over climate change, resource scarcity, and greenhouse gas (GHG) emissions have intensified the search for strategies that enable economies to expand while reducing their environmental footprint (European Commission, 2019). Green decoupling, the ability of an economy to grow without a proportional rise in energy consumption or emissions, has become central to this agenda (Organisation for Economic Co-operation and Development [OECD], 2001).

In this study, decoupling intensity denotes the elasticity of environmental pressures, specifically greenhouse gas emissions and primary energy consumption with respect to GDP growth, change in relation to Gross Domestic Product (GDP) growth. This approach follows the OECD framework in which decoupling occurs when the environmental pressure grows more slowly than its economic driving force (relative decoupling) or decreases while economic activity continues to grow (absolute decoupling) (Organisation for Economic Co-operation and Development [OECD], 2011). In line with Tapio's (2005) classification, values below one indicate relative decoupling, negative values signify absolute decoupling, and values equal to or above one reflect persistent

coupling between economic activity and environmental impact. EU-level initiatives such as the European Green Deal and the Fit for 55 package, together with national energy and climate strategies, aim to enhance energy efficiency, accelerate renewable deployment, and promote structural transformations supporting a low-carbon economy (European Commission, 2019; European Commission, 2021). Understanding how these policy objectives translate into measurable outcomes across Member States is crucial for evaluating performance and designing equitable transition strategies.

This paper examines the dynamics of green decoupling across the 27 EU Member States during the 2013-2023 period, a decade marked by post-crisis recovery, intensified climate policy implementation, and rapid technological modernization. The starting year, 2013, coincides with Croatia's accession to the EU, completing the current EU-27 configuration and ensuring full comparability across the Member States. Using annual Eurostat data (Eurostat, 2025a; Eurostat, 2025b; Eurostat, 2025c), the country-specific log-log regressions of GDP against GHG emissions and primary energy consumption (PEC) were estimated so as to derive elasticity coefficients (β) that quantify the responsiveness of environmental pressures to economic expansion. These coefficients serve as indicators of decoupling intensity: values below one denote relative decoupling, negative values indicate absolute decoupling, and values equal to or above one reflect persistent coupling between growth and environmental impact.

In order to capture cross-country heterogeneity, the β coefficients were subjected to hierarchical and K-means clustering, identifying the groups of countries with similar decoupling trajectories (Ward, 1963; MacQueen, 1967). This multivariate approach facilitates a comparative assessment of structural and policy-related factors underlying divergent environmental outcomes. Discriminant analysis was subsequently employed to validate the robustness of the identified clusters, confirming that the observed differentiation reflects statistically significant patterns rather than methodological artefacts (Hair, Black, Babin, & Anderson, 2019).

The study pursues three main objectives. First, it quantifies the intensity of green decoupling across the EU Member States using elasticity estimates for emissions and energy consumption relative to GDP. Second, it identifies empirically distinct country clusters, revealing the geographical and structural logic of the EU's green transition. Third, it tests the stability of these clusters through discriminant validation, providing a reliable framework for cross-country comparison. By integrating regression analysis, clustering and discriminant techniques, the study develops a replicable empirical approach for mapping progress toward sustainable growth across Europe.

Previous studies have revealed considerable heterogeneity in decoupling performance across European and OECD countries (Liddle & Messinis, 2018; Mikayilov, Hasanov, & Galeotti, 2018). While several Western and Northern European countries exhibit strong relative or absolute decoupling, many Central and Eastern European states remain closely coupled with energy use and emissions, although recent analyses indicate that these countries are experiencing faster improvements in decoupling over time (Sekur, Mustać, & Rogić Dumančić, 2019). Differences in energy efficiency, technological advancement and sectoral composition appear to drive these divergent trajectories (EEA, 2020).

LITERATURE REVIEW

The concept of green decoupling refers to sustaining economic growth while reducing environmental pressures, particularly greenhouse gas emissions and primary energy consumption. Its theoretical basis is the Environmental Kuznets Curve (EKC), which posits an inverted U-shaped relationship between income and environmental degradation (Grossman & Krueger, 1995). Subsequent reviews have emphasized both the appeal and the limitations of the EKC framework, noting its fragile statistical foundation and the need for alternative approaches (Stern, 2004).

Evidence on EKC-like dynamics remains mixed and highly sensitive to methodological choices. Ward et al. (2016) questioned the feasibility of absolute global decoupling, while panel analyses confirmed that results depend strongly on specification (Vollebergh, Melenberg, & Dijkgraaf, 2009). Decoupling may also be temporary, linked to recessions (Wu et al., 2019). National case studies have confirmed that EKC dynamics are not universal, but depend on country-specific factors, as shown for France (Can & Gozgor, 2016).

The existing surveys have underlined the lack of consensus regarding the energy-growth link (Ozturk, 2010; Kalimeris, Richardson, & Bithas, 2014). Cross-country studies have shown that global material use has accelerated and efficiency has declined, leading to renewed coupling of growth and resource pressures (Schandl et al., 2018). Evidence from advanced economies points to recent declines in emissions, explained by shifts in energy use and the displacement of fossil fuels (Le Quéré et al., 2019). These declines are the strongest in richer nations with supportive policy frameworks, while evidence is weaker in emerging markets (Cohen, Jalles, Loungani, & Marto, 2018).

Country-level studies have highlighted the importance of structural change and sectoral composition. In small open economies, structural breaks and

trade effects can alter apparent decoupling (Friedl & Getzner, 2003). Accounting choices, such as production-versus consumption-based measures, can also change the conclusions about national performance (Gavrilova & Vilu, 2012). Evidence from France and the United Kingdom shows that EKC dynamics are shaped by historical breaks and asymmetric adjustments rather than smooth trajectories (Fosten, Morley, & Taylor, 2012; Saglam, Yilanci, & Kongkuah, 2025).

Turning points in the income–environment relationship are highly context-dependent. Structural and institutional constraints make rapid decoupling difficult (Antal & Van den Bergh, 2014), and EKC dynamics hold only in selected European countries (Acaravci & Ozturk, 2010). Financial development can also influence energy demand, underscoring the role of financial factors in shaping the turning points (Sadorsky, 2010).

Clustering and elasticity estimation reveal policy-relevant groupings, with OECD studies linking clusters to institutional quality, energy structure, and financial development (Bella, Massidda, & Mattana, 2014). Time-varying cointegration approaches further highlight heterogeneous EKC dynamics across countries (Apergis, 2015). Decomposition analyses of OECD and EU economies complement these methods by identifying sectoral and intensity effects in emission trends (Chen, Wang, Cui, Huang, & Song, 2018; Cruz & Dias, 2016).

Long-run series have placed contemporary evidence in perspective, showing a weakening but still positive per-capita income–CO_2 link and the rarity of absolute global decoupling (Freire-González, Padilla Rosa, & Raymond, 2024). Sectoral analyses have further clarified how energy demand structures evolve with income, as household shares decline, transport shares rise, and industry follows an inverse-U pattern (Judson, Schmalensee, & Stoker, 1999).

For EU inference, harmonized administrative series are essential to ensure comparability across Member States (Eurostat, 2025a; Eurostat, 2025b; Eurostat, 2025c). The existing studies often treat elasticity estimation and country grouping separately, and integrating both in the harmonized EU-27 data for 2013–2023 closes an important methodological and policy gap (OECD, 2020; Ziemblińska et al., 2025).

EMPIRICAL ANALYSIS

DATA AND METHODOLOGY

This study employs a balanced panel dataset covering the 27 Member States of the European Union (EU-27) over the period 2013–2023. The analysis fo-

cuses on three key indicators that capture the interaction between economic performance and environmental pressures: gross domestic product (GDP), total greenhouse gas emissions (GHG), and primary energy consumption (PEC). Annual data were obtained from Eurostat databases - nama_10_gdp (GDP), env_air_gge (GHG emissions), and nrg_ind_eff (primary energy consumption under the Energy Efficiency Directive). GDP was measured in million euros at chain-linked volumes (2015 reference year), GHG emissions in tonnes of CO_2 equivalent, and PEC in tonnes of oil equivalent.

The analysis begins with 2013 to ensure full comparability across all EU Member States, including Croatia's accession to the Union, thereby providing a consistent panel spanning 11 years. All variables were transformed using natural logarithms to stabilize variance and facilitate interpretation of the estimated coefficients as elasticities. This logarithmic transformation mitigates heteroscedasticity and allows the regression coefficients to be interpreted as the percentage change in environmental pressures associated with a 1% change in GDP.

Table 1. Summary statistics of GDP, GHG, and primary energy consumption (PEC) for EU-27, 2013–2023

Obs	Country	GDP Mean (million €)	GDP Std. Dev.	GHG Mean (t CO_2 eq)	GHG Std. Dev.	PEC Mean (toe)	PEC Std. Dev.
1	Austria	324,994	15,873	77,767,447	4,046,291	31,331,818	1,094,082
2	Belgium	401,385	21,929	112,624,615	7,155,415	46,470,909	2,274,267
3	Bulgaria	44,455	3,998	54,987,813	4,711,189	17,740,909	799,155
4	Croatia	50,039	4,941	24,773,685	519,307	8,109,091	270,313
5	Cyprus	21,446	3,404	8,416,865	319,178	2,383,636	149,350
6	Czechia	185,302	14,401	121,285,518	8,618,689	39,148,182	1,504,605
7	Denmark	276,750	18,145	48,220,977	5,447,169	16,670,000	844,145
8	Estonia	19,404	1,728	16,765,861	4,153,171	5,062,727	658,226
9	Finland	197,555	7,380	52,799,230	6,480,883	31,650,909	934,863
10	France	2,174,796	88,529	437,425,965	34,626,362	230,627,273	15,903,528
11	Germany	2,951,770	119,261	825,001,838	86,139,283	282,057,273	21,415,133
12	Greece	187,258	9,174	88,265,161	10,805,064	21,971,818	1,573,079
13	Hungary	122,077	12,985	61,806,308	3,413,648	23,606,364	1,034,517
14	Ireland	286,696	76,531	59,481,294	2,258,760	14,030,909	611,170
15	Italy	1,600,722	65,559	421,813,376	23,382,643	144,230,909	6,242,955
16	Latvia	22,487	1,658	10,694,669	381,407	4,388,182	142,676
17	Lithuania	38,226	4,375	19,370,265	626,186	6,154,545	280,691
18	Luxemb.	50,843	3,708	9,875,323	1,127,215	4,145,455	262,197

Obs	Country	GDP Mean (million €)	GDP Std. Dev.	GHG Mean (t CO_2 eq)	GHG Std. Dev.	PEC Mean (toe)	PEC Std. Dev.
19	Malta	10,982	2,225	2,230,360	321,608	820,909	69,922
20	Netherl.	717,297	49,511	178,460,280	18,508,894	61,888,182	4,101,577
21	Poland	476,713	60,594	386,664,065	17,284,845	96,686,364	4,996,976
22	Portugal	182,591	12,097	62,297,075	5,648,781	21,198,182	1,113,399
23	Romania	166,767	19,776	114,518,542	4,515,107	31,268,182	1,087,371
24	Slovakia	83,001	6,563	39,775,120	2,174,687	15,885,455	561,202
25	Slovenia	40,817	4,137	16,771,751	1,094,517	6,410,909	251,016
26	Spain	1,130,099	71,237	307,427,209	23,673,216	115,992,727	6,070,669
27	Sweden	434,097	27,925	50,126,383	3,923,454	44,490,000	2,109,517

Source: Eurostat (nama_10_gdp, env_air_gge, nrg_ind_eff).

Note: GDP is measured in million euros (chain-linked volumes, 2015 reference year), GHG emissions in tonnes of CO_2 equivalent, and PEC in tonnes of oil equivalent (toe).

Descriptive statistics reveal substantial heterogeneity across the Union. Advanced Western and Northern European economies exhibit markedly higher GDP levels and lower emission intensities, reflecting progress in energy efficiency and the green transition. In contrast, several Central and Eastern European Member States display higher energy consumption and emission levels per unit of output, consistent with structural differences in industrial composition, technological development, and energy mix. These disparities underscore the importance of country-specific econometric estimation in assessing the degree of green decoupling within the EU.

In order to quantify the relationship between economic activity and environmental pressures, country-specific log–log regression models were estimated for both GHG emissions and primary energy consumption. The empirical model is specified as follows:

$$\ln (Y_{it}) = \alpha_i + \beta_i \ln (GDP_{it}) + \epsilon_{it}$$

where Y_{it} denotes either GHG emissions or primary energy consumption for country i at time t, α_i represents the country-specific intercept, and β_i is the elasticity coefficient capturing the responsiveness of environmental pressures to changes in economic output.

As with all ordinary least squares (OLS) estimations, the results rely on the classical assumptions of linearity, homoskedasticity, independence, and normally distributed residuals. Given the short annual series (2013-2023), formal unit-root and cointegration tests were not applied; instead, log-transformation

and diagnostic checks were used to mitigate non-stationarity concerns. Comparable log-log specifications have been widely employed in the EKC and decoupling literature. For instance, Narayan & Narayan (2010) used panel log-log models to estimate short- and long-run elasticities of CO_2 emissions with respect to GDP in developing countries, a reference approach that has become standard in empirical studies of environmental Kuznets curves and decoupling.

Table 2. Estimated elasticities (β) for GHG and PEC

Obs	Country	β(GHG)	β(PEC)	Decoupling Type (GHG)	Decoupling Type (PEC)
1	Austria	–0.5661	–0.2295	Absolute	Absolute
2	Belgium	–0.9707	–0.3492	Absolute	Absolute
3	Bulgaria	–0.4724	0.1637	Absolute	Relative
4	Croatia	0.0409	0.2840	Relative	Relative
5	Cyprus	0.0191	0.2192	Relative	Relative
6	Czechia	–0.5902	–0.2057	Absolute	Absolute
7	Denmark	–1.5681	–0.5357	Absolute	Absolute
8	Estonia	–2.2308	–0.9317	Absolute	Absolute
9	Finland	–2.5184	–0.2557	Absolute	Absolute
10	France	–1.2768	–0.9499	Absolute	Absolute
11	Germany	–1.8934	–1.2256	Absolute	Absolute
12	Greece	–1.4483	–0.5191	Absolute	Absolute
13	Hungary	–0.0243	0.1800	Absolute	Relative
14	Ireland	–0.0278	0.0730	Absolute	Relative
15	Italy	–0.2616	–0.0923	Absolute	Absolute
16	Latvia	–0.1770	0.0780	Absolute	Relative
17	Lithuania	–0.1517	0.3530	Absolute	Relative
18	Luxembourg	–1.2641	–0.3918	Absolute	Absolute
19	Malta	–0.3122	0.0715	Absolute	Relative
20	Netherlands	–1.3287	–0.7396	Absolute	Absolute
21	Poland	–0.1233	0.2295	Absolute	Relative
22	Portugal	–0.7878	0.0066	Absolute	Relative
23	Romania	–0.2283	0.1040	Absolute	Relative
24	Slovakia	–0.3684	–0.0672	Absolute	Absolute
25	Slovenia	–0.4671	–0.2129	Absolute	Absolute
26	Spain	–0.3882	0.1478	Absolute	Relative
27	Sweden	–1.0702	–0.4320	Absolute	Absolute

Source: Author's calculations based on Eurostat (nama_10_gdp, env_air_gge, nrg_ind_eff).

Note: Blue values indicate relative decoupling ($0 \leq \beta < 1$). Negative values indicate absolute decoupling ($\beta < 0$).

The estimated β coefficients were derived from simple log–log OLS regressions, and can be directly interpreted as elasticities. A β value close to zero indicates strong decoupling, meaning that economic growth occurs with little or no increase in emissions or energy use. Values approaching one imply proportional growth between GDP and environmental pressures, while negative coefficients indicate *absolute decoupling*, suggesting that rising GDP is associated with a reduction in environmental impact.

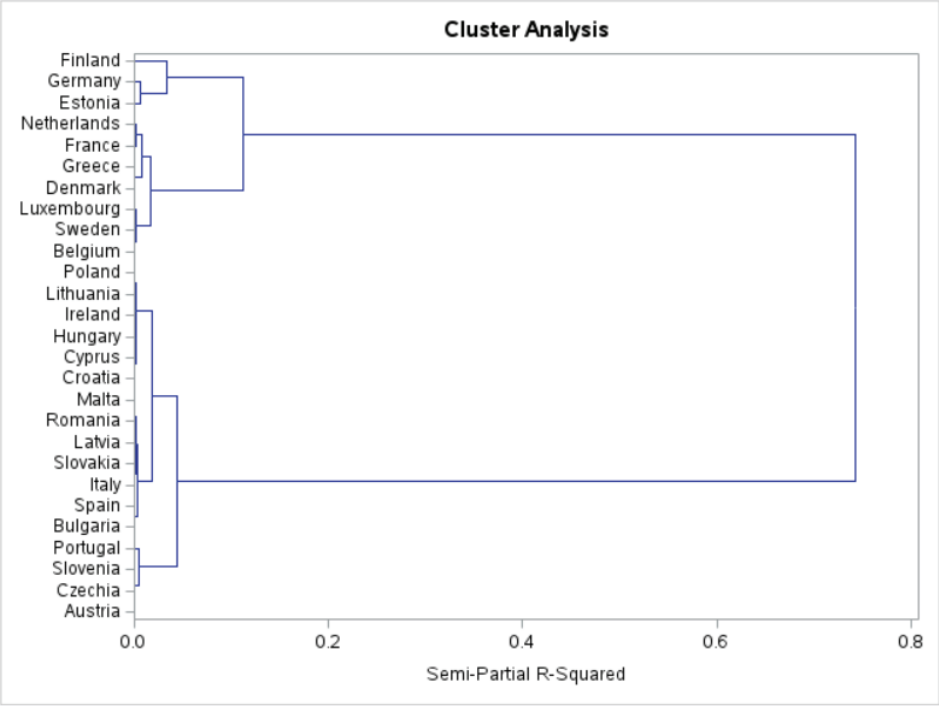
Diagnostic checks confirmed the robustness of the results. For the regressions, R^2 values ranged from very low (Croatia 0.04, Cyprus 0.006) to high (Denmark 0.82, Sweden 0.76), with White's test generally being non-significant (e.g. Austria p=0.34, Belgium p=0.51) and variance inflation factors equalling to 1.0. Residuals were approximately symmetric, although Shapiro–Wilk tests indicated deviations from strict normality. For clustering, Ward's method produced very high pseudo F-statistics in early joins (1248, 667, 592), while FASTCLUS yielded an overall R^2 of 0.735 and pseudo F=69.3, supporting the two-cluster solution. Discriminant analysis further validated the classification (Wilks' Lambda=0.208, p<0.001; canonical correlation=0.89), with cross-validated accuracy of 93% and only one misclassified country (Belgium).

For the subsequent multivariate classification, the β coefficients for GHG and PEC were utilized as input variables prior to clustering. These elasticity estimates were then used as inputs in the clustering procedures described in the following subsection, ensuring comparability across countries and indicators. Building on these country-level elasticity estimates, the subsequent analysis applied clustering techniques to identify groups of EU Member States exhibiting similar patterns of economic growth and environmental decoupling.

CLUSTER ANALYSIS: GROWTH AND DECOUPLING PATTERNS IN THE EU-27

In order to examine cross-country heterogeneity in decoupling performance across the EU-27, a hierarchical cluster analysis was first conducted using β coefficients for greenhouse gas (GHG) emissions and primary energy consumption (PEC), following Ward's standard methodology (Ward, 1963). Ward's linkage method was employed to minimize within-cluster variance while maximizing between-cluster differentiation, ensuring that countries within each group exhibited comparable elasticity profiles. The use of these elasticity estimates ensures a robust multivariate framework for comparing the two environmental indicators.

Figure 1. Dendrogram of EU-27 countries based on β coefficients



Source: Author's calculations based on Eurostat (nama_10_gdp, env_air_gge, nrg_ind_eff).

Figure 1 presents the resulting dendrogram, which reveals a well-defined similarity structure among countries, highlighting natural groupings based on the degree of decoupling between economic growth and environmental pressures. The dendrogram suggests the presence of two dominant clusters, reflecting markedly different relationships between GDP growth and environmental outcomes. Cluster 1 includes economies where GDP growth exerts relatively weak environmental pressures, indicating stronger decoupling, whereas Cluster 2 captures countries in which economic expansion remains more closely tied to emissions and energy consumption, signalling slower progress toward green-transition objectives.

In order to refine the grouping structure identified by Ward's method, a K-means clustering procedure was subsequently applied, following the methodology of MacQueen (1967). The optimal number of clusters was determined using the within-cluster sum-of-squares criterion and by evaluating the interpretability of the classification. Alternative specifications (e.g. k = 3)

were also tested, producing statistically valid groupings, but yielding one very small cluster with limited interpretability. For clarity and policy relevance, the two-cluster solution was therefore retained. Following this choice, the subsequent step examines the underlying characteristics of the clusters using their average elasticity estimates (i.e. average β coefficients).

Table 3. Mean β coefficients by K-means cluster

Obs	CLUSTER	FREQ	Mean_Beta_GHG	Mean_Beta_PEC
1	1	9	-1.62207	-0.66455
2	2	18	-0.32540	0.04186

Source: Author's calculations based on Eurostat (nama_10_gdp, env_air_gge, nrg_ind_eff).

Table 3 summarizes the mean β coefficients by cluster, representing the average elasticity of GHG emissions and PEC with respect to GDP growth. The magnitude of the mean coefficients further supports the dichotomy observed in the dendrogram, with Cluster 1 exhibiting substantially stronger decoupling for both GHG and PEC relative to Cluster 2.

The first cluster predominantly comprises Northern and Western European economies, including Denmark, Estonia, Finland, France, Germany, Luxembourg, the Netherlands, and Sweden, characterized by pronounced decoupling driven by technological innovation, energy-efficiency gains, and ambitious climate and energy policies.

Conversely, the second cluster includes Southern and Eastern European countries such as Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain, where lower energy efficiency and more carbon-intensive industrial structures contribute to a closer coupling between economic growth and environmental pressures.

In order to provide a clear overview of country composition within each cluster and to facilitate the interpretation of decoupling dynamics across the EU, Table 4 reports the full membership of the two groups. The labels 'high-decoupling cluster' and 'low-decoupling cluster' are used here to denote relative positions in decoupling performance, without geopolitical connotations.

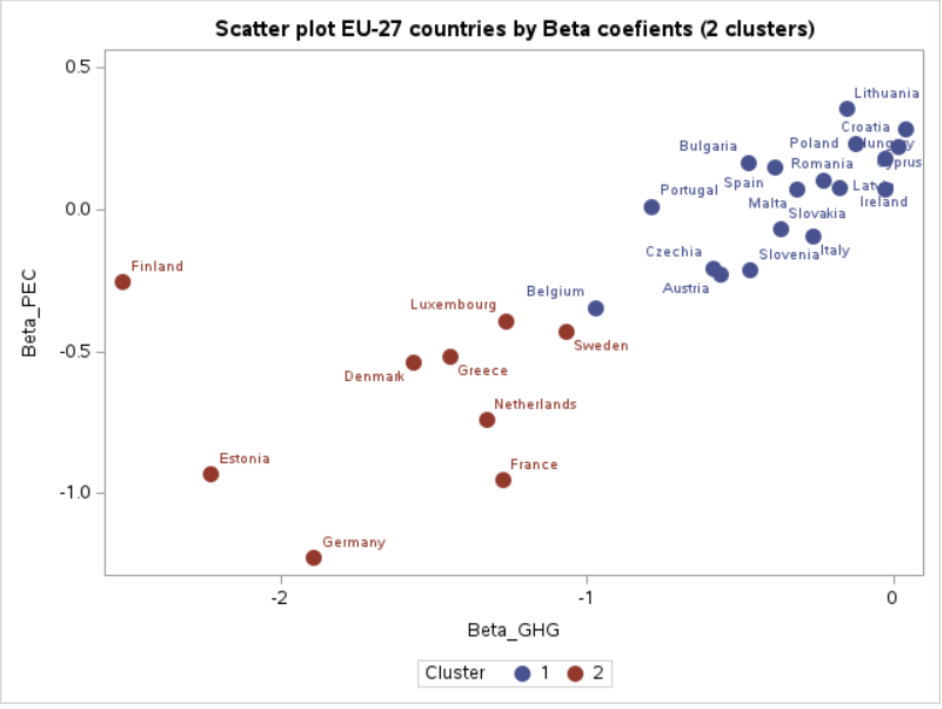
Table 4. Cluster membership of EU-27 countries

Cluster	Cluster name	Countries
1	High-decoupling cluster	Denmark, Estonia, Finland, France, Germany, Luxembourg, Netherlands, Sweden,
2	Low-decoupling cluster	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Spain

Source: Author's calculations based on Eurostat (nama_10_gdp, env_air_gge, nrg_ind_eff).

A graphical depiction of the β coefficients, color-coded by cluster membership, is presented in Figure 2.

Figure 2. Scatter plot of EU-27 countries by β coefficients (2 clusters)



Source: Author's calculations based on Eurostat (nama_10_gdp, env_air_gge, nrg_ind_eff).

The scatter plot illustrates a distinct separation between the two groups. Cluster 1 countries are positioned in the lower-left quadrant, reflecting strong

decoupling, whereas Cluster 2 countries occupy positions closer to the origin or in the upper-right quadrant, indicating weaker decoupling. Within-cluster dispersion also reveals internal heterogeneity, suggesting that the decoupling progress is not entirely uniform even among the best-performing economies, thus highlighting the need for differentiated policy approaches within the EU framework.

The subsequent section, therefore, applies discriminant analysis (DA) to statistically validate the cluster solution and assess the extent to which the identified groupings reflect the underlying structure of decoupling dynamics in the EU-27, following the guidelines for multivariate classification and validation (Hair, Black, Babin, & Anderson, 2019).

DISCRIMINANT ANALYSIS

In order to assess the stability and robustness of the clusters identified in the previous section, a discriminant analysis (DA) with cross-validation was performed. Unlike the non-parametric K-means algorithm, DA assumes multivariate normality and homogeneity of variance-covariance matrices, thereby offering a more stringent test of the distinctiveness of the observed group separations.

The β coefficients for GHG emissions and primary energy consumption (PEC) were used as predictor variables, while the K-means cluster assignments served as the grouping variable. The main objective was to determine whether the two-cluster classification is statistically distinguishable and internally consistent.

Table 5. Misclassified countries based on discriminant analysis

Country	Actual cluster	Predicted cluster
Belgium	1	2

Source: Author's calculations based on Eurostat (nama_10_gdp, env_air_gge, nrg_ind_eff).

The discriminant model correctly classified nearly all EU-27 countries, with only one instance of misclassification. Belgium was reassigned by the DA model, suggesting a borderline position between high- and low-decoupling clusters. This borderline case reflects intermediate elasticity values, which place Belgium close to the discriminant boundary. Such instances are expected in multivariate classification and do not undermine the overall robustness of

the two-cluster solution. Overall, the high classification accuracy (97.2%) confirms the robustness of the two-cluster solution, reinforcing the empirical validity of the grouping obtained through hierarchical and K-means procedures.

Canonical discriminant analysis further confirmed the statistically significant separation (Wilks' Lambda = 0.21, $F(2,24) = 45.7$, $p < 0.0001$; canonical correlation = 0.89, explaining 79% of variance in cluster membership). Both elasticity variables contributed strongly to the discriminant function (coefficients: $\beta(GHG) = 0.73$, $\beta(EC) = 0.46$), with cluster means clearly separated (+1.33 vs –2.66).

The stability of the clusters indicates that the observed decoupling patterns, the strong or absolute decoupling in the 'high-decoupling cluster' versus weaker decoupling in the 'low-decoupling cluster', are not artefacts of the clustering algorithm, but instead reflect substantive structural differences in economic-environmental dynamics across the EU Member States. This provides a solid empirical foundation for the subsequent policy-oriented interpretation of regional disparities in the green transition.

Having established statistically robust country groupings and verified the coherence of decoupling patterns, the next section integrates these empirical findings with broader policy, as well as technological and structural considerations, in order to explore the determinants of decoupling across the European Union.

CONCLUSION

The results of the empirical analysis provide clear evidence of structural heterogeneity in the relationship between economic growth and environmental pressures across the EU-27 during the 2013–2023 period. Elasticity estimates (Table 2) revealed that while most Western and Northern European economies achieved strong or absolute decoupling ($\beta < 0$), many Central and Eastern European countries still exhibit growth patterns closely tied to energy use and emissions ($\beta \geq 0$). This indicates structural heterogeneity in decoupling intensity across the Union.

The cluster analysis (Table 3) confirmed this divide, distinguishing a high-decoupling cluster (N=9) with a mean $\beta(GHG) = –1.62$ and $\beta(PEC) = –0.66$, and a low-decoupling cluster (N=18) with a mean $\beta(GHG) = –0.33$ and $\beta(PEC) = 0.04$). The observed differences are consistent with variation in energy efficiency and industrial composition, though the study does not directly test technological or institutional mechanisms. The discriminant analysis fur-

ther validated the robustness of this two-cluster configuration, demonstrating statistically significant separation (Wilks' Lambda = 0.21; canonical correlation = 0.89). Importantly, the analysis showed a cross-validated classification accuracy of 97.2%, with only one country (Belgium) being misclassified. This confirms that the groupings reflect genuine, statistically significant differences rather than methodological artefacts. This coherence between clustering and discriminant results reinforces the empirical credibility of the observed two-tier decoupling model within the EU.

From a policy perspective, the findings underline that although the European Union as a whole is moving toward reduced emissions and improved energy efficiency, convergence across Member States is far from complete. The persistence of differences between clusters (Tables 2–3, Figure 1) implies that the benefits of the green transition remain unevenly distributed. Countries in the low-decoupling group are facing greater challenges in reducing energy intensity and emissions. Achieving the objectives of the European Green Deal will require differentiated policy support. In particular, investment in clean technologies and modernization of energy-intensive industries should be prioritized in countries with weaker decoupling performance.

Methodologically, this study demonstrates the analytical value of integrating regression-based elasticity estimation with multivariate clustering and discriminant validation. This combined framework effectively captures both the magnitude and structural differentiation of decoupling dynamics, offering a replicable tool for comparative sustainability assessment.

Despite these contributions, several limitations should be acknowledged. The analysis is restricted to the 2013–2023 period and relies on aggregate national data, which may mask sectoral or regional variation within countries. The focus on two environmental indicators, GHG emissions and primary energy consumption, captures only a part of the sustainability transition, leaving out other dimensions such as material use or biodiversity. The clustering approach, while validated through discriminant analysis, is inherently sensitive to variable selection and standardization choices. Finally, the study does not directly test causal mechanisms (e.g. technological innovation, institutional capacity), meaning that the observed differences between clusters should be interpreted as descriptive rather than explanatory.

Future research could extend this approach through sectoral decomposition, dynamic time-series modelling, or by incorporating additional environmental indicators (e.g. material footprint, biodiversity loss) in order to provide a more granular understanding of how technological and structural transformation shape sustainable growth trajectories within the European Union.

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ECO-FEATURES IN LOYALTY APPS: EXTENDING THE TECHNOLOGY ACCEPTANCE MODEL FOR SUSTAINABLE CONSUMER BEHAVIOR

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As retail chains increasingly digitize customer relationships, mobile loyalty applications have become a key interface for managing everyday shopping. At the same time, retailers are facing pressure to demonstrate credible commitment to environmental goals. This article examines how specific features of loyalty apps contribute to customer satisfaction and intention to recommend the app, with a particular focus on transparency and eco-features. Building on the Technology Acceptance Model (TAM), we tested a framework with four predictors of satisfaction: app transparency, personalization, usability, and eco-features. A quantitative online survey was conducted among 180 users of retail loyalty apps in Croatia who use at least one app monthly. The respondents evaluated six constructs, each measured with three or four items on seven-point Likert scales. Reliability analysis indicated acceptable internal consistency, and the research model was tested using multiple regression with two-stage modeling. The results indicate that transparency and eco-features have a positive and statistically significant effect on satisfaction, whereas personalization and usability do not significantly contribute when all predictors are considered simultaneously. In the second model, satisfaction shows a strong positive association with recommendation intention. In this sample, users appear to value clear rules, honest communication, and visible environmental benefits more than additional personalization or incremental usability improvements. For retailers, the study points to the

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importance of designing loyalty apps as transparent and "green" contact points rather than purely functional tools. Future research should replicate and extend this model in other countries, retail formats, and methodological designs to assess the robustness and boundary conditions of the observed relationships.

Keywords: *Loyalty apps, retail, customer satisfaction, eco-features, recommendation intention*

JEL classification: *M31, L81, Q56, D12*

INTRODUCTION

The digital transformation of the retail sector has made mobile loyalty applications a central interface for everyday shopping and customer relationship management. At the same time, consumers are increasingly interested in sustainable practices and pay more attention to ethical and environmental issues. As a result, loyalty apps are being enhanced with features that promote environmentally responsible behavior, linking daily transactions to broader sustainability goals. This trend fits the broader research on encouraging consumers to make more sustainable choices (White, Habib, & Hardisty, 2019). Grimmer and Woolley (2014) highlight that consumer trust and engagement are essential for sustainability-oriented marketing strategies, including the integration of environmental considerations into digital retail platforms. However, little is known about how specific app features, particularly those related to transparency and environmental sustainability, influence user satisfaction and the likelihood of recommending loyalty apps to others.

Technological predictors of user satisfaction are often examined through the Technology Acceptance Model (TAM) and its extensions (Chiu et al., 2009). Usability refers to how easily users navigate the app and perform core tasks. Personalization addresses how strongly app content reflects individual habits and preferences (Riegger et al., 2021; Chandra et al., 2022). These constructs explain much of how loyalty apps influence attitudes and behavior, however they do not explain everything. Two features have, therefore, become more visible in practice, but are less often modeled directly: transparency and environmental elements. Transparency refers to how clearly the app communicates its rules and functions, including how points are earned, how rewards are redeemed, and how user data are handled. Although closely related to trust and perceived fairness, transparency is rarely tested as a separate predictor of sat-

isfaction in loyalty programs. Environmental features such as digital receipts, green rewards, sustainability tips, and tools for tracking "green" behavior have also received limited attention, despite their growing relevance in retail practice (Dabija, Bejan & Grant, 2018; Zhang et al., 2023).

The paper examines the direct effects of transparency, personalization, usability, and eco-friendly features (hereafter "eco-features") on user satisfaction, followed by an exploration of the relationship between satisfaction and recommendation intention in a second-stage model. Sustainable consumer behavior is operationalized here as customer satisfaction and recommendation intention in the context of retail loyalty apps. Overall satisfaction is treated as the outcome variable in the first-stage model and as the predictor of recommendation intention in the second-stage model (Levy et al., 2023; Kolte et al., 2023). Multiple regression is applied in two stages: first, to estimate the direct effects of each feature on satisfaction, and then to assess the direct effect of satisfaction on recommendation intention. The aim is to identify which app features matter most, and to show how transparency and environmental responsibility can be integrated into loyalty app design.

LITERATURE REVIEW

The retail sector has widely adopted loyalty apps, enabling customers to track points, receive personalized offers, and redeem digital rewards. Kolte et al. (2023) stated that well-designed loyalty programs can significantly influence store patronage, suggesting that the structural characteristics of these programs merit closer examination in digital contexts. Prior studies have shown that specific app features shape user satisfaction and behavior. While personalization and usability have received sustained attention, there is limited evidence with regard to constructs such as transparency and eco-features. Recent research indicates that consumers increasingly value sustainability and perceived fairness when it comes to the manner in which loyalty programs operate.

The Technology Acceptance Model (TAM) explains how perceived usefulness and perceived ease of use shape users' evaluations and behavioral intentions toward digital systems (Davis, 1989). Due to its simplicity and predictive power, TAM has been widely applied to mobile services, online shopping, and app-based environments. In loyalty applications, usability corresponds to perceived ease of use, while personalization and other value-adding elements can increase the practical value that the users see in the app. These relation-

ships provide the basis for extending TAM to include characteristics such as transparency and eco-features.

In extended TAM frameworks, personalization is typically associated with perceived usefulness, and usability with perceived ease of use (Chiu et al., 2009). Satisfaction is frequently included as an outcome variable because it summarizes the users' overall assessment of a digital service. Prior research has consistently shown that personalization enhances satisfaction and engagement across different retail and digital contexts (Riegger et al., 2021; Chandra et al., 2022; Yun & Chun, 2024). Usability also plays an important role: clear navigation, responsive performance, and intuitive layouts contribute to more positive evaluations (Kim & Park, 2011; Mariani, Hashemi, & Wirtz, 2023). Evidence from digital retailing shows that satisfaction can influence long-term behavioral outcomes such as loyalty and recommendation behavior (Liu, 2007; Chiu et al., 2009; Yang, Li & Zhang, 2023).

Most studies focus on loyalty rather than recommendation as a distinct outcome, resulting in several constructs receiving limited scholarly attention. One such construct is transparency, treated here as the extent to which the app clearly communicates its functions and terms. Riegger et al. (2021) noted that visible rules help build user confidence, while Chiu et al. (2009) linked perceptions of fairness to the availability of clear information. Additional evidence supports this view: Chen and Sundar (2018) found that greater system transparency enhances trust and satisfaction, and Betzing et al. (2019) showed that clear statements reduce confusion and improve overall satisfaction with the application. Eco-features represent another underexamined area. These include paperless receipts, green reward options, and sustainability tips integrated into the app interface. Sinemus et al. (2022) found that post-purchase cues containing environmental elements increase satisfaction, while Shin, Park, and Moon (2015) reported positive effects of green retail communication on customer attitudes, and Zandi and Sekhavat (2024) demonstrated that gamified environmental features enhance user enjoyment. In European retail, digital receipts and sustainability-linked rewards are becoming increasingly common. Dabija et al. (2018) showed that customers who value sustainability tend to be more loyal to brands that offer green initiatives. Despite this growing relevance, eco-features are rarely modeled as a distinct antecedent of satisfaction. This supports the inclusion of transparency and eco-features, alongside personalization and usability, in the present study's framework for explaining satisfaction and recommendation intention.

Table 1. Main studies informing the conceptual model

Research	Contribution	Context	Constructs	Study Type	Relevance
Riegger et al. (2021)	Identifies the drivers and barriers of personalization technologies in physical retail settings.	Physical retail stores	Personalization, technology adoption	Empirical	Shows that personalization affects technology acceptance in retail environments.
Chandra et al. (2022)	Reviews the evolution and effectiveness of personalized marketing techniques.	Personalized marketing across industries	Personalization, engagement	Review	Confirms that tailored offers enhance user experience and engagement.
Chiu et al. (2009)	Combines TAM and fairness theory to examine loyalty behavior in online environments.	E-commerce	TAM, fairness, transparency	Conceptual/Empirical	Links perceived fairness and informativeness to satisfaction and loyalty intentions.
Mariani et al. (2023)	Provides a systematic literature review of AI-empowered conversational agents and their outcomes.	AI conversational agents	AI agents, customer experience, satisfaction	Empirical	Shows that usability aspects (interface clarity, speed) influence satisfaction.
Kim & Park (2011)	Examines how the quality of mobile applications affects user satisfaction and intention to pay.	Mobile applications	App quality, usability, satisfaction, intention to pay	Empirical	Provides evidence that usability related quality dimensions significantly influence user satisfaction.
Sinemus et al. (2022)	Assesses how shopping app features influence satisfaction and loyalty.	Shopping apps	Post-purchase features, eco-elements	Empirical	Finds that eco-related app features contribute to user satisfaction.
Zandi & Sekhavat (2024)	Examines how green gamification strategies enhance the app experience.	Retail apps	Gamification, eco-features	Empirical	Shows that sustainability-themed features increase user satisfaction.

Research	Contribution	Context	Constructs	Study Type	Relevance
Chen & Sundar (2018)	Tests the effect of transparency and overt personalization in mobile apps on trust and satisfaction.	Eco-friendly app prototype	Transparency, trust, engagement	Empirical	Finds that perceived transparency increases trust and satisfaction in mobile services.
Betzing et al. (2019)	Evaluates the effect of transparent data handling on user decisions and satisfaction.	Mobile permission settings	Transparency, comprehension, satisfaction	Empirical	Shows that clarity in app communication improves user understanding and comfort.

Source: Authors

The studies listed in Table 1 do not all point in the same direction, but they show a clear pattern. Personalization, usability, and satisfaction have been examined extensively. Transparency and eco-features appear less often as central variables. That difference matters because both are becoming easier to observe in current loyalty apps. For that reason, the present study examines all four predictors within one model, and tests their separate relationships with satisfaction and recommendation intention.

HYPOTHESES DEVELOPMENT

TAM is widely used in mobile and online research because it explains the manner in which system characteristics affect how users evaluate the app and how they use it. In loyalty apps, usability corresponds closely to perceived ease of use. Personalization, transparency, and eco-features relate more to perceived usefulness. For that reason, the model is extended here to include app characteristics that are especially visible in retail settings.

Recommendation intention refers to a customer's willingness to suggest a product, service, or program to others. It reflects word-of-mouth behavior and is widely used as an indicator of positive user experience in digital services (Keiningham et al., 2007). Recent studies have shown that satisfaction with digital retail interfaces increases the likelihood of recommendation and continued use (Yang et al., 2023), and advocacy in loyalty-related settings (Kolte et al., 2023). Research on sustainability-oriented retail practices also indicates

that positive perceptions of digital touchpoints are associated with stronger engagement and a higher likelihood of recommending retailer initiatives to others (Costa & Azevedo, 2023; Khalufi et al., 2025). Within loyalty programs, recommending the app or program indicates that users perceive meaningful value for themselves and others, positioning recommendation intention as a clear behavioral expression of satisfaction.

Clarity concerns how transparent information is communicated and how intuitively users can navigate the app. It refers to how easily users can understand program rules, locate important features, and interpret the value of the benefits offered. When users can clearly see how points are collected, how rewards are redeemed, and where essential functions such as coupons, account details, or digital receipts are located, they experience less uncertainty and cognitive strain. As a result, they feel more confident and in control while using the app. This sense of clarity reduces confusion, strengthens perceptions of fairness, and directly contributes to higher overall satisfaction with the user experience. Research supports the relationship between clear communication, comprehension, and satisfaction (Riegger et al., 2021; Chen and Sundar, 2018). Based on this reasoning, H_1 is, therefore, stated as follows:

H_1: *Clear and easy-to-understand app functions and rules have a positive impact on customer satisfaction.*

Personalization refers to the extent to which the app customizes the user experience by analyzing and responding to individual behavior, preferences, and shopping history. In the context of loyalty apps, personalization may include targeted promotions, context-aware notifications, customized product recommendations, and adaptive interfaces that prioritize the functions the user uses most frequently. These mechanisms aim to increase relevance, reduce cognitive effort, and foster a sense of recognition. Examples include discounts on frequently purchased items, reminders timed to typical shopping days, or recommendations based on dietary preferences. Previous research demonstrates that customized content improves satisfaction and engagement (Chandra et al., 2022; Yun & Chun, 2024; Riegger et al., 2021). Therefore, the following hypothesis is proposed:

H_2: *When the app provides personalized and relevant content, customer satisfaction increases.*

Usability reflects how easy it is for users to navigate the app, complete tasks, and access information. A smooth, responsive interface can reduce frustration, while poor functionality negatively affects attitudes and experiences. Earlier studies have consistently linked usability to satisfaction, especially in

mobile applications (Kim & Park, 2011; Mariani et al., 2023). On that premise, the following H_3 is proposed:

H_3: *The technical ease of use and functionality of the app positively influence customer satisfaction*.

Eco-features in loyalty apps include digital receipts, green rewards, and other sustainability-oriented incentives. These features may matter because they make environmental responsibility visible in routine app use. Earlier studies suggest that clear sustainability cues in digital services can improve user responses and satisfaction (Sinemus et al., 2022; Shin et al., 2015). Related research also shows that eco-feedback and environmental prompts can increase perceived usefulness (Berger et al., 2025; White et al., 2019). In loyalty apps, such features may, therefore, raise satisfaction. Accordingly, the following hypothesis is proposed:

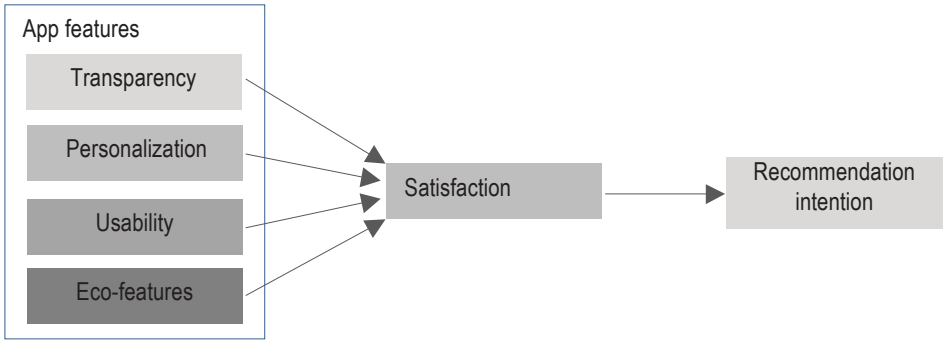
H_4: *The inclusion of eco-features in the loyalty app positively influences customer satisfaction*.

Satisfaction is widely recognized as a key predictor of behavioral intentions. Users who are satisfied with their experience are more likely to recommend the application and remain active in the program (Levy et al., 2023). Previous research in online shopping and digital loyalty contexts has consistently confirmed the positive relationship between satisfaction and recommendation or other loyalty-related outcomes (Liu, 2007; Chiu et al., 2009; Yang et al., 2023). In this study, satisfaction is measured using items adapted from validated scales commonly used in loyalty program research. The items assess overall satisfaction, fulfillment of expectations, perceived value, and positive experience. The final hypothesis states:

H_5: *Customer satisfaction positively influences the intention to recommend the loyalty program to others*.

Based on the proposed hypotheses, the research model conceptualizes transparency, personalization, usability, and eco-features as antecedents of user satisfaction, which is in turn associated with users' intention to recommend the mobile application.

Figure 1. Two-step research model



Source: Authors

Figure 1 shows the role of each variable in the model. Transparency, personalization, usability, and eco-features are exogenous variables. Satisfaction occupies an intermediate position in the model: in the first step it is the dependent variable, and in the second step it predicts recommendation intention. Recommendation intention is the endogenous variable. The arrows show the proposed paths from the four app features to satisfaction and from satisfaction to recommendation intention.

METHODOLOGY

We conducted a quantitative online survey to examine how selected features of loyalty apps influence user satisfaction and recommendation intention. The instrument included six constructs: transparency, personalization, usability, eco-features, satisfaction, and recommendation intention. Each construct was measured using three or four items. All items were rated on a 7-point Likert scale, where 1 indicated "strongly disagree" and 7 "strongly agree".

The data were collected in March 2025. The participants were recruited online and via direct email invitations. A total of 180 respondents from Croatia completed the questionnaire using Google Forms. Given the 23 observed indicators, a minimum sample size of approximately 115 respondents (five observations per indicator) meets the commonly recommended guidelines for multivariate analysis (Hair et al., 2019). The final sample of 180 respondents, therefore, exceeds this threshold. The respondents who were not members of any retail loyalty program were screened out using a filter question at the be-

ginning of the questionnaire. Participation was voluntary and anonymous. The demographic composition of the sample, shown in Table 2, reflects a diverse age distribution with a predominant representation of younger adults. Gender representation is relatively balanced. Educational backgrounds range from secondary school to postgraduate levels.

Table 2. Sample demographics

Variable	Category	N	%
Age	18–24 years	52	28.9
	25–34 years	50	27.8
	35–44 years	45	25.0
	45–54 years	17	9.4
	55+	9	5.0
	Prefer not to say	7	3.9
Gender	Male	79	43.9
	Female	101	56.1
	Prefer not to say	-	-
Education	Secondary school	79	43.9
	Undergraduate	80	44.4
	Graduate	19	10.6
	Prefer not to say	2	1.1

Source: Research data

The questionnaire used in the study is provided in Appendix 1, where all items are shown in English, whereas Croatian translations were used for data collection. Survey items were adapted from validated scales used in previous research on digital services, transparency, personalization, usability, sustainability features, satisfaction, and recommendation behavior (e.g. Chiu et al., 2009; Chen & Sundar, 2018; Riegger et al., 2021; Sinemus et al., 2022; Liu, 2007; Keiningham et al., 2007) and adjusted to the context of loyalty apps.

A pilot pre-test with 16 respondents was conducted before the main data collection. Based on the low internal consistency observed in this phase, seven items were removed from various sections of the questionnaire. In order to assess the internal consistency of the constructs, Cronbach's alpha was calculated. In the final dataset, Cronbach's alpha values ranged from 0.67 to 0.81, which is considered acceptable according to Hair et al. (2019). Table 3 presents the mean and standard deviation, as well as Cronbach's alpha for each

construct and item. Although the reliability of the "Transparency" and "Satisfaction" constructs was slightly below the conventional threshold ($\alpha = 0.70$), they were retained due to their theoretical importance and acceptable internal consistency.

Table 3. Measurement properties

Predictor	Variable	Mean	STD	Cronbach's α
Transparency	info_clear	3.34	1.69	
	rules_visible	5.33	1.93	
	data_open	5.04	1.86	
	points_explained	2.87	1.92	0.68
Personalization	offers_fit	5.36	1.83	
	habits_recognized	2.48	1.81	
	relevant_suggestions	4.44	2.16	
	reminder_effective	3.07	1.83	0.74
Usability	easy_navigation	4.24	2.19	
	fast_loading	3.89	2.05	
	intuitive_layout	4.23	2.02	
	quick_access	3.98	2.10	0.81
Eco-features	green_rewards	4.08	2.07	
	digital_receipts	3.98	2.22	
	eco_tips	3.82	2.00	
	eco_tracking	4.02	2.15	0.70
Satisfaction	overall_satisfaction	4.19	2.04	
	meets_expectations	4.08	2.20	
	fair_value	4.04	2.12	
	positive_experience	4.11	2.21	0.67
Recommendation	recommend_others	4.02	2.05	
	program_worth_it	4.26	2.20	
	share_offers	4.19	2.13	0.76

Note: The dependent variable in the study is "Recommendation". All items were rated on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree).

Source: The data were analyzed using SPSS, based on the responses collected through primary research.

Statistical analysis was performed using SPSS (v.28) and included descriptive statistics, reliability assessment, and multiple linear regression. Following the hypotheses, the analysis proceeded in two stages. The first regression model tested the effects of transparency, personalization, usability, and eco-

features on satisfaction and was statistically significant ($R = .736$, $R^2 = .542$, $F(4,175) = 51.846$, $p < .001$). The second model examined the effect of satisfaction on recommendation intention and showed strong significance ($R = .541$, $R^2 = .293$, $F(1,178) = 73.810$, $p < .001$).

RESULTS

Multiple regression was conducted to examine how transparency, personalization, usability, and eco-features relate to user satisfaction. The model identified two significant predictors (Table 4). Transparency showed a positive and statistically significant effect on satisfaction ($\beta = .167$, $p = .047$), supporting H_1. Eco-features also demonstrated a significant positive influence ($\beta = .214$, $p = .008$), confirming H_4. In contrast, personalization ($\beta = .017$, $p = .838$) and usability ($\beta = .138$, $p = .107$) did not significantly predict satisfaction, leading to the rejection of H_2 and H_3.

Table 4. Regression results (Model 1)

Predictor[1]	**B**	**T**	**P**	**VIF**	**Hypothesis**	**Acceptance**
Transparency (*transparent_mean*)	.167*	1.996	.047	1.996	H_1	*Accepted*
Personalization (*personal_mean*)	.017	.205	.838	2.009	H_2	*Rejected*
Usability (*usability_mean*)	.138	1.618	.107	2.095	H_3	*Rejected*
Eco-features (*eco_mean*)	.214**	2.671	.008	1.842	H_4	*Accepted*

[1]Dependent variable: satisfaction_mean

Note: Variance Inflation Factor - VIF values (1.84–2.19) indicate no multicollinearity problems; all are well below the acceptable threshold of 5 (according to Hair et al., 2019).

Source: Primary data were analyzed using SPSS.

Model 2 examined whether satisfaction anticipates recommendation intention. Satisfaction showed a strong and statistically significant effect on recommending the loyalty app ($\beta = .541$, $p < .001$), supporting H_5 (Table 5).

Table 5. Regression results (Model 2)

Predictor[1]	B	T	P	VIF	Hypothesis	Acceptance
Satisfaction (*satisfaction_mean*)	.541*	8.591	<.001	1.657	H_5	*Accepted*

[1]Dependent variable: recommend_mean

Note: VIF indicates no multicollinearity problem (according to Hair et al., 2019).

Source: Primary data were analyzed using SPSS.

DISCUSSION

The findings show clear differences in the manner in which users respond to loyalty-app features. Transparency stands out as the most consistent contributor to satisfaction. Loyalty applications that openly communicate the logic of point accumulation, reward conditions, or customer data usage appear to reduce ambiguity and strengthen perceptions of fairness. This finding is consistent with earlier studies that link clarity with trust (Riegger et al., 2021; Chen & Sundar, 2018; Betzing et al., 2019). Eco-features complement this effect: digital receipts, rewards for sustainable choices and other environmentally focused cues are interpreted as meaningful benefits that integrate sustainability into routine shopping (Sinemus et al., 2022; Shin et al., 2015; Zandi & Sekhavat, 2024), and not solely as cosmetic additions.

Despite the strong presence of personalization and usability in past research, their effects here do not reach statistical significance. This pattern can be linked to the maturity of loyalty apps in many retail categories, where basic functionality and interface clarity are already standard and, therefore, less noticeable as differentiators. Prior studies have indicated that ease of use may lose influence once users adopt a digital tool long-term (Chiu et al., 2009; Liu, 2007; Yang et al., 2023). A similar reasoning can be applied to personalization: when promotional targeting becomes common across competing apps, its perceived value decreases, which may explain why transparency and eco-features overshadow it in this context (Chandra et al., 2022; Yun & Chun, 2024; Zhang et al., 2023; Mariani et al., 2023). The result also matters for theory. A standard TAM-based explanation is still useful, but it does not capture everything users notice in loyalty apps. Transparency seems important because it makes rules and data practices easier to understand (Chiu et al., 2009; Zhang et al., 2023; Riegger et al., 2021). Eco-features, however, add another criterion by which users assess the app: concrete, easy-to-understand sustainability cues can re-

shape app perceptions even in situations dominated by price promotions or habitual, low-involvement purchases (Chen & Sundar, 2018; Betzing et al., 2019; Sinemus et al., 2022; Shin et al., 2015; Zandi & Sekhavat, 2024; Grimmer & Woolley, 2014; Dabija et al., 2018). Their role here functions as a specific form of perceived usefulness grounded in non-monetary value.

A strong and stable relationship between satisfaction and recommendation intention underscores satisfaction as the central mechanism behind positive word-of-mouth. Higher satisfaction corresponds to substantially greater willingness to recommend the app, consistent with results reported in numerous digital retail and service studies (Riegger et al., 2021; Chandra et al., 2022; Yun & Chun, 2024; Mariani et al., 2023).

Retailers should treat transparency as a primary feature rather than background information. Simple, explicit explanations of how the loyalty program operates, why specific offers are displayed, and how customer data are used foster perceptions of fairness that, in turn, increase satisfaction (Riegger et al., 2021; Chen & Sundar, 2018; Betzing et al., 2019). Eco-features provide a second, practical lever. They require relatively moderate investment, yet can visibly differentiate the app. Digital receipts, "green" rewards or incentives for environmentally friendly actions, make sustainability concrete and relatable at the interface level (Sinemus et al., 2022; Shin et al., 2015; Zandi & Sekhavat, 2024; Grimmer & Woolley, 2014; Dabija et al., 2018). In markets where app usability levels and baseline personalization are already high and widely comparable, these elements can reposition the loyalty app as a channel for both value and responsibility. Technical improvements alone may not be enough to significantly shift user satisfaction in competitive retail settings. This suggests that these factors may be basic expectations rather than features that clearly distinguish one app from another, although retailers still need to maintain good usability and relevant personalization. By contrast, transparency and environmental features appear more likely to differentiate the app and encourage positive word-of-mouth (Chiu et al., 2009; Liu, 2007; Yang et al., 2023).

LIMITATIONS AND FUTURE RESEARCH

The study should be read with several limitations in mind. The sample was based on convenience recruitment and included only respondents from Croatia, which limits broader generalization. The research design was cross-sectional and relied on self-reported perceptions and intentions rather than observed behavior. The analysis is based on multiple regression and represents

an early empirical test of the proposed relationships. Future research could strengthen the measurement model and the robustness of the findings using CFA-based approaches, mediation testing, and additional diagnostics such as effect sizes and confidence intervals.

Future research could expand the model by incorporating variables such as trust, reward value, privacy concern or environmental involvement. Eco-features may be examined in more detail by distinguishing specific types of sustainable incentives. Experimental or longitudinal designs could provide stronger evidence on how transparency and environmental elements shape satisfaction and recommendation intention across different retail sectors.

CONCLUSION

Retail loyalty apps that clearly present program rules and include environmental features receive the most favorable user evaluations. In this research, only transparency and eco-elements increased satisfaction, while personalization and usability did not add explanatory value when assessed together. Satisfaction was closely linked to users' willingness to recommend the app, confirming its importance in understanding digital loyalty behavior. For retailers, loyalty apps serve as more than distribution channels for offers; they are platforms where fairness, clarity, and environmental commitments are visible to customers. Clear explanations of how reward mechanisms work and how data are used, combined with features such as digital receipts or incentives for sustainable choices, provide a stronger foundation for positive evaluations and recommendations. Usability and personalization remain necessary, but primarily as expected standards rather than decisive factors.

Apps that are easy to navigate, transparent, and equipped with meaningful sustainability components meet the current expectations in retail settings where functional and value-based criteria are assessed simultaneously. Such design choices enable retailers to support environmental goals while increasing satisfaction and the likelihood of recommendations among app users.

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APPENDIX 1. SURVEY

Scale:
1 – Strongly disagree/ 2 – Disagree/ 3 – Somewhat disagree/ 4 – Neither agree nor disagree/ 5 – Somewhat agree/ 6 – Agree/ 7 – Strongly agree

No.	Survey Question	Variable Label
0	Are you currently a member of at least one retail loyalty program?*	-
1	The information in the app is clear.	info_clear
2	The program rules are easy to find.	rules_visible
3	The program does not hide important information.	data_open
4	The way to collect points is clearly explained.	points_explained
5	The offers I get are tailored to my interests.	offers_fit
6	The program recognizes my shopping habits.	habits_recognized
7	I get relevant suggestions through the app.	relevant_suggestions
8	The reminders I receive are useful and timely.	reminder_effective
9	The app is easy to use.	easy_navigation
10	The app loads quickly.	fast_loading
11	The layout of the app is intuitive.	intuitive_layout
12	I can quickly find what I need in the app.	quick_access
13	I can choose green (eco-friendly) rewards.	green_rewards
14	Digital receipts are used instead of paper.	digital_receipts
15	The app gives me ecological advice or tips.	eco_tips
16	I can track my environmental impact in the app.	eco_tracking
17	I am satisfied with the loyalty program.	overall_satisfaction
18	The program meets my expectations.	meets_expectations
19	The program gives good value.	fair_value
20	I have a positive experience with the program.	positive_experience
21	I would recommend this program to others.	recommend_others
22	The program is worth using.	program_worth_it
23	I share offers from this program with other people.	share_offers

Note: *Only participants who selected “Yes” continued with the survey.

EVALUATION OF THE IMPLEMENTATION OF SUSTAINABLE DEVELOPMENT GOAL 11: SELECTED EUROPEAN UNION CITIES IN THE CONTEXT OF THE GLOBAL AGENDA

EVALUACIJA IMPLEMENTACIJE CILJA 11 ODRŽIVOG RAZVOJA: ODABRANI GRADOVI EUROPSKE UNIJE U KONTEKSTU GLOBALNE AGENDE

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Urbana područja u Europskoj uniji imaju ključnu ulogu u gospodarskom, društvenom i ekološkom razvoju. Danas u njima živi većina europskog stanovništva, a očekuje se daljnji rast urbanizacije, što čini gradove središtima inovacija, rada i obrazovanja. Istodobno, urbani prostori suočeni su s nizom izazova kao što su pritisak na stambeno tržište, prometna zagušenost, rast društvenih nejednakosti i degradacija okoliša. Ovi problemi dodatno su intenzivirani tijekom posljednjeg desetljeća pod utjecajem pandemije, klimatskih promjena i geopolitičkih nestabilnosti. Budući da urbani razvoj u Europskoj uniji nije ujednačeno institucionalno upravljan te se često odvija kroz fragmentirane sektorske politike, gradovi postaju mjesta u kojima se najsnažnije očituju suvremena razvojna pitanja, ali i okruženja u kojima mogu nastajati nova rješenja. Stoga je pitanje održivog urbanog razvoja od temeljne važnosti za budućnost Europske unije i njezinih stanovnika.

U tom kontekstu, Cilj 11 održivog razvoja postaje temeljni okvir za promišljanje urbanih politika u Europskoj uniji. Polazeći od tog okvira, ovaj rad analizira mjere, strategije i napore koje EU poduzima kako bi se

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gradovi razvili u uključive, sigurne, otporne i održive urbane zajednice, s posebnim naglaskom na promicanje kvalitete života i socijalne pravednosti. Posebno se razmatraju ključne politike i inicijative Europske unije, od Leipziške povelje 2007. i uspostave Urbane agende EU-a 2016. do Nove Leipziške povelje, Teritorijalne agende 2030. i Agende za gradove usvojene 2025.

U drugom dijelu rada provodi se komparativna analiza Stockholma, Kopenhagena i Ljubljane korištenjem alata OECD Local SDGs, koji omogućuje procjenu njihove „udaljenosti" od ciljeva održivog razvoja do 2030. godine na temelju standardiziranih pokazatelja za svih 17 SDG-ova, te konkretno za SDG 11. Alat vizualno prikazuje razine usklađenosti gradova s ciljevima te omogućuje usporedbu među gradovima različitih zemalja. Rezultati pokazuju jasne razlike u stupnju napretka – nordijski gradovi nalaze se znatno bliže ciljnim vrijednostima u većini područja, dok Ljubljana ostvaruje dobre, ali manje ujednačene rezultate, osobito u energetskim i klimatskim ciljevima.

Ključne riječi: *održivi razvoj, Cilj 11, urbane politike, održivi gradovi, Europska unija*

JEL klasifikacija: *O18, Q01, Q56*

Urban areas in the European Union play a key role in economic, social, and environmental development. Today, the majority of the European population lives in cities, and further growth in urbanisation is expected, making cities centres of innovation, employment, and education. At the same time, urban areas are confronted with a range of challenges such as pressure on housing markets, traffic congestion, growing social inequalities, and environmental degradation. These problems have been further intensified over the past decade by the impacts of the pandemic, climate change, and geopolitical instability. Since urban development in the European Union is not governed through a uniform institutional framework and is often shaped by fragmented sectoral policies, cities become places where contemporary development issues are most strongly manifested, but also environments in which new solutions can emerge. Therefore, the issue of sustainable urban development is of fundamental importance for the future of the European Union and its citizens.

In this context, Sustainable Development Goal 11 serves as a key framework for reflecting on urban policies in the European Union. Building on this framework, the paper analyses the measures, strategies, and

efforts undertaken by the EU to support the development of cities as inclusive, safe, resilient, and sustainable urban communities, with particular emphasis on promoting quality of life and social justice. Special attention is given to the key policies and initiatives of the European Union, ranging from the Leipzig Charter of 2007 and the establishment of the EU Urban Agenda in 2016 to the New Leipzig Charter, the Territorial Agenda 2030, and the Cities Agenda adopted in 2025.

The second part of the paper presents a comparative analysis of Stockholm, Copenhagen, and Ljubljana using the OECD Local SDGs tool, which enables an assessment of their "distance" from the Sustainable Development Goals by 2030 on the basis of standardised indicators covering all 17 SDGs, with a specific focus on SDG 11. The tool visually presents the levels of alignment of cities with the goals and allows for comparison among cities across different countries. The results reveal clear differences in the degree of progress: Nordic cities are significantly closer to the target values in most areas, while Ljubljana achieves good but less consistent results, particularly with regard to energy- and climate-related goals.

Keywords: *sustainable development, SDG 11, urban policies, sustainable cities, European Union*

JEL Classification: *O18, Q01, Q56*

UVOD

Godine 1950. život u gradovima bio je relativno rijedak: samo 20 % od tadašnjih 2,5 milijardi stanovnika svijeta živjelo je u gradovima, definiranim kao naseljena središta s najmanje 50 000 stanovnika i gustoćom od najmanje 1 500 stanovnika po km^2. Nakon višedesetljetnog procesa urbanizacije, gradovi 2025. predstavljaju mjesto stanovanja za 45 % od ukupno 8,2 milijarde svjetskog stanovništva, što je više nego dvostruki udio u odnosu na 1950. godinu (United Nations, 2025b).

Sukladno tome, kako dinamični proces urbanizacije nastavlja nuditi prilike i izazove, gradovi i urbana područja postaju sve važniji politički ciljevi za nacionalne vlade (OECD *et al*., 2021) i urbanističko planiranje diljem svijeta, posebno u razvijenim regijama poput Europske unije (EU).

Konkretnije, od industrijske revolucije došlo je do značajnih promjena u geografskoj distribuciji stanovništva diljem Europe. Urbana područja, koja obuhvaćaju gradove, mjesta i njihova predgrađa, danas su dom gotovo triju

četvrtina stanovništva EU-a te stoga imaju važnu ulogu u životima ljudi. Urbanizacija je s vremenom postala globalni fenomen koji sve više doprinosi gospodarskom rastu. Obrasci urbanog širenja u EU-u poprimaju različite oblike, a kao takvi, gradovi imaju potencijal da budu vrlo učinkovita mjesta jer mogu ponuditi širok raspon zdravstvenih, obrazovnih i drugih društvenih i kulturnih usluga, kao i prometne, komunikacijske, energetske i sanitarne mreže, sve po nižim troškovima nego u rijetko naseljenim regijama. Nadalje, blizina ljudi, poduzeća i usluga omogućuje učinkovitije korištenje resursa, veće korištenje javnog prijevoza te više ljudi koji žive u stanovima i obiteljskim kućama (European Commission, 2016).

U tom kontekstu, Europska unija je jedno od najurbaniziranijih područja na svijetu. Danas oko 75 % – gotovo 340 milijuna ljudi – stanovništva EU-a živi u gradovima i drugim urbanim područjima (European Commission, 2025). Prema projekcijama UN-a, do 2050. godine taj će postotak doseći 80 %. Razvoj urbanih područja imat će značajan utjecaj na budući održivi razvoj (ekonomski, okolišni i društveni) Europske unije i njezinih građana. Urbane četvrti svih veličina mogu biti pokretači ekonomije koji potiču rast, stvaraju radna mjesta za svoje građane i poboljšavaju konkurentnost Europe u globaliziranoj ekonomiji. Trenutačno je 73 % svih radnih mjesta i 80 % osoba u dobi od 25 do 64 godine s tercijarnim obrazovanjem smješteno u europskim gradovima, naseljima i predgrađima. Međutim, urbana područja također su mjesta gdje su koncentrirani problemi poput segregacije, nezaposlenosti i siromaštva. S obzirom na navedeno, urbana područja igraju ključnu ulogu u ostvarivanju ciljeva EU-a i rješavanju mnogih izazova, uključujući izbjegličku i azilantsku krizu (Council of the European Union, 2016).

Pored toga, europske regije i gradove potresao je niz izvanrednih stanja, uključujući pandemiju bolesti COVID-19, ruski rat protiv Ukrajine, demografske promjene i klimatsku krizu (European Committee of the Regions, 2024).

Nadalje, urbane politike uvelike se razlikuju među državama članicama i samo ih nekoliko ima zasebna ministarstva za urbane poslove. Urbana politika često je neposredan rezultat urbanog i prostornog planiranja i zajedničke intervencije sektorskih politika, a nije izdvojeno područje kojim se politički i strateški upravlja (Europska komisija, 2014)

Očito je da održivi gradovi imaju ključnu ulogu u postizanju Ciljeva održivog razvoja i ispunjavanju obveza Pariškog sporazuma o klimatskim promjenama, jer predstavljaju središta ekonomske aktivnosti i inovacija, ali su istodobno i značajni izvori ekoloških opterećenja. Gradovi unutar EU-a odgovorni su za najveći udio potrošnje energije i emisija stakleničkih plinova, čime postaju ključni akteri u tranziciji prema zelenijem i održivijem gospodarstvu.

Kao takvi, imaju presudnu ulogu u smanjenju ekološkog otiska kroz implementaciju mjera energetske učinkovitosti, promicanje održive mobilnosti te poticanje korištenja obnovljivih izvora energije.

Stoga, gradovi se doista mogu promatrati kao izvori, ali i rješenja za mnoge suvremene gospodarske, društvene i ekološke izazove. S jedne strane, oni su pokretači gospodarstva EU-a. S druge strane, gradovi se suočavaju s društvenim i ekološkim pitanjima, poput osiguravanja pristupačnog smještaja te rješavanja problema kriminala, zagušenja i zagađenja (European Commission, 2016).

Na tom tragu, ovaj rad analizira mjere, strategije i napore koje Europska unija poduzima radi ostvarivanja Cilja 11 održivog razvoja (SDG 11), s naglaskom na promicanju održivosti, inkluzivnosti i sigurnosti urbanog života. Posebna se pozornost posvećuje ključnim politikama i inicijativama Europske unije, počevši od Leipziške povelje iz 2007. godine i uspostave Urbane agende EU-a 2016., pa sve do Nove Leipziške povelje, Teritorijalne agende 2030. i Agende za gradove usvojene 2025. godine. Središnja tema rada jest analiza globalnog Cilja 11 – Održivi gradovi i zajednice. U tom se kontekstu provodi i komparativna analiza triju odabranih gradova Europske unije, prepoznatih kao Europske zelene prijestolnice zbog svojih napora u tranziciji prema klimatskoj neutralnosti i razvoju održivih urbanih prostora. Analizom su obuhvaćeni Stockholm, Kopenhagen i Ljubljana, pri čemu se, primjenom alata OECD Local SDGs, procjenjuje njihova „udaljenost“ od ciljeva održivog razvoja do 2030. godine na temelju standardiziranih pokazatelja za svih 17 ciljeva održivog razvoja, s posebnim naglaskom na SDG 11. U završnom dijelu rada iznose se zaključci u kojima se sažimaju ključni rezultati istraživanja. Oni upućuju na to da gradovi s jasno definiranim strateškim okvirom i osiguranim financijskim resursima ostvaruju znatno veći napredak u postizanju ciljeva održivosti, dok napredak u svim dimenzijama održivog urbanog razvoja nije ujednačen.

CILJ 11 – ODRŽIVI GRADOVI I ZAJEDNICE

Ciljevi održivog razvoja (SDGs) postavljeni su za petnaestogodišnje razdoblje 2016. – 2030. godine, nakon jednako dugog razdoblja Milenijskih razvojnih ciljeva (MDGs). Već sada je jasno da se SDG-ovi neće postići unutar predviđenog vremenskog okvira, a za to postoje četiri razloga (Sachs *et al*., 2024). Prvo, mnogi ciljevi – poput prijelaza na energetske sustave bez ugljika – nužno zahtijevaju horizont do 2050. godine. Drugo, unatoč obvezama iznesenim u Akcijskom planu iz Adis Abebe (2015.) za usklađivanje financij-

skih tokova s agendom održivog razvoja, potrebna reforma globalne financijske arhitekture (engl. *Global Financial Architecture* – GFA) još uvijek nije provedena. Zbog toga su se zemlje u razvoju suočile s kroničnim nedostatkom financiranja za ostvarenje SDG-ova. Treće, niz globalnih kriza, uključujući pandemiju bolesti COVID-19 i ratove u Ukrajini, na Bliskom istoku, Africi i drugim dijelovima svijeta, ne samo da su izravno ometali napredak u ostvarivanju SDG-ova već su i značajno pojačali napetosti među glavnim svjetskim silama te ugrozili globalnu suradnju potrebnu za postizanje SDG-ova. Četvrto, nacionalno i globalno upravljanje SDG-ovima duboko su narušeni društvenom polarizacijom, snažnim lobijima, nedostatkom osnaživanja (ili stvarnom obespravljenosti) civilnog društva i akademskih institucija te politikama usmjerenima na vlastite nacionalne interese koje su ugrozile globalnu suradnju.

U suštini, međunarodna zajednica ponovno se nalazi u situaciji sličnoj onoj iz 2015. godine, ali uz znatno ograničeniji vremenski okvir za ostvarenje ciljeva održivog razvoja. Nakon gotovo desetljeća provedbe Agende 2030, već je iskorišteno oko dvije trećine predviđenog razdoblja za izgradnju sigurnijeg, pravednijeg i održivijeg svijeta. Istodobno, posljedice izostanka takvog razvoja postaju sve vidljivije, dok sve veći broj ljudi ne dovodi u pitanje samo institucije koje nisu ispunile očekivanja, nego i samu ideju društvenog napretka (United Nations, 2024a). Navedeno potvrđuje i *Sustainable Development Goal Report 2025*, prema kojem Procjena napretka za 2025. godinu pokazuje da je svijet i dalje daleko od ostvarenja Agende 2030. Od ukupno 169[1] ciljeva održivog razvoja, samo 35 posto ciljeva pokazuje zadovoljavajući napredak – 18 posto je na dobrom putu, a 17 posto bilježi umjeren napredak. Nasuprot tome, 48 posto ciljeva pokazuje nedovoljan napredak, uključujući 31 posto s tek minimalnim pomacima i 17 posto bez ikakvog napretka. Najviše zabrinjava činjenica da se 18 posto ciljeva vratilo na razine ispod početnih vrijednosti iz 2015. godine (United Nations, 2025a).

Unatoč tome, Ujedinjeni narodi smatraju da je do 2030. godine još uvijek moguće izgraditi bolji, održiviji i inkluzivniji svijet za sve, pri čemu politička deklaracija sa SDG *summita* zahtijeva konkretnu provedbu (United Nations, 2024b).

Ovi ciljevi od presudne su važnosti za ostvarenje održivog razvoja, s obzirom na to da većina svjetske populacije živi u urbanim sredinama. Detaljna razrada cilja 11 ostvaruje se kroz njegovih 10 podciljeva (11.1. – 1.9., te 11.A.) koji naglašavaju specifične aspekte i mjere nužne za postizanje održivih, inkluzivnih i otpornijih gradova:

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[1] 139 je bilo moguće procijeniti korištenjem globalnih trendova od početne vrijednosti iz 2015. do najnovije dostupne godine, uz dopunske analize nadležnih agencija

11.1 Sigurno i pristupačno stanovanje (do 2030.)
11.2 Pristupačni i održivi transportni sustavi (do 2030.)
11.3 Inkluzivna i održiva urbanizacija
11.5 Smanjenje posljedica prirodnih katastrofa (do 2030.)
11.6 Smanjenje ekoloških utjecaja gradova (do 2030.)
11.7 Pristup sigurnim i inkluzivnim zelenim prostorima (do 2030.)
11.8 Snažno nacionalno i regionalno planiranje razvoja
11.9 Provedba politika za inkluziju i otpornost
11.a Potpora najmanje razvijenim zemljama u održivoj gradnji

Prema Izvješću o ciljevima održivog razvoja iz 2025. godine, s brzom urbanizacijom i činjenicom da više od polovice svjetskog stanovništva danas živi u gradovima, pristupačnost stanovanja dosegnula je razinu krize. Do 3 milijarde ljudi širom svijeta teško si može priuštiti mjesto za stanovanje, a 1,12 milijardi živi u slamovima ili neformalnim naseljima bez osnovnih usluga (United Nations, 2025a). Nadalje, prama podacima Ujedinjenih naroda (United Nations, 2024b), nedostatak pravednog pristupa javnom prijevozu predstavlja ozbiljan problem, osobito u najmanje razvijenim zemljama, gdje samo 4 od 10 osoba ima prikladan pristup. Iako su razine onečišćenja zraka opale u većini regija, one su i dalje znatno više od preporučenih smjernica za javnozdravstvenu zaštitu. Također, samo 40 posto gradskog stanovništva može lako doći do otvorenih javnih prostora. U razdoblju od 2000. do 2020. godine, gradovi su se širili do 3,7 puta brže nego što su povećavali svoju gustoću, što je dovelo do negativnih posljedica po prirodni okoliš i korištenje zemljišta. S porastom urbanizacije i predviđanjem da će gotovo 70 posto svjetske populacije živjeti u gradovima do 2050. godine, nužno je razvijati ključnu infrastrukturu, pristupačno stanovanje, učinkovite prometne sustave i osnovne socijalne usluge kako bi se stvorili otporniji i održiviji gradovi koji će zadovoljiti potrebe svih stanovnika.

Prema podacima za zemlje članice OECD-a, više od 80 % regija nije ostvarilo nijedan od 17 ciljeva održivog razvoja, dok 70 % gradova nije postiglo više od dva cilja. Kao jedan od ključnih izazova ističe se nedostatak financijskih resursa, na što ukazuje 64 % ispitanika u anketi OECD-SDSN-CoR. Financijski jaz za ostvarenje ciljeva održivog razvoja dodatno se produbio tijekom pandemije bolesti COVID-19, povećavši se za više od 50 % u 2020. godini te dosegnuvši 3,9 trilijuna američkih dolara u zemljama u razvoju. Među značajnim izazovima navode se i promjenjivi politički prioriteti, primjerice nakon lokalnih ili regionalnih izbora, na što upozorava 52 % podnacionalnih vlasti. Dodatni problem predstavlja nedostatak vertikalne koordinacije između

lokalnih i nacionalnih razina vlasti, koji je istaknulo 44 % ispitanika, unatoč nastojanjima da se podnacionalni akteri uključe u proces izrade dobrovoljnih nacionalnih izvještaja (United Nations, 2024a).

Kada je riječ o EU-u, praćenje 11. cilja održivog razvoja podrazumijeva razmatranje razvoja kvalitete života u gradovima i zajednicama, održive mobilnosti i štetnih učinaka na okoliš. Općenito, EU je u proteklom petogodišnjem razdoblju ostvario tek skroman napredak prema 11. cilju održivog razvoja. Iako je ostvaren znatan napredak u povećanju kvalitete života u gradovima i zajednicama, trendovi u području održive mobilnosti manje su jasni i pandemija bolesti COVID-19 utječe na njih. Slika je slično raznolika kada je riječ o štetnim utjecajima na okoliš, a vidljivi su i održivi i neodrživi trendovi (Tablica 1.).

Tablica 1. Napredak EU-a prema cilju SDG 11 – Održivi gradovi i zajednice

Pokazatelj	Razdoblje	Godišnja stopa rasta	Ocjena
Kvaliteta života u gradovima i zajednicama			
Stopa teške stambene deprivacije	2010. – 2023.	–3,2 %	Na putu prema ostvarenju EU cilja
	2018. – 2023.	–1,4 %	Na putu prema ostvarenju EU cilja
Stanovništvo koje živi u kućanstvima izloženima buci	2010. – 2023.	–0,9 %	Umjeren napredak prema SD ciljevima
	2018. – 2023.	0,00%	Nema napretka niti udaljavanja od SD ciljeva
Prijevremene smrti zbog izloženosti sitnim česticama ($PM_{2,5}$)	2007. – 2022.	Uočeno: –2,5 % / Potrebno: –2,5 %	Na putu prema ostvarenju EU cilja
	2017. – 2022.	Uočeno: –4,7 % / Potrebno: –3,4 %	Na putu prema ostvarenju EU cilja
Stanovništvo koje prijavljuje kriminal, nasilje ili vandalizam u svojem području	2010. – 2023.	–2,1 %	Na putu prema ostvarenju EU cilja
	2018. – 2023.	–2,8 %	Na putu prema ostvarenju EU cilja
Održiva mobilnost			
Smrtni slučajevi u prometu	2008. – 2023.	Uočeno: –3,9 % / Potrebno: –5,2 %	Umjeren napredak prema SD ciljevima
	2018. – 2023.	Uočeno: –2,7 % / Potrebno: –5,8 %	Nedovoljan napredak prema EU cilju

Pokazatelj	Razdoblje	Godišnja stopa rasta	Ocjena
Udio autobusa i vlakova u putničkom prijevozu	2007. – 2022.	–0,3 %	Nedovoljan napredak prema EU cilju
	2017. – 2022.	–0,7 %	Nedovoljan napredak prema EU cilju
Utjecaj na okoliš			
Indeks zapečaćenosti tla	2006. – 2018.	0,30%	Nedovoljan napredak prema EU cilju
	2015. – 2018.	0,30%	Nedovoljan napredak prema EU cilju
Stopa recikliranja komunalnog otpada	2008. – 2023.	Uočeno: 1,9 % / Potrebno: 2,3 %	Umjeren napredak prema SD ciljevima
	2018. – 2023.	Uočeno: 0,8 % / Potrebno: 2,2 %	Nedovoljan napredak prema EU cilju
Stanovništvo spojeno na barem sekundarni stupanj pročišćavanja otpadnih voda	2007. – 2022.	0,70 %	Umjeren napredak prema SD ciljevima
	2017. – 2022.	0,20 %	Umjeren napredak prema SD ciljevima

Izvor: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=SDG_11_-_Sustainable_cities_and_communities#Highlights

Napomena: podaci su ažurirani u travnju 2025.

Tablica 1. prikazuje napredak EU-a prema cilju održivog razvoja SDG 11, analizirajući različite pokazatelje kvalitete života i održivosti u gradovima tijekom određenog vremenskog razdoblja. Podaci pokazuju da EU ostvaruje značajan napredak u nekoliko ključnih područja vezanih uz cilj SDG 11. Posebno se ističe poboljšanje stambenih uvjeta, uz kontinuirano smanjenje teške stambene deprivacije, te smanjenje prijevremenih smrti povezanih s onečišćenjem zraka, što je u skladu ili čak brže od zacrtane dinamike. Vidljiv je i pozitivan trend u području sigurnosti, s obzirom na to da sve manje stanovnika prijavljuje kriminal, nasilje ili vandalizam. Neki pokazatelji, poput izloženosti buci, recikliranja otpada i pristupa sekundarnom pročišćavanju otpadnih voda, pokazuju umjeren napredak, ali nedovoljno snažan da bi osigurao potpuno ispunjenje ciljeva.

S druge strane, područja vezana uz održivu mobilnost i zaštitu okoliša pokazuju zabrinjavajuće trendove. Smrtnost u prometu opada presporo, a u novijem razdoblju EU se čak udaljava od cilja, dok udio korištenja autobusa i

vlakova u prijevozu kontinuirano pada, što upućuje na slabiji razvoj održivih prijevoznih opcija. Indeks zapečaćenosti tla također ne pokazuje napredak, što ukazuje na nastavak pritiska izgradnje na prirodne površine. Dodatno, recikliranje otpada napreduje sporije nego što je potrebno. Ukupno gledano, rezultati ukazuju na to da, unatoč znatnim pomacima u području kvalitete života i okoliša, EU mora znatno ojačati politike održive mobilnosti, urbanog planiranja i gospodarenja otpadom kako bi u potpunosti ostvarila cilj SDG 11.

STRATEGIJE EU-a ZA RAZVOJ ODRŽIVIH GRADOVA

Europska unija razvila je opsežnu raspravu o gradovima i njihovu razvoju tijekom proteklih desetljeća. Od kraja 90-ih godina prošlog stoljeća, periodični sastanci ministara nadležnih za urbani razvoj doveli su do konsolidacije „perspektive EU-a" o urbanim pitanjima (tzv. „urbana stečevina"), koja se može prevesti u pristup EU-a održivom urbanom razvoju. Taj je pristup tijekom godina dodatno usavršavan kroz njegovu provedbu na terenu, zahvaljujući urbanim inicijativama koje je EU promovirao u sklopu svoje kohezijske politike i drugih posebno usmjerenih inicijativa za gradove (Fioretti, C. *et al*., 2020).

Godina 2007. bila je ključna u ovom dugom procesu. Naime, te je godine na neformalnom ministarskom sastanku održanom pod njemačkim predsjedanjem Vijećem Europske unije potpisana Leipziška povelja o održivim gradovima (Council of the European Union, 2007). Leipziška povelja donosi dva ključna načela za održivi urbani razvoj: primjenu holističke, integrirane politike razvoja i usmjeravanje posebne pažnje na marginalizirana naselja. Godina 2007. također je označila početak novog programskog razdoblja (2007. – 2014.), a politike održivog urbanog razvoja postale su u potpunosti integrirane u financijske sheme EU-a nakon pozitivne evaluacije inicijativa URBAN[2] (engl. *Urban Revitalization Program*), odnosno postale su dio „glavnog toka" kohezijske politike *(Fioretti, C. et al*., 2020).

Potom je 2015. godine usvojen novi petnaestogodišnji plan za održivi razvoj *Transforming our world: the 2030* (United Nations, 2015), u kojem je cilj 11 Održivi gradovi i zajednice eksplicitno dobio mjestu na globalnoj agendi.

Sljedeći važan korak odnosio se na usvajanje *Amsterdamskog pakta* 2016. godine (Council of the European Union, 2016), kojeg su 30. svibnja usvojili

[2] URBAN je kratica za *Urban Revitalization Program*, inicijativu EU-a usmjerenu na promicanje održivog razvoja gradova i urbanih područja, s naglaskom na integrirane pristupe za poboljšanje društvenih, ekonomskih i okolišnih uvjeta u gradovima.

ministri EU-a nadležni za urbana pitanja. Ovim je paktom uspostavljena Urbana agenda EU-a (UAEU). Temeljena na načelima supsidijarnosti i proporcionalnosti, Urbana agenda bila je usmjerena na tri stupa oblikovanja i provedbe politika EU-a: bolju regulaciju, bolje financiranje i bolje znanje, fokusirajući se na sljedeće prioritetne teme: uključivanje migranata i izbjeglica, kvaliteta zraka, urbano siromaštvo, stanovanje, kružna ekonomija, radna mjesta i vještine u lokalnoj ekonomiji, prilagodba klimatskim promjenama (uključujući rješenja zelene infrastrukture), energetska tranzicija, održivo korištenje zemljišta i rješenja temeljena na prirodi, urbana mobilnost i digitalna tranzicija.

Prvi radni program UAEU-a obuhvaćao je razdoblje od 2016. do 2021. godine i bio je usklađen s ciljevima Amsterdamskog pakta. U tom su okviru tematska partnerstva predstavljala glavni mehanizam provedbe, okupljajući predstavnike različitih razina vlasti i druge relevantne dionike radi suradnje na zajedničkim urbanim temama (European Parliament, 2025).

Na tom tragu, 2017. godine Ujedinjeni narodi su također objavili svoju viziju *The New Urban Agenda*, koja je sastavni dio Cilja 11 i Agende za održivi razvoj 2030. Ova agenda naglašava važnost urbanizacije za postizanje održivog razvoja, s fokusom na stvaranje održivih gradova i zajednica. Vizija ima za cilj promovirati inkluzivne, sigurne, otpornije i održive urbane prostore širom svijeta, usklađujući globalne prioritete za urbani razvoj i socijalnu inkluziju (United Nations, 2017).

Uslijedilo je donošenje Europskog zelenog plana koji je pružio vrijednu podršku i poticaj promišljanju o urbanoj politici i dijalogu u okviru Europske unije (Europska komisija, 2019): „Urbana dimenzija kohezijske politike ojačat će se, a predložena europska urbana inicijativa pružit će pomoć gradovima kako bi na najbolji mogući način mogli iskoristiti mogućnosti za razvoj strategija održivog urbanog razvoja."

Konačno, Nova Leipziška povelja – *The transformative power of cities for the common good*, usvojena u studenom 2020., predstavlja revidiranu viziju održivog urbanog razvoja u Europi, s naglaskom na transformativnu moć gradova za zajedničko dobro. To se treba postići kroz akcije poduzete unutar triju tematskih dimenzija Povelje – „Pravedni, Zeleni i Produktivni Gradovi" – kao i kroz jednu međusektorsku dimenziju Povelje „Digitalizacija", koje se provode u okviru višerazinskog upravljanja. Europska urbana agenda smatra se ključnim instrumentom za provedbu Nove Leipziške povelje (European Urban Initiative, 2022).

Teritorijalna agenda 2030 – *Budućnost za sva područja* (*Territorial Agenda 2030 - A Future for All Places*, 2020), usvojena u prosincu 2020., sadrži brojne reference na UAEU i naglašava ulogu gradova u suočavanju s velikim

okolišnim i socioekonomskim izazovima. Agenda služi kao strateški okvir za prostorno planiranje te poziva na jačanje teritorijalne dimenzije u sektorskim politikama na svim razinama upravljanja. Cilj joj je promicati uključivu i održivu budućnost za sva područja te poduprijeti ostvarenje Ciljeva održivog razvoja u EU-u (European Parliament, 2025).

O predanosti na svim razinama, svjedoči i Ljubljanski sporazum, koji je usvojen u studenom 2021., na neformalnom sastanku ministara EU-a nadležnih za urbana pitanja, s ciljem da se gradovima omogući veći utjecaj na razini EU-a. Sporazum je popraćen drugim radnim programom UAEU-a za razdoblje 2022. – 2026. Ovaj program pruža okvir za planiranje, provedbu i praćenje UAEU-a te preporučuje čvršće povezivanje UAEU-a s definiranim političkim procesima EU-a, izradom politika i zakonodavstvom na različitim razinama, kako bi se poboljšao njegov učinak (European Parliament, 2025).

U svojoj posljednjoj Zajedničkoj deklaraciji usvojenoj na neformalnom sastanku ministara nadležnih za koheziju, teritorijalnu koheziju i urbane politike održanom u Varšavi u svibnju 2025., države članice EU-a naglasile su da je teritorijalna i urbana dimenzija ključna sastavnica kohezijske i razvojne politike, pri čemu se naglasak stavlja ne samo na ekonomsku distribuciju, već i na prostornu pravednost. U dokumentu se ističe i očekivanje da budući politički i financijski okviri nakon 2027. godine snažnije integriraju teritorijalnu perspektivu, čime bi se omogućilo ciljano usmjeravanje mjera prema gradovima, regijama te ruralnim i perifernim područjima (Council of the European Union, 2025).

Konačno, u dokumentu *An EU Agenda for Cities: Driving Growth and Prosperity* (2025) daje se vizija europskih gradova kao ugodnih za život, uključivih, prosperitetnih i održivih. Gradovi trebaju osigurati digitalnu povezanost, priuštivo stanovanje, kvalitetne poslove i jednak pristup uslugama, uz primjenu načela Novog europskog Bauhausa. Naglašava se važnost obrazovanja, razvoja vještina, privlačenja talenata i integracije migranata, kao i održivog turizma i očuvanja kulturne baštine. Vizija uključuje i pametnu, održivu mobilnost, suradnju s ruralnim područjima, energetsku učinkovitost i napredak prema klimatskoj neutralnosti (European Commission, 2025).

Sve navedene inicijative pokazuju da je pristup urbanom i teritorijalnom razvoju u EU-u tijekom posljednjih desetljeća postao sustavniji, strateški koherentniji i snažnije usklađen s globalnim ciljevima održivog razvoja. Od Leipziške povelje iz 2007., pa sve do najnovijih deklaracija iz 2025. godine, vidljivo je kontinuirano jačanje uloge gradova i regija u oblikovanju politika te sve veće prepoznavanje teritorijalnih specifičnosti kao ključnog faktora održivog razvoja. Europska unija tako postupno gradi integrirani okvir koji spaja urbanu

politiku, kohezijsku politiku i globalne obveze iz Agende 2030, čineći teritorijalnu dimenziju ključnim elementom za postizanje pravednijeg, inkluzivnijeg i otpornijeg razvoja u cijeloj Europskoj uniji.

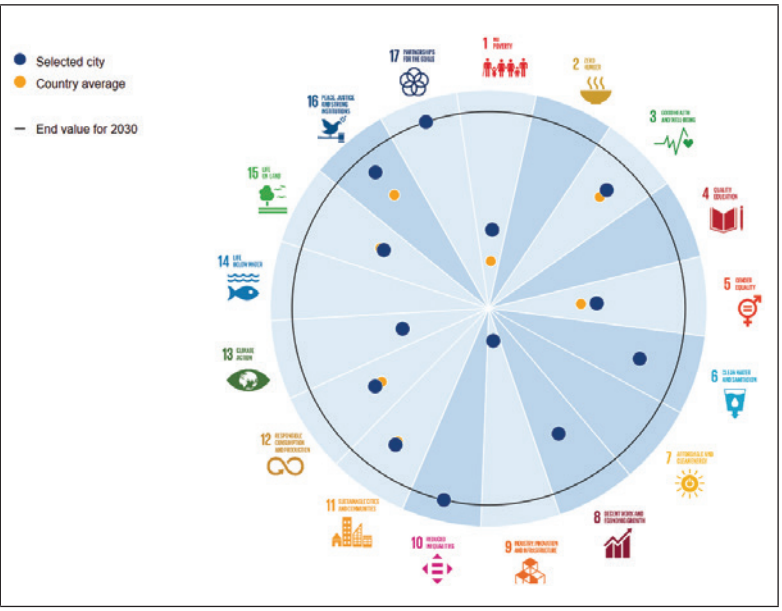
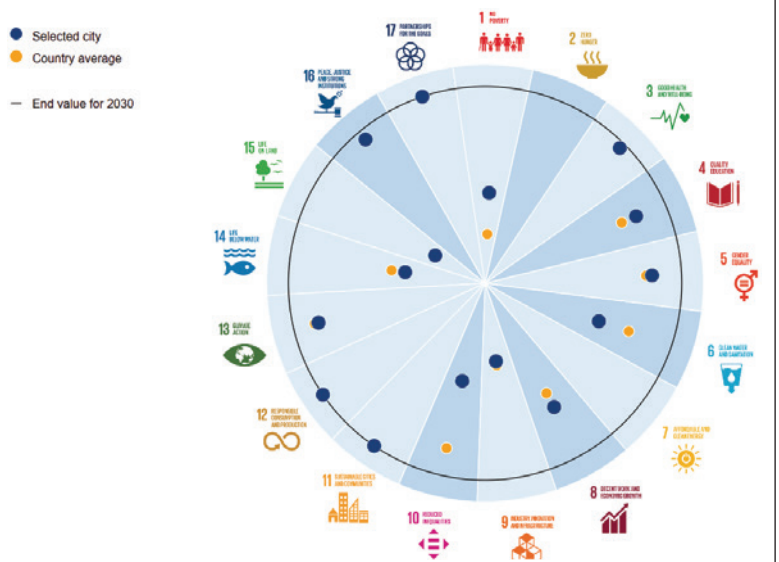
ANALIZA ODABRANIH EUROPSKIH GRADOVA

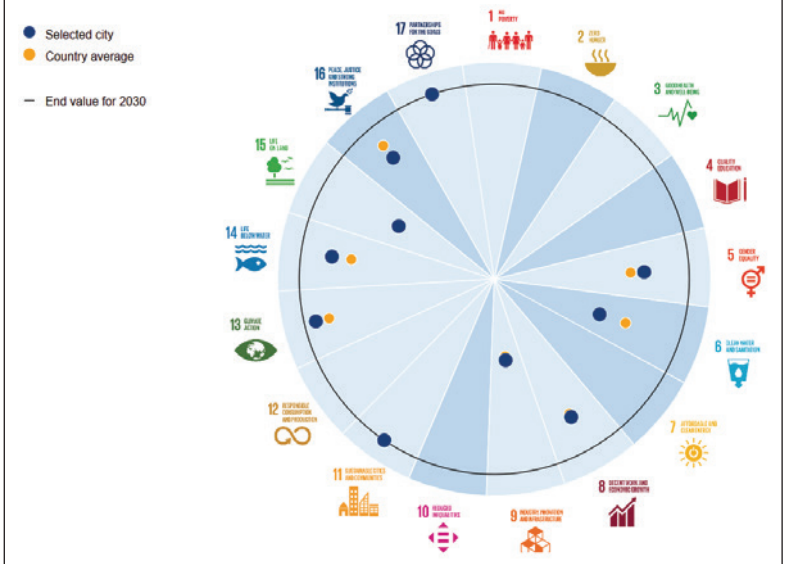
Europski gradovi – bilo da se nalaze u obalnim, otočnim, kontinentalnim, planinskim ili pograničnim područjima – odražavaju veliku raznolikost, ne samo u geografskom smislu, već i u demografskim obilježjima te socioekonomskim kapacitetima. Upravo ta raznolikost oblikuje njihovu sposobnost prilagodbe aktualnim transformacijama. Europski urbani model omogućuje gradovima različitih veličina da značajno doprinose teritorijalnom razvoju i povezanosti. Dok veći gradovi često djeluju kao središta inovacija, srednji i manji gradovi te urbana područja imaju ključnu ulogu u pružanju usluga koje podupiru lokalno stanovništvo i okolna područja, uključujući ruralna, te poboljšavaju pristup prilikama (European Commission, 2025).

U tom kontekstu, za analizu su odabrani primjeri koji se ističu u provedbi politika održivog urbanog razvoja. Odabir se temelji i na njihovu statusu Europske zelene prijestolnice, dostupnosti podataka u okviru platforme OECD Local SDGs te geografskoj i razvojnoj raznolikosti unutar europskog urbanog sustava.

Slijedom navedenog analizom su obuhvaćena tri europska grada – Stockholm, Kopenhagen i Ljubljana. Ljubljana, kao srednje velik europski grad, profilirala se kao jedan od predvodnika održivog urbanog razvoja u regiji. Svoj međunarodni ugled učvrstila je osvajanjem titule Europske zelene prijestolnice 2016. godine te sustavnim ulaganjima u očuvanje zelenih površina, razvoj održive mobilnosti i inovativne modele gospodarenja otpadom. Stockholm, jedan od najnaprednijih europskih gradova u području klimatskih politika, ističe se dugogodišnjom predanošću postizanju visokih okolišnih standarda, što je potvrđeno brojnim međunarodnim priznanjima, uključujući prvu nagradu Europske zelene prijestolnice 2010. godine i ambicioznu viziju klimatske neutralnosti do 2040. godine. Kopenhagen, globalno prepoznat po integriranim rješenjima u području održive mobilnosti, energetike i urbanog planiranja, također je višestruki dobitnik prestižnih međunarodnih nagrada i jedan od najuspješnijih europskih gradova u postizanju ciljeva održivosti. Zajedno, ovi gradovi predstavljaju tri različita, ali komplementarna modela urbanog razvoja koji omogućuju relevantnu usporedbu u kontekstu lokalne provedbe ciljeva održivog razvoja.

Slika 1. Udaljenost od ciljeva održivog razvoja do 2030. godine prema pokazateljima OECD Local SDGs: Ljubljana / Stockholm / Kopenhagen

Ljubljana	
Stockholm	

Kopenhagen	

Izvor: OECD Local SDGs (2025) https://www.oecd-local-sdgs.org/

Napomena: Vizualizacije su generirane pomoću alata OECD Local SDGs. Platforma ne omogućuje istodobni komparativni prikaz više gradova na jedinstvenom grafikonu, zbog čega su rezultati prikazani zasebno za svaki analizirani grad.

Usporedba Ljubljane, Stockholma i Kopenhagena prema OECD-ovih lokalnih pokazatelja SDG-a[3] pokazuje jasnu razliku u stupnju približenosti ciljevima održivog razvoja do 2030. godine. Stockholm i Kopenhagen u većini su područja među europskim gradovima najbližima ciljanim vrijednostima, što se osobito odnosi na socijalne ciljeve (SDG 1, SDG 3, SDG 4, SDG 5) zahvaljujući razvijenim socijalnim sustavima, stabilnom tržištu rada i visokim obrazovnim standardima. Ljubljana ostvaruje dobre rezultate, ponekad i iznad državnog prosjeka, no u pravilu je udaljenija od ciljne vrijednosti od nordijskih gradova. U području energije, klimatskih politika i održivih grad-

[3] Za potrebe komparativne analize u ovom radu koristi se alat OECD Local SDGs. Taj alat omogućuje da se za više od 600 gradova i regija u Europi i svijetu procijeni „udaljenost" do ciljeva održivog razvoja (SDG-ova) za 2030. godinu. Metodologija se zasniva na standardiziranim pokazateljima za svih 17 ciljeva, a rezultati se prikazuju grafički — pomoću „radar-grafikona" pri čemu položaj grada blizu vanjskog ruba označava visoku razinu usklađenosti sa SDG-ciljevima. Alat omogućuje usporedbu unutar države, ali i između gradova u različitim zemljama, čime se potiče međugradsko učenje, transparentnost i evaluacija lokalnih politika.

skih sustava (SDG 7, SDG 11, SDG 13) Stockholm i Kopenhagen raspolažu razvijenim infrastrukturnim i regulatornim kapacitetima, što ih pozicionira vrlo blizu ostvarenju ciljeva, dok Ljubljana pokazuje napredak, ali i dalje zaostaje za nordijskim prilikama. Ipak, Ljubljana se ističe u nekim aspektima urbanog planiranja i zaštite okoliša, primjerice u području zelenih površina i modela gospodarenja otpadom, što je u skladu s OECD-ovim prikazima napretka za SDG 11, SDG 12 i SDG 15.

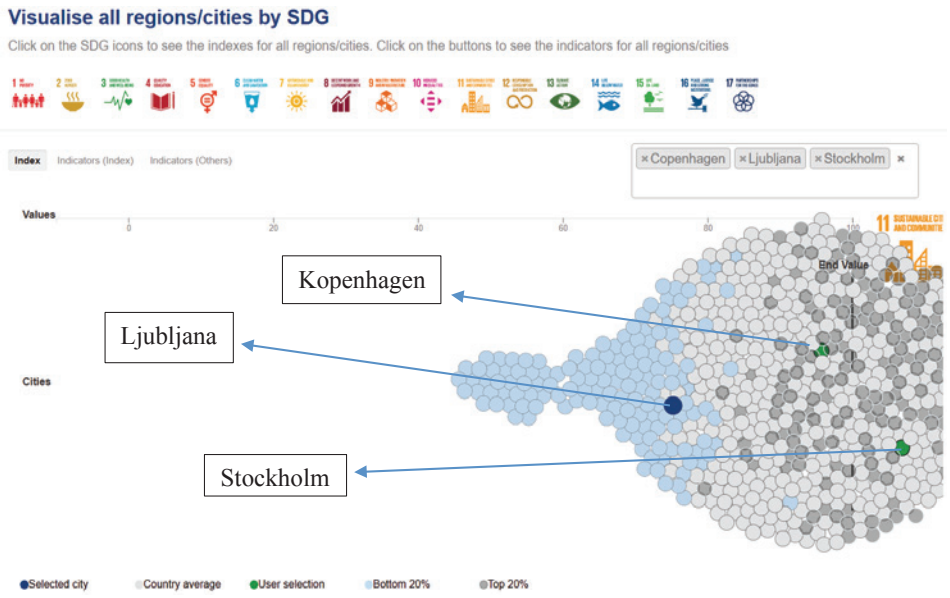
Razlike među gradovima posebno su izražene u domeni ekonomske nejednakosti, klimatske akcije i odgovorne potrošnje (SDG 10, SDG 12, SDG 13), gdje Stockholm i Kopenhagen zauzimaju vodeće pozicije zahvaljujući snažnim redistributivnim modelima, niskougljičnoj infrastrukturi i razrađenim politikama cirkularne ekonomije (Tablica 2.). Ljubljana pokazuje vidljiv napredak, primjerice kroz *Zero Waste* inicijative i visoku kvalitetu urbanog zelenila, no u agregatnom rezultatu ostaje iza skandinavskih gradova. Ukupno gledano, grafički prikazi OECD-ovih lokalnih pokazatelja SDG-a potvrđuju da nordijski gradovi imaju stabilno i široko zasnovano ispunjenje većine ciljeva održivog razvoja, dok Ljubljana, premda napreduje u brojnim segmentima, pokazuje veći razvojni jaz te potrebu za dodatnim ulaganjima i institucionalnim jačanjem kako bi se približila razini ostvarenja SDG ciljeva koju postižu Stockholm i Kopenhagen.

Tablica 2. Zaključna usporedba

Područje SDG-a	Najbolji grad	Najviše za nadoknaditi
Socijalni ciljevi (SDG 1–5)	Stockholm / Kopenhagen	Ljubljana
Energetski i klimatski ciljevi (SDG 7, 13)	Kopenhagen	Ljubljana
Inovacije i ekonomija (SDG 8–9)	Stockholm	Ljubljana
Održivi gradovi (SDG 11)	Kopenhagen	Ljubljana (i dalje vrlo visoka)
Resursi i okoliš (SDG 12–15)	Stockholm	Ljubljana (izuzev SDG 15)

Izvor: izrada autora prema OECD Local SDGs (https://www.oecd-local-sdgs.org)

Slika 2. Vizualni prikaz udaljenosti od ciljne vrijednosti SDG 11 za odabrane europske gradove prema indeksu OECD Local SDGs



Izvor: https://www.oecd-local-sdgs.org/index.html

Analiza indeksa SDG 11[4] pomoću alata OECD Local SDGs pokazuje značajne razlike u razini održivosti među odabranim gradovima (Slika 2.). Stockholm i Kopenhagen pozicionirani su u neposrednoj blizini ciljne vrijednosti, unutar klastera gradova koji pripadaju najuspješnijoj petini (top 20 %), što potvrđuje njihovu visoku usklađenost s ciljevima održivih urbanih zajednica. Nasuprot tome, Ljubljana se nalazi u srednjem području distribucije, bliže prosjeku ostalih europskih gradova, što upućuje na solidan, ali manje ujednačen napredak prema SDG 11. Šira distribucija gradova ukazuje na znatan raspon postignuća, pri čemu se velik broj urbanih područja i dalje nalazi daleko od

[4] Indeks za SDG 11 u okviru OECD Local SDGs sastoji se od dvaju pokazatelja: prosječne izloženosti stanovništva česticama PM2.5 kao mjere kvalitete okoliša te razlike između stope potrošnje zemljišta i stope rasta stanovništva kao pokazatelja održive urbanizacije. Ciljne vrijednosti za ove pokazatelje definirane su stručnim preporukama – za kvalitetu zraka prema WHO smjernicama (≤10 $\mu g/m^3$), a za urbanizaciju postizanjem ravnoteže između rasta izgrađene površine i demografskog rasta. Ovakav pristup omogućuje usporedivo i kvantitativno praćenje napretka gradova prema ostvarivanju održivih, zdravih i prostorno učinkovitih urbanih zajednica (OECD, 2020).

ciljne razine, što naglašava potrebu za intenzivnijim i koordiniranijim politikama održivog urbanog razvoja na europskoj razini.

ZAKLJUČAK

Globalne transformacije – od demografskih promjena, promjenjivih obrazaca trgovine, tehnološkog napretka do klimatskih promjena – imaju različite učinke na pojedine regije. Vlade stoga uvode politike temeljene na specifičnostima pojedinih područja kako bi osigurale bolje prilike za ljude i poduzeća te potaknule regionalnu konkurentnost i produktivnost (OECD, 2024). Dodatno, gradovi imaju ključnu ulogu u gospodarskoj konvergenciji i konkurentnosti, jer privlače talente i investicije te potiču rast. No, takvi procesi mogu istodobno stvarati i izazove, poput rastućih troškova života, zagušenosti te teritorijalnih nejednakosti, uključujući džepove siromaštva. Uravnotežen, policentričan pristup stoga ostaje ključan kako bi se ublažili takvi učinci (European Commission, 2025). Analiza provedena u ovom radu jasno pokazuje da su gradovi, kao prostori najveće koncentracije stanovništva, gospodarskih aktivnosti, ali i okolišnih opterećenja, istovremeno i nositelji promjena potrebnih za ostvarenje Agende 2030. i njezina cilja 11 – Održivi gradovi i zajednice.

Europska unija razvila je snažan i sve koherentniji strateški okvir za razvoj održivih urbanih područja. Od Leipziške povelje iz 2007., preko uspostave Urbane agende EU-a, do Nove Leipziške povelje, aktualnih političkih deklaracija i EU agende za gradove, vidljivo je da europska razvojna politika usmjerena na uloge gradova kontinuirano jača. EU danas promatra gradove ne samo kao administrativne jedinice, nego kao ključne inkubatore inovacijske, socijalne i klimatske otpornosti, uz snažan naglasak na integrirani pristup, višerazinsko upravljanje i teritorijalnu pravednost. Međutim, unatoč toj strateškoj evoluciji, rezultati pokazuju da je napredak prema ostvarenju cilja SDG 11 u EU-u neujednačen i izazovan – osobito u području održive mobilnosti, kvalitete zraka i smanjenja negativnih utjecaja na okoliš.

U tom kontekstu analiza triju odabranih gradova – Stockholma, Kopenhagena i Ljubljane – pruža vrijedan uvid u različite modele i dinamiku lokalne provedbe ciljeva održivog razvoja. Stockholm i Kopenhagen potvrđuju status europskih predvodnika u postizanju klimatske neutralnosti, razvoju održivog prijevoza, korištenju obnovljivih izvora energije i implementaciji inovativnih politika urbanog planiranja. Njihovi rezultati pokazuju da dugoročna vizija, stabilni financijski resursi i snažne institucionalne strukture omogućuju sustavan napredak u ekonomskoj, društvenoj i okolišnoj dimenziji održivosti.

Ljubljana, iako nešto udaljenija od ciljeva u usporedbi s nordijskim gradovima, također predstavlja primjer uspješne transformacije i strateškog upravljanja urbanim razvojem. Njezini rezultati u području zelene infrastrukture, očuvanja prirodnih resursa, gospodarenja otpadom i održivog prostornog planiranja potvrđuju da i srednje veliki europski gradovi mogu postati međunarodno prepoznati modeli održivosti. Ipak, analiza upućuje na to da Ljubljana, kao i mnogi drugi gradovi u Europi, treba dodatno ojačati napore u području energetike, klimatske tranzicije i socijalne uključivosti.

Sveukupno, komparativna analiza triju gradova otkriva nekoliko ključnih zaključaka. Prvo, gradovi s jasno definiranom dugoročnom strategijom, institucionalnom stabilnošću i osiguranim financijskim resursima dosljedno ostvaruju bolje rezultate. Uspjeh Stockholma i Kopenhagena temelji se na kontinuitetu politika, snažnoj političkoj volji i prepoznatom značaju participacije građana. Drugo, socijalna održivost ostaje najveći izazov u većini europskih gradova. Urbana priuštivost, pristupačno stanovanje, smanjenje nejednakosti i osiguravanje inkluzivnih javnih prostora predstavljaju područja u kojima su postignuti najmanji pomaci – kako globalno, tako i na razini EU-a. Treće, klimatska tranzicija nije moguća bez integriranog pristupa koji povezuje transport, energetiku, prostorno planiranje i gospodarenje resursima. Primjeri Kopenhagena i Stockholma potvrđuju važnost multisektorskih politika, dok rezultati Ljubljane upućuju na nužnost daljnjeg ulaganja u infrastrukturu niskougljične budućnosti.

Ograničenje istraživanja odnosi se na ograničenu dostupnost usporedivih lokalnih pokazatelja za pojedine dimenzije SDG-a 11, zbog čega je analiza provedena kroz širi okvir svih ciljeva održivog razvoja dostupnih u okviru platforme OECD Local SDGs.

Zaključno, održivi urbani razvoj nije samo tehničko ili infrastrukturno pitanje, nego transformativan proces koji zahtijeva uključivanje svih razina vlasti, ali i samih građana. Pri tome, gradovi polaze iz različitih pozicija, s različitim zakonskim ovlastima i raspoloživim resursima – osobito oni manji – te se često suočavaju s ograničenim administrativnim kapacitetima i proračunskim mogućnostima (European Commission, 2025). Primjeri Stockholma, Kopenhagena i Ljubljane pokazuju da transformacija jest moguća – no zahtijeva strateško planiranje i dugoročnu političku predanost. Njihova iskustva mogu poslužiti kao smjernice drugim europskim i svjetskim gradovima koji se nalaze na putu prema održivosti, inkluzivnosti i otpornosti, te ispunjenju cilja SDG 11.

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CHALLENGES IN THE IMPLEMENTATION OF THE CORPORATE SUSTAINABILITY REPORTING DIRECTIVE IN CROATIA (CSRD)

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Background: The adoption of the Corporate Sustainability Reporting Directive (CSRD), which entered into force in 2023**,** *represents a significant development in the European Union's legal framework for sustainable corporate governance. The directive emerged as a response to the EU's growing emphasis on transparency, accountability, and the integration of sustainability considerations into corporate decision-making. Its adoption is closely connected to the objectives of the European Green Deal, the EU Sustainable Finance Agenda, and the Union's broader circular economy priorities aimed at promoting resource efficiency, reducing environmental impact, and supporting a climate-neutral economy by 2050. The CSRD builds upon the earlier* Non-Financial Reporting Directive (NFRD) adopted in 2014*, which was the first attempt at the European level to regulate non-financial disclosures. Despite its pioneering role, the NFRD proved inadequate due to its narrow scope, the absence of detailed and standardized reporting requirements, and significant inconsistencies in national implementation. These limitations reduced the comparability and reliability of sustainability information and weakened its value for investors, supervisory authorities, and other relevant stakeholders, ultimately hindering the EU's capacity to track corporate progress in relation to circular-economy goals. The aim of the CSRD is to establish a unified and legally binding framework for sustainability reporting across the Union.*

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Purpose: *This paper examines the key legal aspects of the CSRD, including materiality principles, reporting obligations, assurance requirements, and supervisory mechanisms. Special attention is given to the alignment of Croatian legislation with the CSRD and the challenges arising from extending reporting obligations to small and medium-sized enterprises (SMEs) listed on regulated markets.*

Method: *The research adopts a legal-analytical approach, reviewing the CSRD text, the recently adopted Omnibus I Simplification Package amendments, and the Croatian Accounting Act as amended on 31 December 2025.*

Conclusion: *The paper shows that the CSRD substantially strengthens the credibility of sustainability information through binding reporting obligations. At the same time, its ambitious scope poses significant implementation challenges, particularly for SMEs. The Omnibus I Simplification Package recalibrates these obligations by narrowing the number of mandatory reporters. The Croatian case illustrates the importance of adapting EU sustainability requirements to national economic structures to ensure proportionality, feasibility, and effective implementation.*

Keywords: *Sustainable corporate governance, Corporate Sustainability Reporting Directive, Non-Financial Reporting Directive, Croatia*

JEL classification: *G30, G32, G34, M14, Q56*

INTRODUCTION

LEGAL AND POLITICAL BACKGROUND OF CORPORATE SUSTAINABILITY REPORTING IN THE EUROPEAN UNION

The increasing integration of sustainability into corporate governance within the European Union (EU) reflects broader political, environmental, and social priorities. Sustainability has evolved from a reputational concern into a strategic priority within the corporate governance framework. Climate change, social inequality, and governance failures have driven policymakers to enhance corporate transparency and accountability. As a result, stakeholders increasingly demand comprehensive, reliable, and comparable information on how companies affect and are affected by environmental, social, and governance (ESG) factors. At the political level, sustainability reporting has become

a central instrument for achieving the EU's strategic objectives, particularly those outlined in the European Green Deal (European Commission, 2019) which is the EU's key strategy for achieving climate neutrality by 2050. At the international level, the sustainability reporting requirements align with the United Nations 2030 Agenda for Sustainable Development (United Nations, 2015) and its Sustainable Development Goals, as well as with the objectives of the Paris Agreement (United Nations, 2016), by strengthening the availability of corporate sustainability data necessary to channel capital towards sustainable economic activities. The COVID-19 pandemic further accelerated this regulatory momentum. The crisis exposed the deep interconnections between environmental degradation, social vulnerabilities, and economic stability, reinforcing the need for a holistic understanding of corporate performance beyond purely financial metrics (La Torre M., Sabelfeld S., Blomkvist M., Dumay J., 2020). Sustainability reporting requirements are grounded in the EU's internal market competence, seeking to harmonize disclosure standards to ensure comparability, reduce information asymmetry, and support sustainable finance.

THE NON-FINANCIAL REPORTING DIRECTIVE (NFRD) AS THE FIRST REGULATORY STEP

The European Union's first binding attempt to regulate non-financial disclosures was the adoption of the Non-Financial Reporting Directive (NFRD) in 2014 (Directive 2014/95/EU). The Republic of Croatia fully transposed the NFRD. While the NFRD marked an important milestone, its practical impact remained limited. The NFRD required certain large public-interest entities with more than 500 employees to disclose the non-financial and diversity information. Under the NFRD, companies were obliged to report on environmental, social and employee matters, respect for human rights, anti-corruption, and bribery issues (Rep, A., Sever Mališ, S., & Dumančić, K., 2022). However, the directive followed a principles-based approach, allowing significant flexibility in reporting formats, standards, and depth of information. While this flexibility reduced the administrative burden, it also led to inconsistent, incomparable, and often boilerplate disclosures. These shortcomings ultimately justified the need for a more robust and harmonized regulatory framework (European Commission, 2021).

The aim of this paper is to contribute to the literature by offering a legal-analytical review of the CSRD and the role of the Omnibus I Simplification Package, which seeks to facilitate implementation by providing additional time

through the so-called "Stop-the-Clock Directive", and by reducing the number of mandatory reporters through the so-called "Content Directive" which will be explained later in the paper. Given that the second part of the Omnibus I Simplification Package has only recently been adopted, this analysis provides a timely evaluation of its potential impact on sustainability reporting.

KEY CHALLENGES INTRODUCED BY THE CORPORATE SUSTAINABILITY REPORTING DIRECTIVE (CSRD)

The European Union adopted the Corporate Sustainability Reporting Directive (CSRD) under the title 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, as regards corporate sustainability reporting in December 2022, with entry into force on 5 January 2023. The CSRD represents a fundamental overhaul of the EU sustainability reporting regime. The Directive can be structured into the following seven key novelties: expansion of the scope of entities subject to the obligation, more detailed content of the report, introduction of the double materiality, mandatory use of the European Sustainability Reporting Standards (ESRS), digital tagging rules, mandatory assurance, and phased application of the Directive. In the following text, each novelty will be explained.

1. Significant Expansion of the Number of Companies Required to Report

One of the most substantial changes introduced by the CSRD is the significant increase in the number of reporting entities. As stated in the Proposal of the CSRD, under the NFRD, sustainability reporting obligations applied to approximately 11,000 companies (Commission, 2021). The CSRD expands this number to around 50,000 companies across the EU. The directive applies to all large undertakings that meet at least two of the following criteria: more than EUR 40 million in net turnover, more than EUR 20 million in total assets, or more than 250 employees. In addition, all companies listed on EU regulated markets are included, except micro-enterprises, as well as all financial institutions regardless of their legal form. The CSRD also extends the reporting obligations beyond EU borders. Companies from third countries are required to report if they generate more than EUR 150 million in turnover within the EU or if they have an EU subsidiary or branch that qualifies as a large undertaking.

This expansion ensures that sustainability risks and impacts connected to EU markets are properly disclosed, even when corporate headquarters are located outside the Union. A significant novelty introduced by the CSRD is the extension of the reporting obligation to small and medium-sized enterprises that had not previously been subject to this requirement. While the CSRD directly applies only to listed SMEs, its indirect effects extend much further through value chain reporting requirements imposed on large undertakings. Given that SMEs constitute the backbone of the European economy (Communication from the Commission to the European parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 2020), the success of the CSRD framework will largely depend on its practical feasibility for these actors (Zubović, 2024).

2. Substantially Broader and More Detailed Report Content

The CSRD introduced a comprehensive and standardized structure for sustainability disclosures. Companies are required to report a wide range of information covering their business model, strategy, governance, policies, impacts, risks, and opportunities related to sustainability matters. Companies must describe the roles and responsibilities of administrative, management, and supervisory bodies with regard to sustainability, demonstrating that sustainability oversight is embedded at the highest level of decision-making. In addition, the CSRD requires detailed explanations of sustainability-related policies, due diligence processes, and the identification of actual and potential environmental, social, and governance (ESG) impacts throughout the value chain. Companies must also identify the key sustainability risks that could affect their financial position, and explain how these risks are managed. Reporting must include both qualitative and quantitative data, cover past performance, as well as future projections, and address short, medium and long-term time horizons. Importantly, the disclosures must extend beyond the company's own operations to include the entire value chain.

3. Introduction of the Double Materiality Principle

A cornerstone of the CSRD is the mandatory application of the double materiality principle. This principle requires companies to assess and disclose sustainability information from two complementary perspectives. The first is impact materiality, which focuses on how a company's activities affect the environment and society, including climate change, ecosystems, employees, consumers, and local communities. The second is financial materiality, which

examines how sustainability issues, such as climate risks or social disruptions, may affect the company's financial performance, position, and future prospects. By requiring both perspectives, the CSRD ensures that sustainability reporting captures not only risks to the company, but also the company's broader impacts on people and the planet. This dual approach responds to the information needs of a wide range of stakeholders, including investors, employees, civil society, and regulators, and represents a significant evolution from traditional financial materiality assessments.

4. Mandatory Use of the European Sustainability Reporting Standards (ESRS)

Another major change introduced by the CSRD is the obligation to use the European Sustainability Reporting Standards (ESRS) when preparing sustainability reports (EFRAG, 2022). These standards establish a common reporting framework across the EU, replacing the fragmented and voluntary use of multiple international guidelines. The use of a single set of standards enhances comparability between companies and sectors, improves data quality, and increases confidence among report users. The standards are designed to ensure that sustainability information is as rigorous and decision-useful as financial information. This alignment reflects the EU's objective of treating sustainability information as an integral part of corporate reporting rather than a separate or secondary disclosure.

5. New Rules on the Digital Format

The CSRD introduced specific requirements regarding where and how sustainability information must be published. Sustainability disclosures must be included in a clearly identifiable section of the management report, ensuring that they are easily accessible and integrated into mainstream corporate reporting. In addition, the management report must be published in XHTML format, and sustainability information must be digitally tagged in accordance with the EU digital taxonomy requirements. Digital tagging enables machine-readable data, facilitating access, comparison, and analysis by investors, regulators, and other stakeholders. This emphasis on digitalization reflects the growing importance of data usability in sustainable finance and supports the development of EU-wide databases and analytical tools.

6. Introduction of Mandatory External Assurance

For the first time, the CSRD introduces a mandatory requirement for the external verification of sustainability reports. Mandatory assurance significantly enhances the credibility, reliability, and consistency of sustainability information and reduces the risk of greenwashing. All entities within the scope of the CSRD are obliged to obtain limited assurance from a third-party assurance provider from their initial reporting year. Initially, conclusions should be based on a limited assurance engagement, with the possibility to transition to reasonable assurance once deemed feasible.

The European Commission is tasked with issuing delegated acts to adopt limited assurance standards by 1 October 2026. Following a feasibility assessment, reasonable assurance standards must be adopted by 1 October 2028, including the date from which reasonable assurance will become mandatory. In the interim, before EU-wide standards are in place, the Member States may continue to apply national assurance standards, procedures, or requirements.

The CSRD introduced additional educational requirements for statutory auditors beyond those in the Statutory Audit Directive. Candidates must complete eight months of relevant practical training, and theoretical examinations must cover: legal requirements and reporting standards for annual and consolidated sustainability reports, sustainability analysis, due diligence processes related to sustainability and assurance procedures, and standards for sustainability reporting. What is more, transitional arrangements are provided for auditors qualified before 1 January 2024.

The Directive highlights independence as critical to maintaining trust in sustainability reporting. Companies must ensure independence across several key governance areas, including having sufficient independent directors on the Board and Audit Committees to provide impartial oversight. The Audit Committee is responsible for overseeing the audit process, appointing independent and objective assurance providers, and mitigating familiarity or bias threats. Organizations should also disclose any relationships or connections that could potentially compromise independence, including links to auditors, board members, and assurance providers.

7. Clear Implementation Timeline and Phased Application

The CSRD is implemented gradually, allowing different categories of companies to adapt over time. Companies that were already subject to the NFRD had to report under the CSRD for the 2024 financial year. Other large companies followed in 2025, listed small and medium-sized enterprises follow in 2026, and

third-country companies in 2027. This phased approach recognizes the differences in organizational capacity while ensuring a steady expansion of high-quality sustainability reporting across the EU economy. The Member States were required to transpose the Directive into their national legislation by 6 July 2024.

However, its implementation has encountered significant difficulties in many Member States. The European Commission has publicly acknowledged that a number of countries have failed to transpose the directive into national law by the official deadline**,** creating risks for effective enforcement, harmonization, and legal certainty in sustainability reporting across the EU. In September 2024, the Commission initiated formal infringement procedures against 17 Member States**,** including Belgium, Czechia, Germany, Estonia, Greece, Spain, Cyprus, Latvia, Luxembourg, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, and Finland, for not completing the CSRD transposition on time. Letters of formal notice were issued as the first legal step in the infringement process, requiring these countries to respond and justify their delays within two months or face further legal action (European Commission, 2024).

"One of the most discussed issues regarding the introduction of mandatory disclosure of nonfinancial information was related to the cost that it will represent from companies, a question that remains unanswered regarding the amount of resources used by companies to comply with these new regulatory requirements and the opportunity costs for these resources" (Mion & Loza Adaui, 2019; Baumüller J., Sopp K., 2022).

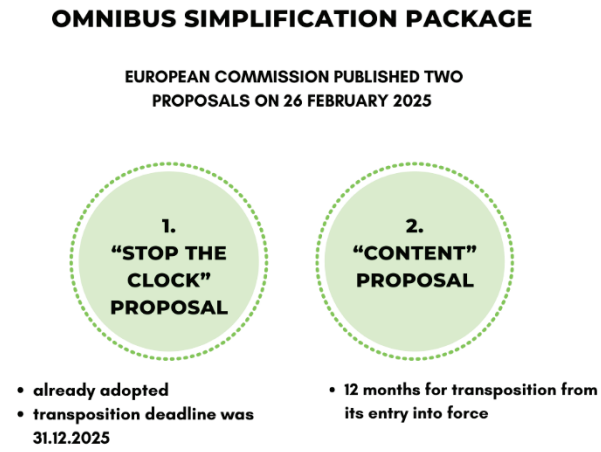
As European Member States struggled with the timely transposition and practical implementation of the CSRD, the European Commission responded with a major initiative: the Omnibus Simplification Package (European Commission, 2025).

THE OMNIBUS I SIMPLIFICATION PACKAGE

The Omnibus I package emerged as part of this response to practical difficulties with the CSRD roll-out and the concerns about the regulatory burdens on EU businesses. The package was first proposed by the European Commission in February 2025 as a set of coordinated proposals aimed at simplifying reporting rules and reducing administrative burden across sustainability reporting, due diligence, taxonomy disclosures, and related areas.

The Omnibus I package encompasses multiple interrelated legislative instruments, however, the following two stand out as the most significant for CSRD reporting**:** the "Stop-the-Clock" Proposal and the "Content" Proposal.

Figure 1. Infographic of the Omnibus Simplification Package



Source: Author, based on the European Commission data

THE "STOP-THE-CLOCK" DIRECTIVE

A central part of the first Omnibus I package is the "Stop-the-Clock" Directive**,** which was formally adopted in April 2025 (Directive (EU) 2025/794 of the European Parliament and of the Council of 14 April 2025 amending Directives (EU) 2022/2464 and (EU) 2024/1760 as regards the dates from which Member States are to apply certain corporate sustainability reporting and due diligence requirements). The "Stop-the-Clock" Directive introduces a postponement of certain CSRD reporting obligations, primarily affecting companies that were originally scheduled to start reporting in later phases. Specifically, companies belonging to the second and third reporting waves (other large undertakings and listed SMEs and smaller entities) will now begin their CSRD reporting two years later than initially planned. In contrast, very large public-interest entities that were already subject to the NFRD and included in the first wave of CSRD reporting are not affected by the delay. EU Member States were required to transpose this Directive into their national legislation by 31 December 2025. The primary purpose of this delay is not to abolish CSRD requirements, but to allow time for EU legislators to revise and simplify them. The "Stop-the-Clock" measure was widely seen as necessary to maintain regulatory credibility and avoid imposing prematurely burdensome obligations on companies still awaiting clarity on substantive reporting standards.

THE "CONTENT" PROPOSAL

A central focus of the "Content" Proposal is the revision of scope and reporting thresholds, aiming to substantially decrease the number of companies subject to mandatory CSRD reporting. Specifically, it has been proposed that EU companies should fall within the CSRD's scope only if they employ more than 1,000 individuals and generate at least €450 million in net turnover, replacing the current lower thresholds. Similar increases are envisaged for third-country companies, which would only be required to report once they reach higher levels of turnover within the EU. The proposal also addresses concerns related to value chain reporting and the indirect burden placed on smaller companies. Under the original CSRD framework, large companies could have been required to collect extensive sustainability data from SMEs throughout their supply chains, creating a significant "trickle-down" effect. The "Content" Proposal seeks to limit these value chain obligations and explicitly protect SMEs from disproportionate reporting demands that exceed their capacity, thereby reinforcing the principle of proportionality. A central element of simplification is the restructuring of the European Sustainability Reporting Standards (ESRS). In March 2025, the European Commission formally requested EFRAG to develop simplified ESRS as part of the Omnibus process. At its annual conference in December 2025, EFRAG presented its final technical advice on the draft simplified European Sustainability Reporting Standards (ESRS), marking an important milestone in the implementation of the Omnibus roadmap (EFRAG, 2025.). These simplified standards build on the practical experience gained during the first wave of CSRD reporting, as well as extensive stakeholder consultations, and are designed to address the challenges identified during the initial implementation. As such, they will play a decisive role in shaping how companies meet their CSRD reporting obligations in practice. For companies falling outside the revised CSRD scope, voluntary reporting standards would remain available. Finally, the "Content Directive" was adopted and published in the Official Journal of the European Union on 24 February 2026, granting Member States a period of 12 months for its transposition into national law.

IMPLEMENTATION OF THE CSRD DIRECTIVE IN THE CROATIAN CONTEXT

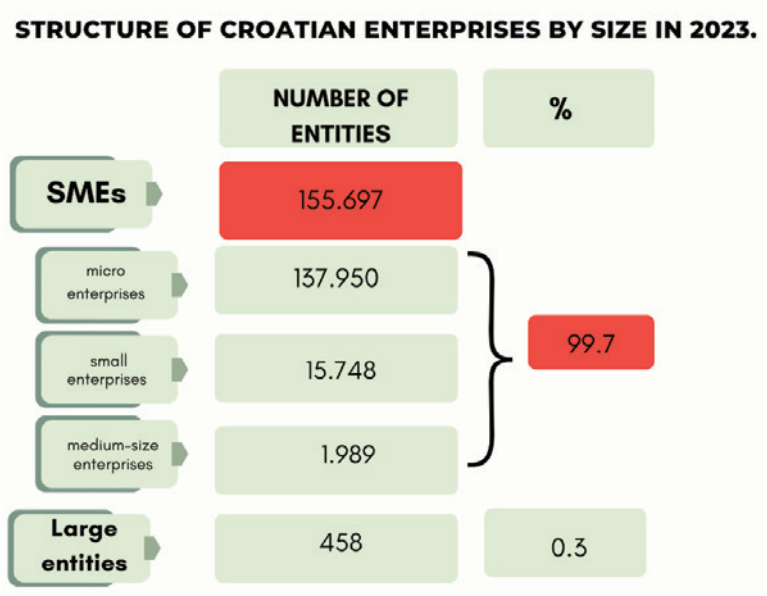
The implementation of the CSRD in the Republic of Croatia was completed relatively early compared to many other EU Member States. Croatia

fully transposed the CSRD into national legislation on 27 July 2024 (Croatian Financial Services Supervisory Agency, 2024).

Namely, the CSRD has been implemented through the amendments to the Accounting Act (OG No. 85/2024), the Audit Act (OG No. 127/2017, 27/2024, 85/2024) and the Capital Markets Act (OG No. 65/18, 17/20, 83/21, 151/22, 85/24).

Under the original Croatian transposition of the CSRD, the scope of mandatory sustainability reporting was expected to expand significantly over time. While this approach was legally consistent with the directive, it soon became apparent that it raised serious concerns about proportionality, particularly in countries such as Croatia, where the economic structure is overwhelmingly dominated by SMEs. SMEs play a central role in the Croatian economy. According to the last official report, SMEs accounted for 155,697 enterprises, representing 99.7% of all business entities in Croatia. This structure is dominated by micro-enterprises, followed by small and medium-size enterprises. In addition, according to the 2025 SME Country Fact Sheet for Croatia (European Commission, 2025), SMEs employ around 70% of the total workforce, and generate more than 62% of the total value added. These numbers clearly demonstrate the importance of SMEs in the Republic of Croatia.

Figure 2. Infographic of the structure of Croatian enterprises by size in 2023



Source: Author, based on the SME Report for Croatia by CEPOR, 2024

From this perspective, the Omnibus "Content" Proposal represents a critical adjustment for Croatia because it directly affects the number of companies that will ultimately fall within the mandatory scope of CSRD reporting. By removing most SMEs from the mandatory reporting scope, the revised framework acknowledges that sustainability reporting requirements must be proportionate to company size, capacity, and economic role.

According to the preliminary analyses conducted by the Ministry of Finance, the application of the "Content" Proposal would reduce the number of Croatian companies subject to mandatory sustainability reporting from approximately 500 to only 101 entities (Ministry of Finance of the Republic of Croatia, 2025). This represents a reduction of around 80% in the number of reporting companies. In practical terms, this means that 369 companies which would have been required to report would no longer fall within the mandatory CSRD regime. This substantial reduction in the number of mandatory reporters must be assessed in light of the broader structure of the Croatian economy.

Figure 3. Infographic of the impact of the "Content" Proposal on the number of reporting entities in Croatia



Source: Author, based on the Report of the Ministry of Finance of the Republic of Croatia, 2025

At the same time, the Omnibus I package does not exclude SMEs from sustainability reporting altogether. Instead, it introduces a system of voluntary reporting standards, based on the Voluntary Sustainability Reporting Standard for SMEs framework (VSME) developed by EFRAG, which allows smaller companies to disclose sustainability information in a simplified and propor-

tionate manner. In addition, the revised simplified rules for value chain reporting are especially relevant for Croatia, where many SMEs operate as suppliers to large domestic or international companies and would otherwise face de facto reporting obligations despite being formally outside the CSRD scope. In parallel with these legislative changes, Croatia has initiated several supporting measures to facilitate implementation and build capacity, particularly for SMEs (European Commission, 2025).

Overall, the Croatian case illustrates why the Omnibus I package was necessary at both the EU and national levels. Although Croatia successfully implemented the CSRD, the original scope of the directive would have placed a heavy burden on an economy dominated by SMEs. The Omnibus reforms recalibrate the balance between regulatory ambition and economic reality by concentrating mandatory reporting on the largest companies while preserving flexibility and proportionality for SMEs.

The first "Stop-the-Clock" Directive has been fully transposed into the Croatian legal system through the Act on the Amendments to the Accounting Act, published in the Official Gazette, No. 151/25 of 15 December 2025, which entered into force on 31 December 2025. By adopting this Act within the prescribed deadline, which was 31 December 2025, Croatia ensured timely alignment of its national legislation with the relevant EU requirements. The second part of the Omnibus package, the so-called "Content Directive" has not been transposed yet since the implementation deadline is March 2027. However, in the case of Croatia, the transposition is expected to proceed under an accelerated procedure through new amendments to the Accounting Act and the Capital Market Act, reflecting the clear policy objective of reducing the scope of entities subject to the Directive, in particular by relieving small and medium-sized enterprises (SMEs) from reporting obligations (Ministry of Finance, 2026).

CONCLUSION

In conclusion, the adoption of the Corporate Sustainability Reporting Directive marks a decisive step in the EU's effort to integrate sustainability into corporate governance. By introducing binding reporting obligations, the double materiality principle, mandatory European Sustainability Reporting Standards, digital reporting, and external assurance, the CSRD enhances the credibility, consistency, and usefulness of sustainability information. However, its ambitious design has created implementation challenges at both the EU and

company levels, including delays in transposition, complexity, administrative burden, and proportionality concerns for small and medium-sized enterprises.

Against this background, the Omnibus I Simplification Package represents a crucial recalibration of the EU sustainability reporting framework. Rather than weakening the objectives of the CSRD, the Omnibus reforms seek to preserve its core principles while ensuring that reporting obligations remain proportionate and implementable. The "Stop-the-Clock" mechanism provides additional time for adaptation, while the "Content Directive" reshapes the scope and depth of reporting requirements by narrowing the number of mandatory reporters and simplifying the obligations related to value chains, assurance, and data collection. The Croatian case clearly illustrates these dynamics. Croatia has transposed the CSRD promptly and comprehensively. However, given that its economy is predominantly composed of SMEs, the original scope of the directive would have imposed a disproportionate burden.

This research is, however, subject to certain limitations. The analysis is based on the current legal framework and policy developments, while the key elements of the Omnibus I Simplification Package, including the "Content Directive", have not yet been fully implemented into Croatian legislation. Consequently, the assessment of their effects remains partly prospective. In addition, the paper relies on a legal-analytical approach and does not include empirical evidence on the practical application of sustainability reporting requirements.

Despite these limitations, the findings have important implications. They highlight the necessity of balancing regulatory ambition with proportionality and economic diversity across the Member States. In particular, the Croatian example demonstrates the importance of adapting EU sustainability requirements to national economic structures in order to ensure effective implementation and avoid excessive administrative burdens, especially for SMEs.

Future research should also examine the long-term effects of the Omnibus reforms, including the simplified ESRS standards and the reduced scope of reporting obligations, as well as provide comparative analyses across the Member States.

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DECOUPLING EFFECTS IN THE NAUTICAL TOURISM SECTOR: ECONOMIC GROWTH, RESOURCE USE, AND ENVIRONMENTAL FOOTPRINT IN MARINE DESTINATIONS

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Nautical tourism is a highly resource-dependent industry, requiring extensive marine resources, coastal areas, water, and other inputs. The industry is growing rapidly in marine destinations worldwide, contributing to an increased use of natural resources, their degradation, and environmental pollution. Nevertheless, industries can balance economic performance with sustainable resource use and environmental pressures through decoupling. Moreover, decoupling is becoming imperative and synonymous with the sustainable and resilient development of industries. Achieving decoupling requires separating economic growth from resource depletion and adverse environmental impacts, thereby enabling a sustainable society. Balancing economic growth and resource use indicates the presence of resource decoupling in the nautical sector, while balancing economic growth and environmental footprint indicates impact decoupling effects in the industry. Therefore, the actual decoupling effects in nautical tourism indicate its sustainability and resilience. Moreover, decoupling effects in the nautical tourism sector suggest that its economic performance grows while reducing resource use and environmental pollution. Given that local community acceptance and engagement contribute significantly to the sustainability and viability of tourism destinations, understanding how they perceive these dynamics is increasingly important.

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Purpose: This study investigates 'resource decoupling' and 'impact decoupling' in tourism-oriented destinations where nautical tourism is a popular and increasing sector, focusing on how local community perceptions reflect these dynamics. It aims to analyze the relationship between economic growth and resource use in nautical destinations in order to identify evidence of the 'resource decoupling effect'. It further analyses the relationship between economic growth and environmental footprint to assess the presence of the 'impact decoupling effect'. The study additionally investigates whether environmental measures and actions influence environmental pressures in nautical tourism destinations.

Method: Empirical research was conducted in May and June 2025 by surveying community members of marine destinations in Croatia (N=373), using a structured online questionnaire. The research operationalized four variables: economic growth, resource use, environmental footprint, and environmental measures and actions. All variables were measured with a 5-point Likert scale, and the data were analyzed using SPSS.

Conclusion: The results show that the respondents perceive significant increases in economic growth, resource use, and environmental footprint variables, and a low level of environmental measures and actions. Correlations between economic growth, resource use, and environmental footprint are positive and statistically significant, whereas correlations between environmental measures and environmental pressures are negative. The findings, based on perception-based data, indicate that economic growth is not currently associated with reductions in resource use or environmental pressures, implying that neither resource decoupling nor impact decoupling is evident in nautical tourism at the observed marine destinations. Furthermore, increases in resource use and environmental footprint are as significant as economic growth, indicating the absence of decoupling, both in absolute and relative terms. The results showed that economic growth and environmental measures are predictors of resource use, while economic growth, environmental measures, and resource use are predictors of environmental footprint. Although the paper is limited to the perceptions of the local community and a single research method, it contributes to a deeper understanding of the research problem, which is crucial for the sustainable development of nautical destinations heavily focused on tourism. The findings are relevant to all levels of decision-making and strategic planning, and reveal the need for further research.

Keywords: *Nautical sector, economic performance, resource decoupling, impact decoupling, marine destination*

JEL classification: *L83, O44, Q01, Q56, Z32*

INTRODUCTION

Tourism is one of the global engines of development, contributing significantly to employment creation and income generation (World Tourism Organization, 2004, 2023; UNEP/WTO, 2005; Rasool et al., 2021; European Commission, 2017). Coastal and maritime tourism are considered among the oldest and most significant segments of the tourism industry (Tonazzini et al., 2019), representing at least 50% of the total global tourism and creating 1 out of 11 jobs (World Economic Forum, 2023), as well as the largest sector of the EU Blue Economy in terms of GVA (with a share of 29%) and employment (with a share of 54%) (EC, 2017, 2024), with significant growth (Tonazzini et al., 2019).

Nautical tourism is a significant segment of the coastal and marine tourism industry, with a continuous growth in the number of nautical tourists, recreational boats, infrastructures, and traffic in popular marine destinations worldwide (European Boating Industry EBI, n.d.; EC, 2017; Martínez Vázquez et al., 2021; Marušić et al., 2024a, 2024b; Hsu et al., 2025). The sector encompasses a broad range of interconnected marine and coastal tourism activities, primarily associated with yachting and boating (including marina and charter activities) and cruising, as well as land-based services and infrastructure that support the accommodation and stays of vessels and tourists. It often includes boat-related services (e.g. repair, maintenance, management, assistance), as well as the boatbuilding sector (ECORYS, 2015). The terms 'recreational boating' and 'yachting' are often used interchangeably with 'nautical tourism', and Ivandić and Marušić (2025) highlight the lack of a consistent definition. Different nautical tourism activities require specific types of infrastructure and inputs, and generate distinct but interrelated patterns of resource use, economic growth, and environmental pressures (ECORYS, 2013, 2015; EC, 2017; Tonazzini et al., 2019; Carreño & Lloret, 2021; Martínez Vázquez et al., 2021; Hsu et al., 2025). In this study, nautical tourism is perceived as an integrated sector, focusing on overall relationships among economic growth, resource use, and environmental pressures as perceived by local communities.

The recreational boating industry alone generates substantial economic value, producing several billion euros in annual turnover and supporting tens

of thousands of jobs across marina and charter segments (EBI, n.d.). At the same time, nautical tourism is highly resource-dependent, relying intensively on marine and coastal space, water, energy, and ecosystem services. Its economic performance is therefore closely linked to the availability, quality, and ecological integrity of marine and coastal resources (WEF, 2023; Carreño & Lloret, 2021). The growth of nautical tourism intensifies pressures on marine and coastal ecosystems through increased spatial use, pollution, congestion, and biodiversity degradation (Dudley, 2008; EC, 2017; Carreño & Lloret, 2021; WEF, 2023; Ausserladscheider, 2024; Hsu et al., 2025).

These pressures raise concerns about the long-term sustainability and resilience of nautical destinations, particularly in spatially constrained coastal and marine systems characterized by cumulative ecological impacts (Tonazzini et al., 2019; Martínez Vázquez et al., 2021). In response to similar challenges across sectors, scholars, practitioners, and policymakers have developed a range of sustainability-oriented frameworks aimed at reconciling economic growth with environmental protection, including sustainable development, green growth, degrowth, decoupling, and the circular economy (Brundtland, 1987; OECD, 2011; UNEP, 2011; Parrique et al., 2019; Naudé, 2023). The common idea behind the proposed concepts is minimizing the environmental footprint while achieving business performance. These approaches vary in their assumptions about the compatibility of economic growth with environmental protection, ranging from efficiency-oriented strategies, such as green growth and resource efficiency, to more transformative paradigms, such as degrowth and post-growth.

Decoupling is embedded in broader sustainability-oriented frameworks that address the relationship between economic activity and environmental pressures (OECD, 2011; UNEP, 2011; Sanyé-Mengual et al., 2019; Yaremova & Mytrofanova, 2022). Table 1 provides an overview of the decoupling and related concepts, clarifying their conceptual differences within broader sustainability and growth debates relevant to nautical tourism.

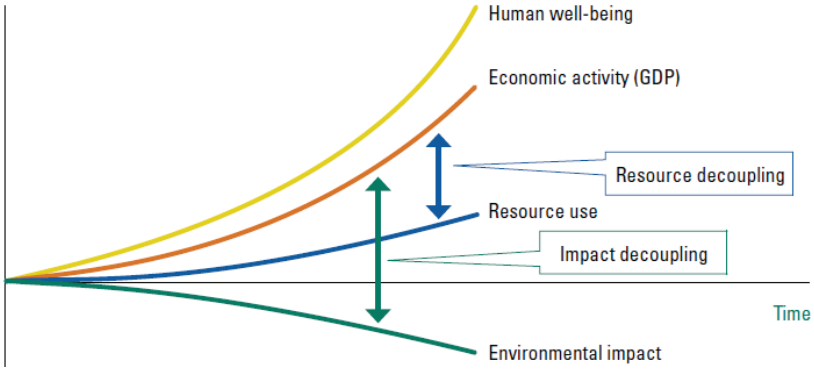
Table 1. Decoupling and related concepts in sustainability and growth debates

Concept	Core idea	'Economic growth-environment' relationship	Primary focus	Key references
Decoupling	Separation of economic growth from environmental pressures and impacts	Growth ↑ with reduced resource use and/or environmental impacts	Empirical assessment of growth–environment relationships	OECD 2011; UNEP 2011; Parrique et al., 2019; Sanyé-Mengual et al., 2019; Yaremova & Mytrofanova, 2022
Resource decoupling	Reduced resource use per unit of economic activity	Growth ↑; resource use ↓ or growth at a slower rate	Resource productivity and efficiency	
Impact decoupling	Reduced environmental impacts per unit of economic activity	Growth ↑; environmental impacts ↓ or growth at a slower rate	Reduction of environmental pollution and degradation	
Sustainable development	Meeting present needs without compromising future generations	Conditional compatibility of growth and environment	Integrated economic, social, and environmental balance	Brundtland, 1987; UNEP/WTO, 2005
Degrowth	Deliberate reduction of resource-intensive economic activities	Growth ↓; environmental pressures ↓	Ecological limits and reduced resource demand	Kallis, 2011; Hickel & Kallis, 2020
Green growth	Pursuing economic growth through environmental efficiency, innovation, and policy intervention	Growth ↑; environmental pressures may ↓	Technological innovation, efficiency improvements, policy instruments	OECD, 2011
Blue economy	Sustainable use and governance of marine and coastal resources	Conditional compatibility	Marine governance and ecosystem health	EC, 2024; Eikeset et al., 2018
Circular economy	Optimizing resource use through reduction, reuse, recycling, and recovery	Growth ↔; resource use ↓	Resource circulation and waste reduction	Geissdoerfer et al., 2017; Keskin et al., 2025
Resource efficiency	Increasing economic value generated per unit of resource input	Growth ↑; resource intensity ↓	Reducing the resource intensity of economic activity	OECD, 2016

↑ increase; ↓ decrease
Source: Authors

Decoupling refers to the separation of economic activity from resource use and environmental footprint. Figure 1 (UNEP, 2011) shows the decoupling effects, that is, the relationship between economic activity and environmental pressures, i.e. resource use (resource decoupling) and environmental impact (impact decoupling). Resource decoupling refers to reducing the amount of resources used per unit of economic output, while impact decoupling refers to reducing the environmental footprint per unit of economic activity (UNEP, 2011; Parrique et al., 2019). When economic growth continues while environmental pressures (resource use and environmental footprint) decline, decoupling is absolute. In contrast, when environmental pressures increase more slowly than economic activity, decoupling is relative (OECD, 2011).

Figure 1. Decoupling



Source: (UNEP, 2011)

Achieving decoupling effects in nautical tourism indicates the sector's sustainable development and resilience over time through the responsible use of natural resources (marine and coastal spaces, land areas, energy, water, etc.), and through reduced environmental footprint. Marine environmental impacts can take various forms, such as waste that disturbs marine life, pollutants that affect human and animal health, or biodiversity loss.

Although decoupling has been extensively analyzed at the macroeconomic and national levels, empirical evidence at the sectoral and destination levels remains limited, particularly for nautical tourism and maritime-related activities. The existing general tourism-focused studies predominantly examine emissions, energy consumption, or aggregate environmental stress (Lanfranchi et al., 2015; Chen et al., 2017; Qin & Li, 2021; Zha et al., 2021; Xiong et al., 2022). Despite the growing relevance of nautical tourism, empirical evidence

on resource and impact decoupling in this sector remains scarce, particularly from a destination-level and stakeholder-perception perspective (Martínez Vázquez et al., 2021; Cao et al., 2023; Marušić et al., 2024a, 2024b; Marušić et al., 2025).

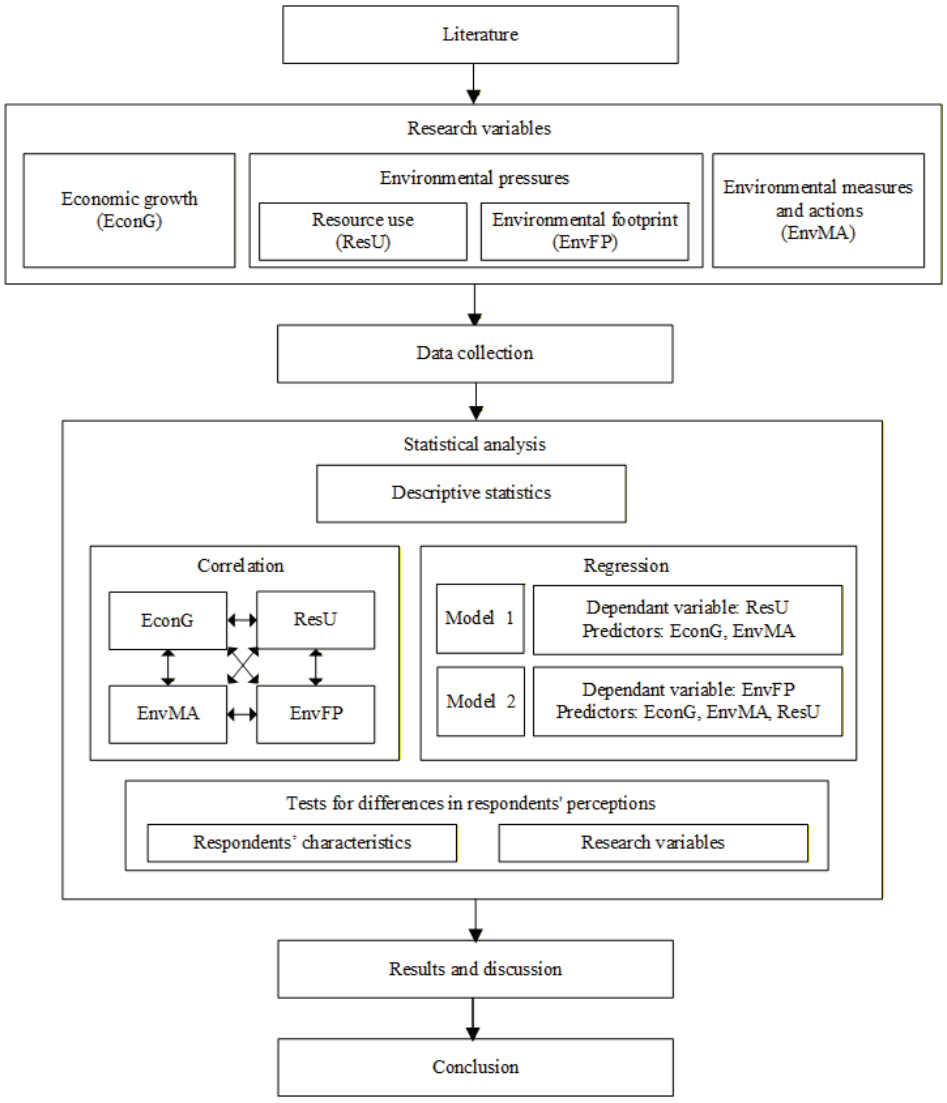
Following the identified research gap, this study investigates the relationship between the economic growth of the nautical tourism sector and its environmental pressures (resource use and environmental footprint), as perceived by the local community. It analyses 'resource decoupling' and 'impact decoupling' in tourism-oriented destinations where nautical tourism is a popular and increasing sector, focusing on how local community perceptions reflect these dynamics. Around 10% of the world's population lives in coastal areas, and about 40% lives within 100 km of the coast; hence, they are dependent on and vulnerable to the quality, stability, and accessibility of the sea and marine resources (Tonazzini et al., 2019). Given that local communities' acceptance and engagement contribute significantly to the sustainability and viability of tourism destinations, understanding how they perceive economic and environmental dynamics is increasingly important. Therefore, this study analytically assesses decoupling in the observed destinations using perception-based data on economic growth, resource use, and environmental pressures.

MATERIALS AND METHODS

This study aims to determine the presence of decoupling in marine destinations by examining the relationships between economic growth, resource use, and environmental footprint in the nautical tourism sector. It aims to determine the relationships between economic growth and resource use to identify evidence of the 'resource decoupling effect'. The study also seeks to determine the relationships between economic growth and environmental footprint to assess the presence of the 'impact decoupling effect'.

Furthermore, this study aims to investigate the impact of environmental measures and actions on environmental pressures, both the resource use and environmental footprint. It will also examine the relationship between economic growth and environmental measures and actions. Figure 2 shows the research model that integrates the following: i) literature foundations, ii) identifying research variables and indicators related to decoupling effects in the nautical tourism, iii) data collection, iv) statistical analysis, v) results and discussion, and vi) conclusion.

Figure 2. The research model



Source: Authors

Table 2 presents the key research variables and their indicators, while Table 3 shows the matching of indicators across variables in three environmental areas.

Table 2. Research variables and indicators

	"Over the past 3 to 5 years, there has been a change in the…"
Code	Economic growth (EconG)
EconG1-Rev	*Revenues related to nautical tourism*
EconG2-Buss	*Number of businesses generated by nautical tourism*
EconG3-Jobs	*Number of jobs related to nautical tourism*
Code	Resource use (ResU)
ResU1-MaSS	*Use of marine and sea space for nautical tourism*
ResU2-CoastA	*Use of the coastal area for nautical tourism development*
ResU3-LandA	*Use of the land area for nautical tourism development*
Code	Environmental footprint (EnvFP)
EnvFP1-MarP	*Marine environmental pollution, biodiversity loss, and ecosystem degradation related to nautical tourism*
EnvFP2-CADaP	*Coastal area degradation and pollution related to nautical tourism*
EnvFP3-LADaP	*Land area degradation and pollution related to nautical tourism*
	"The level of implemented measures and actions for …"
Code	Environmental measures and actions (EnvMA)
EnvMA1-CMEP	*Controlling marine environmental pollution related to nautical tourism*
EnvMA2-RCCaD	*Regulating coastal construction and development related to nautical tourism*
EnvMA3-RLUaD	*Regulating land use and development related to nautical tourism*

Source: Authors, based on UNEP & UNWTO 2005; UNEP, 2011; OECD, 2011, 2016; ECORYS, 2013, 2015; Lanfranchi et al., 2015; EC, 2017, 2024; Sanyé-Mengual et al., 2019; Tonazzini et al., 2019; Carreño & Lloret, 2021; Martínez Vázquez et al., 2021; Quin et al., 2021; Yaremova & Mytrofanova, 2022; Marušić et al., 2024a, 2024b, 2025; Hsu et al., 2025; Ivandić and Marušić, 2025

Table 3. Environmental pressures and measures in three environmental areas

Environmental Performance				**Economic Performance**
Variables / Areas	**Sea /marine**	**Coast**	**Land**	**Economic growth (EconG)**
Resource use (ResU)	*ResU1-MaSS Use of marine and sea space*	*ResU2-CoastA Use of the coastal area*	*ResU3-LandA Use of the land area*	*EconG1-Rev Revenues* *EconG2-Buss Number of businesses* *EconG3-Jobs Number of jobs*
Environmental footprint (EnvFP)	*EnvFP1-MarP Marine environmental pollution*	*EnvFP2-CADaP Coastal area degradation and pollution*	*EnvFP3-LADaP Land area degradation and pollution*	
Environmental measures and actions (EnvMA)	*EnvMA1-CMEP Controlling marine environmental pollution*	EnvMA2-RCCaD *Regulating coastal construction and development*	*EnvMA3-RLUaD Regulating land use and development*	

A survey was conducted in 2025 (May – June) using a structured online questionnaire among a sample of community members in Adriatic Croatia (N=373). Perception-based data were used to capture how local communities experience and evaluate economic and environmental changes associated with nautical tourism. The questionnaire comprised a set of respondents' characteristics in the first section (gender, age, education, residency, frequency of stay/visit, main reason for staying/visiting, and experience in nautical tourism). In the second section, the questionnaire operationalized four research variables (EconG, ResU, EnvFP, and EnvMA) using three indicators for each (Tables 2 and 3). The indicators for EconG, ResU, and EnvFP were measured on a 5-point Likert scale, with 1 indicating a significant decrease and 5 indicating a significant increase. The indicators for the EnvMA were also measured on a 5-point Likert scale, with 1 indicating a very low level of implementation and 5 a very high level. Decoupling is not directly measured through survey questions, but is analytically inferred from the relationships among the constructed variables. This study validated the questionnaire using in-depth interviews with five experts (n=5) from the industry and academia with knowledge/experience in nautical tourism. Data analysis was performed using SPSS Statistics and included descriptive statistics, correlation and regression analysis, and tests for group differences in respondents' perceptions.

RESULTS AND DISCUSSION

DESCRIPTIVE STATISTICS AND SCALE RELIABILITY

Table 4 shows the descriptive statistics for the research variables - economic growth, resource use, environmental footprint, and environmental measures and actions, including indicators and composite indexes.

Table 4. Descriptive statistics (N=373)

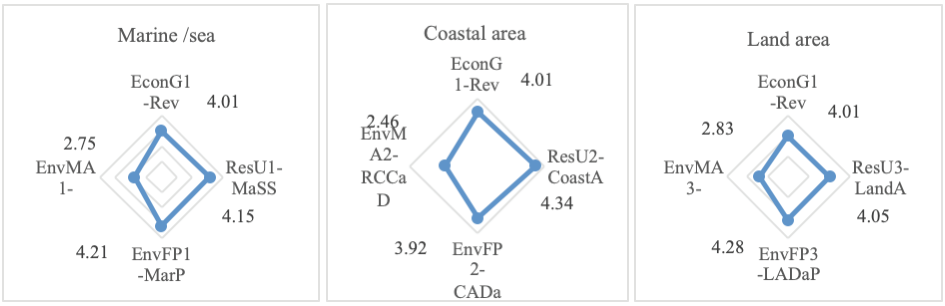
Indicators	Mean	Mean Std. Error	Std. Deviation	Skewness	Kurtosis
EconG1-Rev	4.01	.052	1.008	-.850	.248
EconG2-Buss	3.61	.056	1.076	-.382	-.598
EconG3-Jobs	4.10	.055	1.063	-1.071	.405
ResU1-MaSS	4.15	.050	.974	-1.071	.627
ResU2-CoastA	4.34	.045	.861	-1.327	1.375
ResU3-LandA	4.05	.051	.980	-.815	-.055
EnvFP1-MarP	4.21	.048	.932	-1.121	.755
EnvFP2-CADaP	3.92	.053	1.022	-.684	-.145
EnvFP3-LADaP	4.28	.045	.875	-1.198	1.141
EnvMA1-CMEP	2.75	.064	1.239	.035	-1.051
EnvMA2-RCCaD	2.46	.062	1.199	.332	-.860
EnvMA3-RLUaD	2.83	.067	1.286	-.012	-1.147
Economic growth*	3.90	.040	.77827	-.621	.360
Resource use*	4.18	.042	.80296	-.979	.838
Environmental footprint*	4.14	.042	.81687	-.947	.670
Environmental measures*	2.68	.057	1.09949	-.006	-.977

Std. Error of Skewness = .126, Std. Error of Kurtosis = .252; * c-score

Source: Authors

The results (Table 4) indicate that the respondents perceive strong increases in economic growth, resource use, and environmental footprint, while environmental measures and actions are assessed as relatively weak. This contrast, based on perception-based data, suggests the absence of both resource and impact decoupling. Figure 3 presents the mean values for the variables, with revenues (EconG1-Rev) shown in all three graphs, and the other variables serving as indicators that correspond across the three environmental areas. The mean values for revenues and all indicators for ResU and EnvFP are high. By contrast, indicators for EnvMA are notably lower, as shown in Table 4.

Figure 3. Relationship between revenues and the indicators from the three areas



Source: Authors

The internal consistency of the variables (EconG, ResU, EnvFP, and EnvMA) was assessed using Cronbach's alpha coefficients prior to further analysis. All scales demonstrated satisfactory reliability for exploratory research, with alpha values exceeding commonly accepted thresholds. Table 5 shows Cronbach's Alpha coefficients for the research variables.

Table 5. Scale Reliability (Cronbach's Alpha)

Variables	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Economic growth (EconG)	.591	.593	3
Resource use (ResU)	.815	.820	3
Environmental footprint (EnvFP)	.831	.832	3
Environmental measures and actions (EnvMA)	.862	.863	3

Source: Authors

The reliability of the resource use ($\alpha = 0.815$), environmental footprint ($\alpha = 0.831$), and environmental measures and actions ($\alpha = 0.862$) scales was high. The economic growth scale demonstrated lower internal consistency ($\alpha = 0.591$), which is acceptable for exploratory research and reflects the heterogeneous nature of economic growth indicators.

CORRELATION ANALYSIS

Tables 6 -8 present the Pearson correlation coefficients for economic growth (EconG), resource use (ResU), environmental footprint (EnvFP), and environmental measures and actions (EnvMA). Table 6 shows the correlation matrix for variables EconG, ResU, and EnvFP; Table 7 shows the correlation matrix for variables EnvMA, ResU, and EnvFP; and Table 8 shows the correlation matrix for variables EnvMA and EconG.

Table 6. Correlation matrix (Pearson) - EconG, ResU, and EnvFP

Indicator	EconG1-Rev	EconG2-Buss	EconG3-Jobs	ResU1-MaSS	ResU2-CoastA	ResU3-LandA	EnvFP1-MarP	EnvFP2-CADaP	EnvFP3-LADaP
EconG1-Rev	1								
EconG2-Buss	.374**	1							
EconG3-Jobs	.353**	.254**	1						
ResU1-MaSS	.284**	.262**	.173**	1					
ResU2-CoastA	.277**	.322**	.155**	.729**	1				
ResU3-LandA	.335**	.272**	.287**	.505**	.574**	1			
EnvFP1-MarP	.265**	.284**	.123*	.484**	.499**	.415**	1		
EnvFP2-CADaP	.321**	.328**	.195**	.450**	.408**	.496**	.711**	1	
EnvFP3-LADaP	.239**	.228**	.188**	.369**	.367**	.416**	.603**	.555**	1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)
Source: Authors

Table 7. Correlation matrix (Pearson) - EnvMA, ResU, and EnvFP

Indicator	EnvMA1-CMEP	EnvMA2-RCCaD	EnvMA3-RLUaD	ResU1-MaSS	ResU2-CoastA	ResU3-LandA	EnvFP1-MarP	EnvFP2-CADaP	EnvFP3-LADaP
EnvMA1-CMEP	1								
EnvMA2-RCCaD	.744**	1							
EnvMA3-RLUaD	.719**	.568**	1						
ResU1-MaSS	-.184**	-.199**	-.068	1					
ResU2-CoastA	-.231**	-.225**	-.122*	.729**	1				
ResU3-LandA	-.102*	-.154**	-.059	.505**	.574**	1			
EnvFP1-MarP	-.247**	-.209**	-.205**	.484**	.499**	.415**	1		
EnvFP2-CADaP	-.220**	-.219**	-.142**	.450**	.408**	.496**	.711**	1	
EnvFP3-LADaP	-.247**	-.296**	-.214**	.369**	.367**	.416**	.603**	.555**	1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)
Source: Authors

The correlation analysis (Tables 6-8) reveals a consistent pattern of relationships among economic growth, resource use, environmental footprint, and environmental measures and actions. Indicators of economic growth are positively and significantly correlated with indicators of resource use and environmental footprint, suggesting that, based on the respondents' evaluations, increases in revenues (EconG1-Rev), number of businesses (EconG2-Buss), and number of jobs (EconG3-Job) are associated with intensified use of marine, coastal, and land areas and increased environmental footprint. Strong positive correlations are observed among resource-use indicators and among environmental-footprint indicators, suggesting that spatial pressures and environmental impacts tend to co-occur within the observed nautical tourism destinations.

Table 8. Correlation matrix (Pearson) - EnvMA and EconG

Indicator	Env-MA1-CMEP	Env-MA2-RCCaD	Env-MA3-RLUaD	EconG1-Rev	EconG2-Buss	EconG3-Jobs
EnvMA1-CMEP	1					
EnvMA2-RCCaD	.744**	1				
EnvMA3-RLUaD	.719**	.568**	1			
EconG1-Rev	-.156**	-.122*	-.003	1		
EconG2-Buss	-.082	-.085	-.011	.374**	1	
EconG3-Jobs	-.037	-.094	.002	.353**	.254**	1

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Source: Authors

In contrast, environmental measures and actions are negatively and significantly correlated with both resource use and environmental footprint indicators, implying that stronger regulatory and control measures are associated with lower perceived environmental pressures. Correlations between environmental measures and actions and economic growth are weak and predominantly negative, suggesting that environmental measures impede economic activity to a limited extent. Overall, the correlation results support the existence of 'economic growth - resource use - environmental footprint' relationships and highlight the mitigating, but limited, role of environmental measures and actions. These correlation patterns provide preliminary support for the regression models used to examine resource decoupling and impact decoupling effects.

REGRESSION ANALYSIS AND DECOUPLING EFFECTS

This study calculated the composite index scores (c-score) for all investigated variables to perform the regression analysis. Composite index scores were calculated for each respondent as the arithmetic mean of the indicators, and descriptive statistics (mean and standard deviation) were computed across respondents (Table 4). The internal consistency of the composite indices was assessed using Cronbach's alpha coefficients (Table 5). The results support aggregating indicators into composite indices for all variables.

Tables 9 and 10 (Model 1) present the results of the regression analyses for resource use (ResU) as the dependent variable, with environmental measures and actions (EnvMA) and economic growth (EconG) as predictors. Tables 11 and 12 (Model 2) present the results of the regression analyses for environmental footprint (EnvFP) as the dependent variable, with resource use (ResU), environmental measures and actions (EnvMA), and economic growth (EconG) as predictors.

Table 9. Model 1 - Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.442[a]	.195	.191	.72237	.195	44.814	2	370	.000

a. Predictors: (Constant), Environmental measures, Economic growth

b. Dependent Variable: Resource use

Source: Authors

Table 10. Model 1 – Coefficients

Model 1	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.874	.221		13.005	.000
Economic growth	.412	.048	.399	8.518	.000
Environmental measures	-.113	.034	-.154	-3.288	.001

a. Predictors: (Constant), Economic growth, Environmental measures

b. Dependent Variable: Resource use

Source: Authors

Table 11. Model 2 - Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.630a	.397	.392	.63698	.397	80.930	3	369	.000

a. Predictors: (Constant), Economic growth, Environmental measures, Resource use

b. Dependent Variable: Environmental footprint

Source: Authors

Table 12. Model 2 – Coefficients

Model 2	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.766	.235		7.510	.000
Economic growth	.166	.047	.158	3.563	.000
Environmental measures	-.132	.031	-.177	-4.300	.000
Resource use	.496	.046	.488	10.821	.000

a. Predictors: (Constant), Economic growth, Environmental measures, Resource use

b. Dependent Variable: Environmental footprint

Source: Authors

The results of Model 1 indicate that economic growth and environmental measures and actions jointly explain a meaningful share of the variance in resource use ($R^2 = 0.195$; $p < 0.001$). Economic growth is observed to have a strong, positive association with resource use ($\beta = 0.399$; $p < 0.001$), based on the respondents' evaluations, indicating that increases in revenue, business activity, and employment in nautical tourism are associated with an intensified use of marine, coastal, and land areas. Environmental measures and actions show a statistically significant negative effect on resource use ($\beta = –0.154$; $p = 0.001$), suggesting a mitigating influence. However, the positive effect of economic growth substantially outweighs the mitigating effect of environmental measures, suggesting that resource use increases alongside economic growth. These findings provide no evidence of resource decoupling based on perception-based data in the observed nautical tourism destinations.

Model 2 demonstrates strong explanatory power, explaining approximately 40% of the variance in environmental footprint ($R^2 = 0.397$; $p < 0.001$). Resource use is the strongest predictor of environmental footprint ($\beta = 0.488$;

$p < 0.001$), confirming that intensified use of marine, coastal, and land areas is the primary driver of environmental footprint. Economic growth remains positively and significantly associated with environmental footprint ($\beta = 0.158$; $p < 0.001$), based on the respondents' evaluations; however, its effect is reduced when resource use is included in the model, indicating that part of the impact of economic growth operates through increased resource use. Environmental measures and actions exhibit a significant negative effect on environmental footprint ($\beta = -0.177$; $p < 0.001$), reflecting their mitigating role. Nevertheless, the combined effects of economic growth and resource use prevail, indicating no evidence of relative or absolute impact decoupling based on perception-based data. Overall, the regression results confirm an 'economic growth – resource use – environmental impact' relationship in the observed nautical tourism destinations, based on perception-based data, with environmental measures mitigating, but not transforming the underlying dynamics.

DIFFERENCES IN PERCEPTIONS AMONG RESPONDENT GROUPS

The differences in respondents' perceptions of economic growth, resource use, environmental footprint, and environmental measures and actions were examined using Independent-Samples *t*-tests and one-way ANOVA. The results indicate that gender-based differences are present for ResU1-MaSS, ResU3-LandA, and EnvFP2-CADaP, with female respondents perceiving higher levels of resource use and environmental footprint than male respondents. No statistically significant differences were identified with respect to residency. Employed respondents assigned higher scores to the EnvFP2-CADaP (Mean 4.09) and lower scores to all EnvMA indicators (Mean 2.18–2.52) compared to other employment groups. The respondents who stay in the destination more often rated the level of implementation of environmental measures across all three indicators (Mean 2.30–2.64) lower than the respondents who visit or stay less often. Moreover, the respondents whose visits were for property maintenance rated the level of EnvMA across all three indicators (Mean 2.11–2.33) lower than those whose visits were for vacation, job, or permanent stay. The results regarding the respondents' tourism experiences are mixed and insufficient to draw conclusions.

CONCLUSION

This study examined resource decoupling and impact decoupling in nautical tourism destinations by analyzing the relationships between economic growth, resource use, and environmental footprint. It also analyzed the impact of environmental measures and actions on environmental pressure in nautical tourism. From a sectoral, destination-level approach grounded in local community perceptions, the findings provide no evidence of either relative or absolute decoupling in the observed nautical tourism destinations. Economic growth is strongly associated with increased resource use and environmental footprint, confirming the persistence of an 'economic growth–environmental pressures' relationship in this highly resource-dependent sector. Resource use and environmental footprint are growing just as strongly as economic growth.

The regression analysis revealed that economic growth and environmental measures are predictors of resource use, while economic growth, environmental measures, and resource use are predictors of environmental footprint. The results highlighted the commonly assumed relationship between economic growth, resource use, and environmental footprint. They also showed that environmental measures reduce environmental pressures, and the magnitude of the reductions depends on the level of the measures.

From a theoretical perspective, the study contributes to the decoupling literature by extending the empirical analysis beyond macroeconomic and dominantly emissions-focused approaches to a sectoral, spatially constrained tourism context. However, this research is limited to perception-based data, a single regional case study, and a relatively low number of indicators for operationalizing the research variables. It does not directly measure objective environmental or economic data; therefore, the identified decoupling patterns should be interpreted with caution. Future research should combine perceptual and objective indicators, employ broad research methods, and conduct further statistical analyses, including tests of mediating and moderating mechanisms for additional variables, to further investigate decoupling pathways in nautical tourism and other marine-based sectors. The findings provide valuable insight into the environmental challenges in the sustainable development of nautical destinations, where the tourism industry is a leading economic activity and a primary driver of development.

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ENERGY ECONOMICS and ENVIRONMENTAL ECONOMICS

ENVIRONMENTAL TAXES AND THE TRANSITION TO RENEWABLE ENERGY SOURCES IN THE EUROPEAN UNION

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The global problem of pollution, and consequently climate change, also affects the European Union which is trying to increase the use of renewable energy sources to a larger extent. For that purpose, EU governments are, among other instruments, implementing environmental taxation. This paper explores the role of environmental taxes in accelerating the transition to renewable energy sources within the European Union, with a novel focus on disaggregated categories of renewables. Unlike previous studies that treat renewable energy as a single measure, this research distinguishes between three categories: (i) renewable energy sources in transport, (ii) renewable energy sources in electricity production, and (iii) renewable energy sources in heating and cooling. Each category is modeled as a separate dependent variable in three panel data models covering EU Member States from 2004 to 2023. Using a fixed effects (FE) estimation with Driscoll–Kraay standard errors to account for heteroskedasticity, serial correlation, and cross-sectional dependence, the study investigates the effectiveness of tax policy in increasing the renewable energy use in each of the three categories. The findings suggest that an increase in environmental tax revenues relates to lower shares of renewable energy sources in heating and cooling, while domestic net greenhouse gas emissions have a negative impact on both renewable energy sources in heating and cooling and renewable energy sources in electricity production. Furthermore, higher real GDP per capita is as-

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sociated with a lower share of renewable energy sources in electricity production. Future research could consider different instruments, such as subsidies and institutional factors. The results highlight that policymakers should implement targeted incentives that address different industry sectors along with environmental taxation.

Keywords: *Environmental taxes, renewable energy, panel data analysis, European Union*

JEL classification: *H23, Q20, Q53, Q58.*

INTRODUCTION

Climate change and pollution are among the greatest challenges of today's society. There is a consensus that the causes and possible consequences of climate change are associated with fossil fuels and other forms of non-renewable energy sources. Governments are trying to solve this problem by using various instruments. One of those instruments is environmental taxation, which is used for raising public revenues, but is also a tool that should help reduce pollution and greenhouse gas (GHG) emissions. The European Union (EU) institutions decided that the EU should become climate neutral by 2050. This will only be possible by implementing strong measures, including tax policy that takes this goal into account. EU energy taxation is regulated primarily by the Energy Taxation Directive (Directive 2003/96/EC), which sets the minimum tax rates on motor fuels, heating fuels, and electricity across the Member States. It is currently undergoing a major revision in order to align it with the EU Green Deal and the broader 2050 climate neutrality objective (European Commission, 2025). Tax bases for environmental taxes have a negative impact on the environment, meaning that their purpose is to reduce pollution and, consequently, climate change by introducing and raising the tax burden on pollutants. Still, environmental taxes can also have a negative impact on lower income citizens since they generally use goods and services that are associated with non-renewable energy sources and are, therefore, affected by environmental taxes such as energy taxes.

The revision of the Energy Taxation Directive under the EU's *Fit for 55* package aims to better align energy taxation with climate and energy objectives by ensuring that tax rules reflect environmental impact and support the transition away from fossil fuels toward cleaner energy (European Commission, 2021). By increasing the relative prices of polluting fuels, environmental

taxes internalize the negative externalities and improve the competitiveness of renewables, which influences investment and consumption decisions (OECD, 2019). However, the effectiveness of environmental taxes in increasing renewable energy use may vary due to other macroeconomic factors, including energy prices and gas emissions.

Energy production represents one of the most important technological, economic, political and scientific issues. The modern world uses large amounts of energy for industry, transport, business, and household consumption. In order to reduce pollution and climate change, many countries, especially in western and northern Europe, are trying to increase the use of renewable energy sources. Renewable sources include hydropower, biomass, solar, wind and geothermal energy. The use of renewable sources causes significantly less harm, and their quantities cannot be exhausted. However, the use of renewable sources is usually less economically feasible (Yang, 2024). Because of this issue, technological progress is of paramount importance, because technology offers different options for producing, storing, and distributing clean energy at a lower cost. Reducing non-renewable energy consumption, in addition to its impact on consumers, also has a macroeconomic impact. Lower energy consumption results in lower imports of fossil fuels, and the reduction of imports increases GDP (Gelo et al., 2021).

The objective of this paper is to measure the effect of environmental taxes, GHG emissions, GDP and oil prices on renewable energy use for three categories of renewables. First, the theoretical background is described, followed by the data and methods, and the results and discussion. In the conclusion section, implications for policymakers are presented on how to proceed with policy decisions regarding environmental taxation.

LITERATURE REVIEW

Several studies identified environmental taxes as an effective way to reduce carbon emissions and positively affect the transition to renewable sources. Energy taxes increase renewable energy adoption and innovation in green technology, especially when revenues are recycled into green projects and programs that reduce the financial impact of taxes on lower income households (Sing et al., 2025). Doğan et al. (2022) showed that environmental taxation, when combined with green growth strategies, is strongly linked to lower CO_2 emissions. Likewise, Gerni et al. (2025) found that such taxes have an impact on the transition to renewable energy in newly industrialized economies.

Environmental taxes can reduce emissions in countries which are known as the largest pollutants, but their success largely depends on financial development and green innovation (Sakilu and Chen, 2024). However, Bashir et al. (2022) found that in OECD economies, strong environmental regulation can slow the adoption of renewables, which is an argument for more flexible policy. Despite extensive empirical evidence, the literature provides no consensus on the conditions under which environmental taxes effectively promote renewable energy use.

Institutional quality is a decisive factor in whether environmental taxation works as intended by the government. Governance and innovation systems are key elements in strengthening the environmental tax impact on advancing the renewable energy objectives (Rahbi et al., 2024; Enusah et al., 2024; Sen et al., 2025). Sen et al. (2025) found that taxes encourage renewable energy consumption only when paired with sound governance and technological innovation. Accordingly, Enusah et al. (2024) showed that renewable energy aid weakens governments' own tax efforts in low-income Sub-Saharan African countries. In many developing countries, environmental taxation has not produced the same benefits, largely because of weak institutions and inadequate implementation (Rabhi et al., 2024). In the EU, the environmental taxes may lower the renewable energy consumption, partly because of weak policy coordination and the continued subsidization of fossil fuels (Doğan et al., 2023). Energy taxes did not lead to increases in the share of renewable energy nor to lower GHG emissions at the EU level, concluding that energy tax policy is ineffective for shifting the energy mix toward renewables and should be reformed or paired with emissions trading system mechanism (Liobikienė et al., 2019). On the other hand, Savranlar et al. (2024) showed that environmental tax revenues are associated with lower CO_2 emissions in the EU and exhibit a bidirectional causal link with emissions. Fatur Šikić and Hodžić (2023) found that environmental taxes significantly reduce final energy consumption (both renewable and non-renewable) in both old and new EU countries, though the effect is notably weaker in the new EU countries. This reflects structural and institutional differences of these two blocks, also implying slower technological modernization in post-transition economies. These findings suggest that environmental taxation should be viewed as part of a broader institutional framework that includes regulatory quality, fiscal capacity, and innovation support. Differences in administrative efficiency and enforcement capacity may therefore explain the heterogeneous outcomes of environmental tax policies across countries.

Some studies analyzed the relationship between renewable energy and economic growth, and argue that it largely depends on technological progress, income level, and investment in innovation (Kocsis and Kiss, 2015; Salim et al., 2014; Sart et al., 2024; Thombs, 2017; Xuan, 2025). When supported by higher R&D investment, there is a positive relationship between GDP and renewable energy consumption in the EU countries, which means that technological innovation is important in addition to higher income level (Kocsis and Kiss, 2015). Similarly, Salim et al. (2014) confirmed a long-term relationship between renewable energy sources, non-renewable energy sources, and GDP growth in 29 OECD countries, where unidirectional causality is present from renewable energy consumption to GDP, and there is bidirectional causality from GDP and non-renewable energy consumption. Furthermore, increases in renewable energy adoption not only enhance GDP, but higher income level countries also facilitate greater renewable energy adoption, forming a two-way relationship (Sart et al., 2024). The impact of renewable energy consumption on GDP and emissions is weaker at higher income levels (Thombs, 2017). Xuan (2025) showed that renewable energy adoption and R&D investment both increase the positive impact of foreign direct investment (FDI) on GDP in Germany. Furthermore, investments in renewable energy improve energy security and contribute to long term GDP growth (Sart et al., 2024).

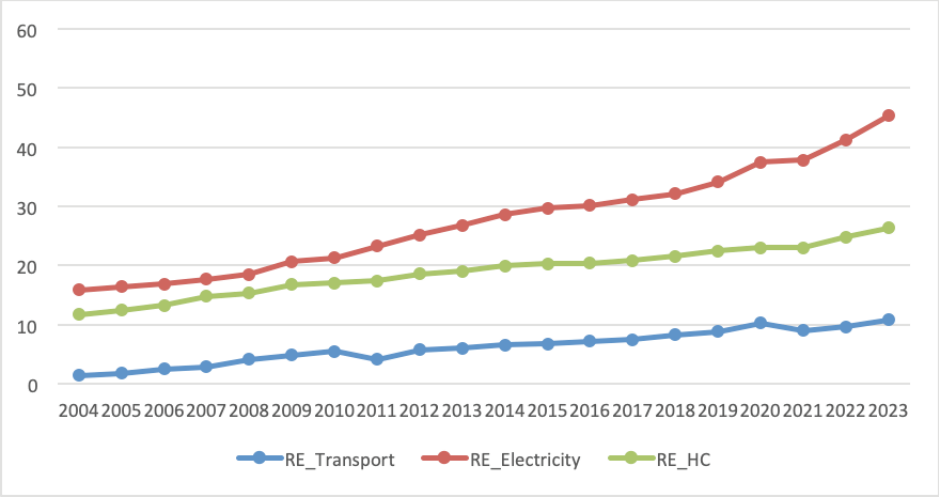
The relationship between GHG emissions and renewable energy use is also an important aspect of the environmental policy analysis. Higher renewable energy use contributes to environmental sustainability in Korea by reducing GHG emissions, and fossil fuel consumption has the opposite effect (He, 2023). Similarly, an analysis of BRICS economies showed that renewable energy sources in electricity production decrease GHG emissions, while economic growth increases them (Qing et al., 2023). Chen et al. (2023) found that renewable energy consumption, together with digitalization and energy efficiency, reduces GHG emissions in G7 countries. That highlights the role of technological progress in reducing emissions. In the Eurozone, Zarrad et al. (2025) found that an increase in renewable energy consumption reduces long run GHG emissions, but reducing renewable energy consumption leads to an increase in emissions. Digitalization increases the benefits of renewable energy use in developed countries, which improves both efficiency and sustainability (Chen et al., 2023; Zarrad et al., 2025). Rising CO_2 emissions globally encourage higher investment in renewables, while non-CO_2 GHG emissions tend to discourage it (Ghezelbash et al., 2023).

DATA AND METHODS

DATA SOURCES AND VARIABLES

This study uses a balanced panel dataset covering all EU Member States (EU-27) for the years 2004-2023. The data were collected from Eurostat and the Energy Institute. The time frame allows for the observation of major policy developments in environmental taxation and renewable energy adoption across the EU's energy transition agenda. We distinguish between three renewable energy sources (each measured as a percentage of total energy consumption): share of renewable energy in transport (*RE_Transport*), share of renewable energy in electricity production (*RE_Electricity*), and share of renewable energy in heating and cooling (*RE_HC*).

Figure 1. Share of renewable energy sources as a percentage of total energy consumption (EU-27)



Source: The authors according to Eurostat (2025)

Figure 1 shows long term growth in renewable energy use across all three sectors in the EU-27. Electricity production from renewable sources increased the most, rising from 15,87% in 2004 to 45,36% in 2023. Heating and cooling from renewable sources grew more moderately, while transport from renewable sources remained the lowest, increasing slowly from 1,43% to 10,86%. Electricity production benefited from cost reductions in wind and solar technologies and

strong targets at the EU level, which accelerated renewable energy use in this sector. In contrast, the heating and cooling sector remains more dependent on existing infrastructure, where transition costs are higher and policy incentives are often less harmonized across the EU Member States. Renewable energy use in transport has expanded most slowly, mostly due to a slower electrification of vehicle fleets, particularly in the presence of continued fossil fuel subsidies. Each of these renewable energy categories is the dependent variable in three panel regression models.

The explanatory variable is environmental tax revenue (*EnvTax*), measured as the total revenues from environmental taxes in euros (including energy taxes, transport taxes and taxes on pollution/resources). Several control variables are included: domestic net greenhouse gas emissions (*GHG*; index 1990=100), indicating the environmental pressure and pollution intensity of each economy; real GDP per capita (*GDPpc*), capturing the level of economic development that may affect energy structure and policy priorities; and crude oil price in US dollars per barrel (deflated to constant prices using Consumer Price Index), included as an energy market control (*OilPrice*). Including the oil prices in the model also accounts for global energy shocks, which can alter both investment incentives in renewables and governments' fiscal decisions on environmental taxation (Liu et al., 2024). The logarithmic transformation was applied for the environmental tax revenues. It is commonly applied to variables that exhibit high variability across countries and over time. Moreover, it helps to stabilize the variance and approximate a normal distribution (Škrinjarić, 2023).

ECONOMETRIC MODELS

Firstly, diagnostic tests were conducted to examine cross-sectional dependence, multicollinearity, and the stationarity of the variables. Cross-sectional dependence was tested using the Pesaran CD test, multicollinearity was tested by analyzing the variance inflation factor (VIF), and stationarity was tested by using unit-root tests. Given the panel structure of the data, a fixed effects (FE) model was used to control for unobserved, time-invariant heterogeneity among EU countries, such as geography, institutional settings, or natural resource base. The estimated econometric models are as follows:

I. $$RE_Transport_{i,t} = \alpha_i + \lambda_t + \beta_1 ln(EnvTax_{i,t}) + \beta_2 GHG_{i,t} + \beta_3 GDPpc_{i,t} + \beta_4 OilPrice_{i,t} + \varepsilon_{it}$$

II. $$RE_Electricity_{i,t} = \alpha_i + \lambda_t + \beta_1 ln(EnvTax_{i,t}) + \beta_2 GHG_{i,t} + \beta_3 GDPpc_{i,t} + \beta_4 OilPrice_{i,t} + \varepsilon_{it}$$

III. $$RE_HC_{i,t} = \alpha_i + \lambda_t + \beta_1 ln(EnvTax_{i,t}) + \beta_2 GHG_{i,t} + \beta_3 GDPpc_{i,t} + \beta_4 OilPrice_{i,t} + \varepsilon_{it}$$

where ***i*** denotes country, ***t*** time, α_i country fixed effects, λ_t year dummies that capture common shocks such as EU-wide regulatory or market changes, β are model coefficients to be estimated for each variable, and ε_{it} is the error term. Standard fixed-effects estimators may yield biased standard errors in the presence of heteroskedasticity, serial correlation, or cross-sectional dependence. Therefore, we applied the Driscoll–Kraay standard errors (Driscoll and Kraay, 1998), which are robust to these diagnostic concerns and have become a standard approach in environmental taxation and energy studies (Nchofound et al., 2023; Estevão and Lopes, 2024; Suproń, 2024; Soufiene et al., 2025).

RESULTS AND DISCUSSION

Firstly, the variables were checked for multicollinearity, and the variance inflation factor (VIF) amounted to less than 5 for all the variables which means that multicollinearity was not present. For the absence of multicollinearity, the VIF value should be smaller than 5 for all the variables (Hair, 2018). Secondly, we applied the cross-sectional dependence (CD) test (Pesaran, 2004). Table 1 shows that the null hypothesis of cross-section independence was rejected for all the variables at the 1% significance level. Unit root tests were applied to test the non-stationarity in the panel data, which would otherwise bias the estimation results if not properly addressed. Specifically, the Im-Pesaran-Shin (IPS) panel unit root test (Im et al., 2003) and cross-sectionally augmented Dickey-Fuller (CADF) panel unit root test (Pesaran, 2007) were applied to check the stationarity of the variables. The OilPrices variable was not included in the unit root tests, since this variable does not vary across countries because it is determined at the global level. All the other variables are stationary in their first differences. Therefore, the first differences for dependent, explanatory, and control variables were used in the model estimation. The results of both panel unit root tests are presented in Table 2.

Table 1. Cross-sectional dependence test results

	RE_ Transport	RE_ Electricity	RE_HC	EnvTax	GHG	GDPpc	OilPrice
CD-test	61.28	76.63	71.57	54.72	33.52	57.69	83.79
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: The cross-section dependence is tested according to Pesaran (2004).

Table 2. Panel unit root test results

	Levels		First-differences	
	IPS	CADF	IPS	CADF
RE_Transport	2.7637	-2.157 **	-10.1114***	-4.694***
RE_Electricity	17.5573	-0.078	-5.0966***	-1.502**
RE_HC	6.6806	0.330	-9.8545 ***	-3.593***
EnvTax	2.5301	1.914	-11.4949***	-4.114***
GHG	2.7847	1.332	-10.8517***	-6.501***
GDPpc	3.7974	1.598	-10.2882***	-3.596 ***

Note: *** and ** represent 1% and 5% levels of significance.

Table 3 reports the fixed-effects estimation results with Driscoll–Kraay standard errors for the three dependent variables: renewable energy in transport (Model I), renewable energy in electricity production (Model II), and renewable energy in heating and cooling (Model III). The F-statistics indicate that the explanatory variables are jointly significant in Models II and III, while the joint significance in Model I is weaker. The within R^2 values are modest, which is common in macro panel data where structural and institutional factors change gradually over time, and are only partially captured by observable regressors.

Table 3. Results of the static panel analysis (Fixed effects with Driscoll-Kraay standard errors)

	Model I		**Model II**		**Model III**	
	Coeff.	**Std. Err.**	**Coeff.**	**Std. Err.**	**Coeff.**	**Std. Err.**
ΔEnvTax	-1.98	1.150	-2.04*	1.027	-1.31**	0.608
ΔGHG	-0.01*	0.006	-0.03***	0.008	-0.03***	0.007
ΔGDPpc	0.00	0.000	-0.0002***	0.000	0.00	0.000
OilPrice	0.00	0.004	0.00	0.004	0.00	0.002
Constant	0.67	0.431	1.55**	0.588	0.744***	0.261
Within R^2	0.0472		0.0860		0.0397	
	Value	Prob	Value	Prob	Value	Prob
F-stat	1.58	0.2235	12.98	0.00	24.66	0.00

Note: *, **, *** represent 10%, 5% and 1% levels of significance.

Environmental taxation (*EnvTax*) has a negative and statistically significant effect in Model III, while the coefficient in Model II is weakly significant but negative, and in Model I it is not statistically significant. These results indicate that higher environmental tax revenues were not associated with a greater share of renewable sources in electricity production or in heating and cooling during the observed period. Instead, the estimates suggest that increases in environmental taxation were associated with a declining share of renewables in these two sectors. These findings should be interpreted as associations rather than evidence of causality. One possible explanation is that countries with a lower share of renewable energy remain more dependent on fossil fuel-based energy consumption, which may simultaneously generate higher environmental tax revenues. Greenhouse gas emissions (*GHG*) display a negative and statistically significant relationship with renewable energy deployment in all three models. This means that higher domestic net emissions are associated with lower renewable energy sources. Real GDP per capita (*GDPpc*) shows a negative and highly significant effect in Model II, which suggests that higher income levels are linked to a lower share of renewable energy use in electricity production. There is no statistically significant relationship with other renewable energy sources. Oil prices (*OilPrice*) do not have statistical significance in any of the three models, indicating that short-term price movements in fossil energy did not have a decisive role in renewable energy uptake across the sectors.

Overall, the most important results were observed with regard to environmental taxation and greenhouse gas emissions, both of which are consistently negative in Models II and III. The results suggest that environmental taxation

alone was not sufficient to stimulate greater renewable energy use in the EU and that countries with higher emissions showed slower progress in renewable energy adoption, particularly in the electricity, and heating and cooling sectors. This is in line with previous studies (Liobikienė et al., 2019; Dogan et al., 2023; Rahbi et al., 2024). Furthermore, the negative relationship between GHG emissions and renewable energy sources has been confirmed in other studies (He, 2023; Qing et al., 2023; Chen et al., 2023; Zarrad et al., 2025). In contrast to previous studies, economic growth in this study was not associated with an increase of renewables.

CONCLUSION

This study analyzed the role of environmental taxation in the transition to renewable energy sources in the EU. Three econometric models, each with a separate renewable energy category (transport, electricity production, and heating and cooling) were used in the empirical analysis. There were several key findings. The results show that environmental taxation decreases the renewable energy use in heating and cooling. This suggests that the current design of environmental taxes in the EU does not improve the transition to renewable energy use. These findings are consistent with previous studies on the effectiveness of energy taxation in EU countries. Higher greenhouse gas emissions are associated with a lower share of renewables in electricity production and in heating and cooling, which means that higher emitting countries are lagging in their renewable transition process. Real GDP per capita has a negative effect on renewable energy use, but only in the electricity production sector. This contrasts with some literature that shows a positive link between GDP levels and renewable energy use. In other words, income level is insufficient in increasing the use of renewable energy sources in the EU. Given the applied empirical approach, the results should be interpreted as partial correlations, while potential reverse causality remains possible.

The results show that environmental taxation, in its current form, is not increasing the renewable energy use in the EU. In order to improve effectiveness, environmental taxes should be used with other policies such as targeted revenue recycling, and fossil fuel subsidies should be reduced. Without implementing other environmental policies, fiscal measures are primarily used as instruments to increase public revenues rather than to support the energy transition. Future research could analyze how different categories of environmental taxes, such as energy, transport, or pollution taxes are affecting renewable

energy use. Furthermore, a separate analysis for old and new EU Member States could show how institutional differences may have heterogeneous results on environmental taxation and renewable energy use across the EU.

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POLITICAL IDEOLOGY, AUTHENTICITY AND MORAL (DE)COUPLING IN SHAPING CONSUMER REACTIONS TO BRAND ACTIVISM: A NARRATIVE REVIEW AND RESEARCH AGENDA

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Background: Brand activism has become one of the key features of corporate engagement in an increasingly polarised public sphere, as consumers increasingly expect firms to take a stand on socioeconomic, environmental and political issues. Unlike traditional corporate social responsibility (CRS), which addresses broadly accepted pro-social causes, brand activism entails taking sides on controversial matters, thereby risking the alienation of consumers whose values diverge from those promoted. Despite a growing number of empirical studies in the past decade, there are still areas deserving of attention in this emerging field.

Purpose: This paper aims to provide a theoretically grounded overview of brand activism and to identify the key opportunities for future research. Specifically, it aims to clarify the distinction between brand activism and related constructs, synthesise the existing literature explaining consumer reactions, and propose a structured research agenda. By doing so, the paper contributes to the discussion on how brands function beyond their immediate economic interest, as drivers of social, political, economic and environmental change in the increasingly polarised society, with particular attention given to the role of activism in shaping public acceptance of sustainability initiatives.

Method: A narrative literature review was conducted, drawing on peer-reviewed journal articles identified through keyword-based searches

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in Web of Science. The synthesis is organised around three themes selected for their theoretical and conceptual prominence: the role of political ideology, authenticity as a precondition for positive consumer response, and moral (de)coupling as a mechanism linking ideological and authenticity-based perspectives to consumer behaviour outcomes. These areas highlight the need for a broader, cross-cultural and multi-level research to advance the theoretical understanding of brand activism as a complex and context-dependent phenomenon.

Conclusion: The paper identifies political ideology, perceived authenticity and moral (de)coupling as critical conditions shaping consumer reactions and determining the acceptance or rejection of corporate environmental and social initiatives. By examining how these mechanisms influence responses to activism and sustainability-oriented strategies, the paper contributes to the broader research agenda of decoupling.

Keywords: *Brand activism, political ideology, authenticity, moral (de)coupling, consumer response, sociopolitical issues*

JEL classification: *M31, M37, M14, Q59*

INTRODUCTION

In the past decade, the world has witnessed significant socioeconomic, political and environmental changes which have led to the increasing polarisation of the public on a number of issues (Edelman, 2023). These range from geopolitical conflicts and environmental pressures to racial and gender inequality, and frequently include an ideological dimension. These areas are no longer reserved for public policy alone. That is, consumers increasingly expect businesses to address societal issues and take a clear stand; in fact, compared with the government, the media and NGOs, only businesses are seen as both ethical and competent (Edelman, 2025, p. 24). With their unambiguous support to causes that call for action and change, causes that deeply polarise the public, firms can significantly influence consumers' behaviours and attitudes around sustainability and environmental issues as well (Romani, Grappi & Bagozzi, 2016). Such corporate engagement can, on the one hand, strengthen brand affinity among consumers who share the promoted values, but on the other hand can provoke strong backlash among segments of the public who oppose them.

Corporate engagement with societal issues can take several forms. Corporate social responsibility (CSR) addresses generally accepted non-divisive pro-

social causes (Mukherjee & Althuizen, 2020). Brand activism goes further, by explicitly addressing and publicly taking a stance on divisive sociopolitical issues, aligning with those consumers who share the same values, and potentially alienating others (Kotler & Sarkar, 2017; Moorman, 2020; Vredenburg et al., 2020). Environmental initiatives can illustrate this distinction. That is, while general sustainability commitments fall within CSR, taking a more explicit stand on environmental policies, coupled with diversity, equity and inclusion (DEI) initiatives, crosses into brand activism territory.

One such case of public backlash was a renowned car manufacturer's rebranding campaign following the company's decision to decouple its future from the internal combustion engine, and its transition from fossil-fuelled to electric vehicles. The campaign video showed another departure – that from the brand's traditional identity rooted in heritage and luxury, into DEI space featuring models promoting racial, gender and body-type diversity, without any cars being shown (Jaguar, 2025). The backlash to such a U-turn was intense, with critics arguing that the company had disregarded its traditional customer base and abandoned the brand's core identity (Faulconbridge, 2024; Hyde, 2024), while analysts pointed out that the company had already been struggling with sales and profitability (Leggett, 2024). For the purpose of this paper, this case is revealing. Firstly, the campaign's promotion of progressive DEI values caused polarising reactions among consumers along ideological lines, reflecting the role of political ideology in shaping consumer reactions. Secondly, as a brand whose identity had been rooted in high performance and luxury, this rather unexpected turn toward sociopolitical activism raised the question of authenticity, which is a precondition for a positive consumer response. Finally, consumer reactions to the campaign raised questions central to moral (de)coupling: do some consumers choose to evaluate the company's products independently of a campaign that they object to, while others transfer their disapproval to the brand as a whole? Does this choice determine the extent to which the brand loses or recovers its position among consumers? These questions point to broader issues of brand activism research: Why do businesses decide to take a stance on divisive social issues in the first place? What happens if the values they promote align with one consumer segment, but misalign with another? And as a result of such antagonism, can a loyal customer turn into an outspoken critic?

Scientific literature on brand activism is growing, but research is still relatively fragmented (Pimentel, Bassi-Suter & Didonet, 2024; Francioni et al., 2025), especially research that encompasses cultural and political diversity and different levels of controversy regarding the issues that trigger activism

(Hong and Li, 2021; Wang and Bouroncle, 2024; Pecot, Vasilopoulou & Cavallaro, 2021; Mukherjee and Althuizen, 2020). The purpose of this paper, therefore, is to provide an overview of the current state of brand activism and identify the research opportunities.

In this paper, a narrative literature review approach is adopted (Baumeister & Leary, 1997; Grant & Booth, 2009; Snyder, 2019), as it is well suited for linking studies spanning multiple disciplines, for the purpose of theoretical integration (Baumeister & Leary, 1997), rather than employing a systematic literature review (Snyder, 2019). Keyword-based searches were conducted in October–November 2025 in the Web of Science, using different combinations of the following search terms: "brand activism", "corporate sociopolitical activism", "political ideology", "consumer response", "environment", and "sustainability". The search was limited to peer-reviewed English-language journal articles published since 2017, the year in which "brand activism" was introduced in academic literature (Kotler & Sarkar, 2017). The initial search was further expanded based on the references of seminal works, which resulted in the selection of additional relevant papers. The papers were selected for their conceptual relevance (Torraco, 2005) to the three identified research themes: the role of political ideology, authenticity as a precondition for positive consumer response, and moral (de)coupling as one of the mechanisms of consumer reaction. The resulting sample draws primarily from top marketing journals (52% of reviewed literature), followed by communication and media management, ethics/CSR, sustainability/ESG sources, political science and psychology. The synthesis is presented thematically and leads to a research agenda, identifying the key opportunities for future empirical work (Baumeister & Leary, 1997).

The three main areas in this paper were selected based on two criteria. Political ideology and authenticity emerged as the dominant constructs in reviewed literature and were, therefore, selected as the primary organising categories on the basis of their theoretical prominence (Baumeister & Leary, 1997; Torraco, 2005). Moral (de)coupling was selected as the third theme for conceptual reasons: while less frequently treated as a singular construct in brand activism research, it offers a distinct view of the consumer response mechanism that complements the other two themes, and connects the ideological and authenticity perspective to behavioural outcomes.

The paper is organised as follows: following this introduction, a theoretical background is provided in part two, followed by the discussion of the current state of brand activism research and key research opportunities in part three. The paper ends with the key implications and conclusion.

THEORETICAL BACKGROUND AND ROOTS OF BRAND ACTIVISM

In the face of pressing sociopolitical issues, customers demand that brands take a clear stand, challenge the status quo, and demonstrate responsibility (Vredenburg et al., 2020), all with the aim of facilitating change (Mirzaei, Wilkie & Siuki, 2022). The issues that trigger activism are social, political, economic, environmental, and legal, and range from global conflicts and climate change to sustainability initiatives and fight against racial and gender inequality (Kotler and Sarkar, 2017; Bhagwat et al., 2020; Moorman, 2020; Shukla, Rosendo-Rios & Khalifa, 2025; Tsougkou, Karampela & Balabanis, 2024; Miguel and Miranda, 2024).

Brand activism is a value-driven strategy in which a firm takes a stance on divisive sociopolitical issues with the aim of promoting social, political, economic or environmental change related to a common good (Kotler & Sarkar, 2017; Pöyry & Laaksonen, 2022; Kim & He, 2023; Moorman, 2020). The more controversial the issue and the resulting activism, the more polarised consumer response to such activity becomes (Weber, Joireman & Sprott, 2025). The purpose of such activism expands beyond the pursuit of profit, and toward contributing to public interest (Kotler & Sarkar, 2018), by influencing consumers' perception and their consumption choice, which includes sustainable products (Romani, Grappi & Bagozzi, 2016). Brand activism is different from corporate social responsibility (CRS) which addresses non-divisive, pro-social issues (Mukherjee & Althuizen, 2020); it is also different from cause-related marketing, where companies make a financial contribution to a non-controversial cause related to a customer's purchase (Jungblut & Johnen, 2021), and from corporate political activity, which aims to influence government policy to gain a competitive advantage rather than to promote social values (Bhagwat et al., 2020; Jiménez et al., 2025).

Given that a divisive, polarising issue is at the centre of brand activism, it could be argued that environmentalism and sustainability, as non-contested issues, do not fall into that category. Why would anyone oppose to preserving the planet, protecting waters or minimising pollution? Should these topics not be met with a consensus across the board? As an idea they should, and in that regard environmental and sustainability initiatives do fall under the umbrella of CSR, when addressing generally accepted causes. However, they enter the brand activism territory when addressing divisive, ideologically coloured issues that polarise consumers, such as climate change or fossil fuels policies that lead to regulatory or lifestyle changes and generate stronger polarisation (Directive (EU) 2019/904, 2019; Smith, 2024), additionally connected to po-

tentially divisive sociopolitical topics (as is the case with Jaguar). The controversy level of the cause that triggers activism is significant, i.e. proportional to the negative effect in the case of a misalignment with consumer values (Zhao, Cui & Du, 2024). Some have, in fact, argued that *all* corporate responsibility initiatives are prone to controversy, as they rely on moral judgments which do not have a universal consensus, and that an initiative framed as morally "right" need not necessarily be perceived as such (Eabrasu, 2012).

CURRENT STATE OF BRAND ACTIVISM AND KEY OPPORTUNITIES FOR FUTURE RESEARCH

The research on brand activism is still fragmented (Pimentel, Bassi-Suter & Didonet, 2024; Francioni et al., 2023), and would benefit from additional studies to cover different economic, cultural and political systems and ideologies, as well as the nature of divisive issues that polarise the public (Pecot, Vasilopoulou & Cavallaro, 2021; Hong and Li, 2021; Ketron, Kwaramba & Williams, 2022; Tsougkou, Karampela & Balabanis, 2024). This is particularly relevant for global organisations that operate in multiple, and often diverse markets, in order to be able to decide whether to adjust their approach considering the local context, or to keep the "corporate line" consistent (Kim and He, 2023; Zhao, Yim & Peng Cui, 2025; Schmidt et al., 2021). Such research would allow for the comparison od "multiple realities" on the one hand (Cammarota et al., 2023), and provide global organisations with the opportunity to change their approach on diverse markets on the other.

This paper highlights three research opportunities in the field of brand activism that require further development, in order to deepen the understanding of the mechanisms in this domain. These are summarised in Table 1 at the end of this section.

THE ROLE OF POLITICAL IDEOLOGY

Political ideology, as a system of beliefs about social change, stability and (in)equality that distinguishes liberal and conservative consumers (Jost et al., 2003), influences how consumers perceive brand activism on divisive issues. That is, ideological differences lead to a misalignment of values and therefore

negatively influence brand attitudes, intentions, and behaviour (Mukherjee and Althuizen, 2020). The part of the political spectrum that consumers belong to is one of the key features determining consumer behaviour, reaction, and choice as a consequence of brand activism (Hydock, Paharia & Blair, 2020; Tsougkou, Karampela & Balabanis, 2024).

Given that most global brand activism has a liberal tendency, i.e. advocates change related to progressive values such as equality or diversity (Bhagwat et al., 2020), liberal consumers believe that companies should take a stand and perceive such messaging more positively (Haupt et al., 2023). Therefore, they are more likely to have stronger reactions to ideological activism, as they value change and challenging the status quo (Jost, Langer & Singh, 2017).

On the other hand, conservative consumers believe less in corporate engagement, they have a greater need for order and structure, are less sensitive to political messaging, and therefore react less to brand activism (Haupt et al., 2023). They perceive activist campaigns more negatively as they want to preserve the current sociopolitical and economic structures and stability, and are less inclined to change (Jost, Langer & Singh, 2017; Tsougkou, Karampela & Balabanis, 2024; Khalifa and Osburg, 2025). Interestingly, in the wider context of political options, in countries with politically right-leaning governments, companies are more likely to engage in activism, as these governments usually promote free markets and are more business friendly (Jiménez et al., 2025).

However, despite some findings that left-wing consumers are more likely to react to activism by engaging, for instance, in boycotts, while right-wing individuals tend to support the existing system, Pecot et al. (2021) have shown that anti-consumption movements (which boycott is a part of) are not in fact limited to progressive, left-wing activism. That is, individuals who do not advocate change, and favour hierarchy, nationalism and tradition (traditionally right-wing, conservative), will also engage in a boycott if they feel that their social values are threatened (Pecot, Vasilopoulou & Cavallaro, 2021). These findings indicate that firms should consider the political ideologies of the majority of their customers and lean toward them; whereas if the customer base is more or less equally divided, firms should in fact not take a stance at all (Gidakovic et al., 2025). Based on the presented insights, the following research opportunity is suggested:

Research opportunity 1:

How does the country's dominant ideology affect the perception of brand activism among consumers with diverse ideology affiliations (liberal to conservative)? How does ideology affect the consumer perception of the issue

of divisiveness and controversy? How does a "business-friendly" environment mitigate negative reactions of conservative customers when a brand takes a progressive stand? How does brand activism affect the attitude of the general public about the contested issue? To what extent does ideological (mis)alignment lead to consumers abandoning the brand's traditional base?

AUTHENTICITY AS A PRECONDITION FOR POSITIVE PERCEPTION

Perceived authenticity of brand activism has been identified as one of the key preconditions for a positive response. Several factors contribute to it, and one of them is the perceived motivation of the brand. For a positive consumer perception, activism should be motivated by altruism and genuine support for the cause, in which case consumers will show greater support for the causes and the choice of ecological products (Romani, Grappi & Bagozzi, 2016). Inversely, if the motivation is self-interest or brand image, consumers are more sceptical and view activism as insincere (Wang and Bouroncle, 2024). Following such perceptions of selfishness, consumers become sceptical and green behaviour drops (Romani, Grappi & Bagozzi, 2016). This is the case with brands that publicly promote an issue, but then fail to adopt the same approach and commitment within the organisation, clearly reflecting a value misalignment and using activism only for promotional purposes (Ahmad, Guzmán & Al-Emran, 2024).

Another factor contributing to authenticity is previous corporate engagement. That is, brands with a history of corporate activism are more likely to be seen as authentic than those that engage only sporadically (Mirzaei, Wilkie & Siuki, 2022; Zhao, Yim & Peng Cui, 2025). Additionally, in the long run, brand activism can serve as a reputational credit; in the event of a brand failing in terms of quality or reliability, brands with a history of activism can still count on maintaining consumer trust and loyalty, as customers are more resistant to negative information (Francioni et al., 2025). However, a history of social engagement is not a guarantee of positive perception. When companies fail consumers on the core values they advocate, this is perceived as betrayal, and the company's activist image will not protect it from an even stronger backlash (Francioni et al., 2025).

Next, activist engagement of competitors also plays an important role, as in this case consumers expect firms to react, given that a lack of a reaction from the brand may be described as *qui tacet, consentire videtur*; while imitation, on the other hand, can be perceived as inauthentic (Zhao, Yim & Peng Cui,

2025). In this context, corporate activism will be perceived more authentic and original if only a few competitors argue or advocate the same issue. What is more, being the only one to advocate for an issue is perceived as original, showing that the company is truly concerned about the issue, and is not only following suit (Parcha and Kingsley Westerman, 2020). In the context of a timely response, brands that react quickly and show no hesitation to an event that requires taking a stand are perceived as more authentic, especially with causes that are not highly divisive (Nam et al., 2023), which is the case with many environmental issues.

Finally, if consumers believe that a brand is selective in choosing a cause to advocate, i.e. it openly supports one cause, but fails to support a similar cause or the same cause but in a different setting, the consumers will perceive this to be hypocritical, which will negatively influence their attitudes (Malik, Ahmad & Guzmán 2025).

Research opportunity 2:

How does the company CSR history influence consumers' perceptions of brand activism around divisive issues, if there is a (mis)alignment of values? How does it serve as reputational "insurance" around highly divisive activism? How do newer generations (Z, Y) respond to perceived (in)authenticity? How do brands with no history of corporate activism approach brand activism to ensure authenticity?

CONSUMER REACTION AND MORAL (DE)COUPLING

Brand activism is purpose-driven, i.e. it demonstrates ethical values and beliefs that go beyond making profit (Kotler and Sarkar, 2017). For such activism to be received positively, brand values must align with consumer values, as this alignment is the key driver in shaping consumer attitudes towards the advocated issue (Zhao, Cui & Du, 2024). While some data suggests that a third of consumers will make purchase decisions based on brand purpose and value (Amed et al., 2019), and two thirds are willing to buy or boycott based on social stance, the most recent polls suggest that the market is divided. Specifically, recent surveys (conducted by Gallup and NBC) have found that nearly half of consumers believe that companies should not engage with politics at all (Weber, Joireman & Sprott, 2025).

The importance of value as a criterion for assessing brand activism can be connected to moral (de)coupling proposed by Mukherjee and Althuizen

(2020). When a brand's and consumers' moral values align, the consumers tend to identify more with the brand, although this does not necessarily translate into a significant increase in support for the brand. However, in cases of value misalignment, consumer identification with the brand becomes lower, in which case consumers either rationalise the issue or resort to moral coupling or decoupling. Moral coupling occurs when consumers connect the brand's values with the brand itself. In this case, value misalignment is transferred to the brand's attributes, which is an unfavourable outcome for the brand. Conversely, moral decoupling means separating the brand's controversial stand from the brand's attributes, which can be a strategy to help brands protect themselves from the potential backlash.

Mukherjee and Althuizen (2020) proposed that in order to ensure more positive perception, brands can facilitate the decoupling by choosing a cause that is not strongly associated with the brand itself. In this case, the disagreeing consumers will separate the position from the brand. The research has also confirmed an asymmetric effect of brand activism, with the negative impact of disagreement (lower evaluations and purchase intentions) being stronger than the positive impact of agreement, which consumers take for granted (Jungblut and Johnen, 2021; Haupt et al., 2023). This asymmetry is even riskier for large-share brands, which are more likely to lose alienated customers than gain new ones, whereas small-share brands may have a net-positive result from taking a stand (Hydock, Paharia & Blair, 2020).

Finally, consumer reactions can range from positive ones, such as buycott – which reward value-alignment through deliberate purchasing (Jungblut and Johnen, 2021) – to negative ones, such as boycott and even cancellation. Boycott is used to express consumers' negative feelings, reflecting a decision to avoid a particular brand as a result of the misalignment in political or ethical values (Jungblut and Johnen, 2021), thus punishing the company for its behaviour or business practice. Finally, in the case of consumers' perception of "irreparable transgression" (Demsar et al., 2023, p. 323), consumers may call for the brand to be cancelled. Ultimately, although the value-based activism can strengthen brand equity, brand loyalty, and consumer-brand identification (Cammarota et al., 2023) especially among certain demographics like Gen Z (Tuan, Visentin & Di Domenico, 2023), the following important questions remain: What happens if the chosen path towards pursuing societal change means departing from the values or ideology dominant among a segment of loyal customers? How can companies fulfil the criteria of social responsibility without antagonising the customers with different values?

RESEARCH OPPORTUNITY 3:

What are the conditions affecting the consumers' choice of engaging in moral decoupling rather than coupling, when faced with value misalignment? How does the asymmetric effect of brand activism change over time? What determines the length of boycott? Can moral decoupling facilitate restoring and preserving brand loyalty?

Table 1. Research opportunities in brand activism

	Theme	**Key mechanism**	**Research opportunities**
1	Political ideology	Ideological (mis)alignment	How does the country's dominant ideology affect the perception of brand activism among consumers with diverse ideology affiliations (liberal to conservative)? How does ideology affect the consumer perception of the of issue of divisiveness and controversy? How does a "business-friendly" environment mitigate negative reactions of conservative customers when a brand takes a progressive stand? How does brand activism affect the attitude of the general public about the contested issue? To what extent does ideological (mis)alignment lead to consumers abandoning the brand's traditional base?
2	Authenticity	Perceived motivation and CSR history	How does the company CSR history influence consumers' perceptions of brand activism around divisive issues, if there is a (mis)alignment of values? How does it serve as reputational "insurance" around highly divisive activism? How do newer generations (Z, Y) respond to perceived (in)authenticity? How do brands with no history of corporate activism approach brand activism to ensure authenticity?
3	Moral (de) coupling	Value (mis) alignment and consumer response	What are the conditions affecting the consumers' choice of engaging in moral decoupling rather than coupling, when faced with value misalignment? How does the asymmetric effect of brand activism change over time? What determines the length of boycott? Can moral decoupling facilitate restoring and preserving brand loyalty?

CONCLUSION AND KEY IMPLICATIONS

Brand activism has emerged in recent years as a response to customers' expectations from firms to take a stand on relevant sociopolitical and environmental issues. Despite growing literature on the subject, the research remains rather fragmented. Therefore, this paper has provided an overview of the current literature, and has highlighted some of the key areas that could be relevant in the context of environmentalism and sustainability initiatives. By examining the roles of political ideology, perceived authenticity and moral (de)coupling, the study sheds a light on the mechanisms determining the consumers' response on the spectrum from buycott to boycott, as a reflection of backlash. The review indicates that although brand activism offers a path for firms to contribute to public interest and the general good by driving a social or environmental change, it is characterised by a significant asymmetric effect, where the risk of alienating customers can outweigh the rewards of alignment.

The paper proposes a research agenda centred on three key opportunities, in order to deepen the understanding of this phenomenon. Firstly, there is a need to explore the role of ideology, both in terms of national politics and individual consumer affiliations, regarding the engagement in and the perception of brand activism. Secondly, future studies could focus on the effect of history of social responsibility as a factor mitigating radical brand transformations, particularly in the case of a brand's shift from its traditional market identity. Finally, the study of the role of moral (de)coupling can be expanded to determine the conditions under which consumers choose to separate a brand's controversial stance from its features and attributes, as this may serve as a brand strategy to mitigate the potentially negative effects of brand activism.

From an academic perspective, this paper contributes to the synthesis of a fragmented field by examining it through three key lenses, including both institutional context and individual response mechanisms. As for managerial implications, the findings suggest that firms should consider the high-risk nature of not only brand activism per se, but also of strategic decoupling from their traditional identities. Any misstep in terms of authenticity and value (mis) alignment may lead not only to reputational damage, but also to losses in the market share following a negative backlash.

Finally, several limitations must be acknowledged. First, the insights presented are based solely on the narrative literature review, with more than 50% of the analysed papers originating from top-tier marketing journals, while the remaining sample comprises specialised journals and multidisciplinary sources. While providing a theoretical foundation, this also prioritises consumer

behaviour over a more multi-disciplinary perspective related to sustainability and environmentalism. Second, this study lacks primary data, therefore further empirical research is needed. Addressing the identified research opportunities with real-world empirical studies would further advance the field, and clarify the extent to which the proposed theoretical mechanisms are valid in diverse economic and cultural systems.

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ENERGY CROWDFUNDING – AN ANALYSIS OF EUROPEAN CAMPAIGNS ON KICKSTARTER

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One of the major problems in the world today is global warming. Namely, global warming is likely to reach 1.5 degrees Celsius between 2030 and 2052 if it continues to increase at the current rate. In view of the above, especially from policymakers' point of view, it is important to reduce fossil use, as well as to promote low-carbon electrification. Furthermore, it is essential to foster the renewable energy (RE) transformation in order to achieve the goals of the Paris Agreement. For this purpose, it has been estimated that 275 trillion US dollars in cumulative investments in renewable energy will be needed by 2050. Banks and governments are unable to cover the different kinds of projects, especially renewable energy projects that are riskier – therefore, crowdfunding appears as a viable alternative finance tool. Crowdfunding represents an alternative source of finance where people/projects can collect the necessary amounts of money by using internet platforms to finance various projects. On the other hand, people all around the world can lend support or invest in any project by providing small amounts of money. Different crowdfunding subtypes exist nowadays, such as green crowdfunding, energy crowdfunding, etc. Energy crowdfunding is a method of financing energy-related projects. Those projects include renewable energy installations such as solar, wind, hydro, and energy efficiency improvements. The possibility of financing renewable projects through crowdfunding is an underexplored area, as are the success factors for those kinds of projects. Consequently, we extracted 60 European crowdfunding campaigns from the Kickstarter plat-

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form by searching for the following keywords in campaign blurb and slug: "energy", "solar", "wind", "renewable", "hydro", and "biofuel". Logistic regression was performed on the extracted campaigns, where campaign success was a binary dependent variable, and the following three predictors were included: campaign goal, campaign duration, and number of backers. Logistic regression results show that the number of backers and duration are statistically significant at the level of 5%, whereby an increase in backers count raises the success probability, and duration has a negative effect.

Keywords: *green crowdfunding, sustainable, success determinants, finance, CEE*

JEL classification: *G11, G20, G40, Q01, Q56,*

INTRODUCTION

The increase in world population has led to a drastic demand for energy (Vivek et al., 2021). Furthermore, the economic and technological progress also increases energy consumption. Oil, coal and natural gas, the so-called fossil fuels, as well as nuclear energy, are known as non-renewables. The use of fossil fuels results in a significant amount of greenhouse gas emissions, which, consequently, negatively affects the global ecosystem (Dirma et al., 2024; Kuman and Rathore, 2023). The negative effects are evident through global warming, which is likely to reach 1.5 degrees Celsius between 2030 and 2052 if it continues to increase at the current rate (Appiah-Otoo et al., 2022). The use of energy is essential for the modern civilization today, however, to save the planet, it is necessary to turn to alternative, green energies (Kuman and Rathore, 2023) since more than 80 percent of the world's energy comes from non-renewable sources (Deshmukh et al., 2023). Those types of energy sources must be sustainable and renewable. Renewable energy (RE) is a kind of energy that can be reproduced, i.e. is inexhaustible in nature. The sources of renewable energy can be wind, solar, hydroelectric, biomass, geothermal, tidal, etc. (Deshmukh et al., 2023). Although there is an agreement on the reduction of the use of fossil fuels and the transition to renewable energy, one major problem still exists – the need for a large amount of capital that would enable this transition (Horly, 2024; Horky and Martin, 2024; Mukherjee et al., 2024; Appiah-Otoo et al., 2022). Furthermore, investment in RE projects involves some challenges such as lack of traditional financing options, risk perception, policy and technology uncertainty, information asymmetry between investors and entrepreneurs, regulatory and policy sup-

port, lack of financial literacy and investor awareness, low rates of return, etc. (Mukherjee et al., 2024; Le et al., 2020).

Moreover, for that reason, countries must ultimately take into account that climate risk translates into financing risk, because investment costs in technologies associated with renewable energies are higher and often ambiguous. Banks and governments are unable to cover those kinds of projects, especially renewable energy projects that are riskier; therefore, crowdfunding appears as a viable alternative finance tool (Menyeh and Acheampong, 2024; Prasetyo and Dazki, 2024). According to Mukherjee et al. (2024) it is necessary to "*understand the underlying dynamics of success and failure among crowdfunded ventures*". Regarding Europe, there is still a lack of fostering citizen participation in the financing of these kinds of projects, primarily through crowdfunding, due to the focus of EU policy on institutional sources of finance (Eurocrowd, 2025).

The contribution of this paper is manifold. First, it provides a theoretical overview of EU energy crowdfunding, which enriches the limited literature. The second contribution relates to the identification of success determinants for Kickstarter energy crowdfunding campaigns located in EU countries. To the best of our knowledge, this is the first study focused on energy crowdfunding in the EU region exclusively. It was observed that statistically significant predictors for campaign success include the number of backers and project duration, with the project goal being only weakly significant. These results are in line with the findings presented in other studies addressing renewable energy campaigns on other platforms. Since the field of energy crowdfunding is underexplored, our study contributes to a better understanding of the factors affecting successful financing via crowdfunding platforms.

The organization of the paper is as follows. After the introduction, a theoretical review of renewable energy, energy crowdfunding, and success determinants is provided. After that, the methodology is explained, which includes data collection, measures, data analysis, results, and implications. The paper ends with the conclusion and references.

THEORETICAL REVIEW

RENEWABLE ENERGY

Renewable energy (RE) represents a critical field of research due to the rising concerns regarding sustainable development, climate crisis, and energy security (Mukherjee et al., 2024). For a sustainable development of the mod-

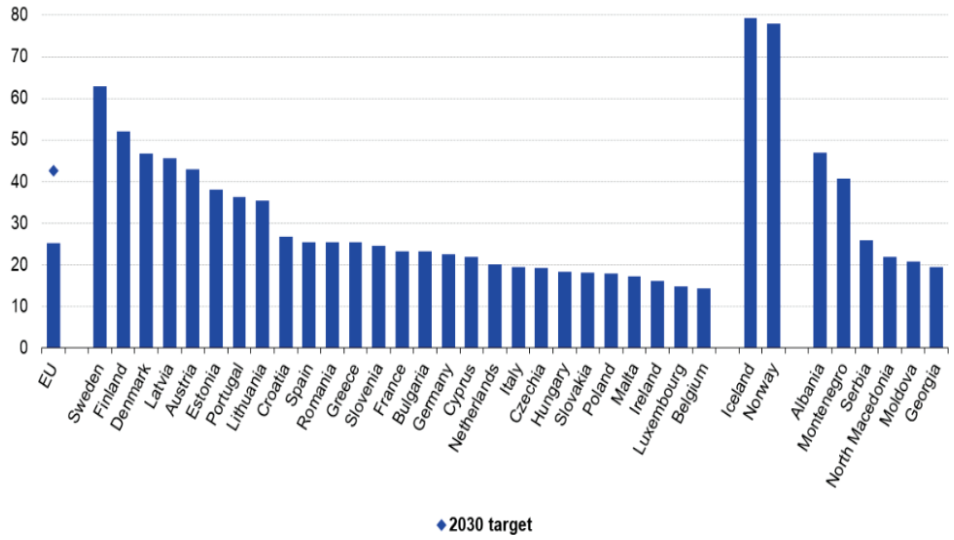
ern society and the world today, the use of renewable energy sources (RES) is crucial. The use of RES has a significant effect on the economy of a country, job creation, technology development, and economic and social well-being (Dirma et al., 2024).

Renewable energy is a type of energy that can be reclaimed and reproduced (Deshmukh et al., 2023). It includes the energy from wind, sun, tides, water, and geothermal heat (Mukherjee et al., 2024; Deshmukh et al., 2023). Due to the non-existence of trading history and the novelty of technologies, RE projects are viewed as highly risky projects. In addition, high information asymmetry, lack of financial literacy, and absence of predictable and consistent regulation and government policies toward RE also affect the growth of risk (Mukherjee et al., 2024).

The possibility of RE production depends on a heterogeneous set of technologies, and its use varies between regions and countries. This is not the only factor that affects the use of RE. It also depends on a supportive policy framework, favorable economic conditions, and financial situation. In the EU, a lot of the legislation has been changed to promote the use of RES. Namely, EU leaders are committed to ensuring that approximately 50% of all EU's energy consumption derive from RES by 2030, whereby it is expected that 65% of all global electricity should come from RES in the same period (Dirma et al., 2024).

Looking at the share of energy derived from renewable sources in European countries, vast differences are also observable. The target share to be achieved by 2030 amounts to a little above 40%, and the average for EU is around 25% (Figure 1). Sweden has the highest percentage, a little above 60%, whereby Belgium has the lowest percentage in the EU.

Figure 1. Share of energy from renewable sources in 2024



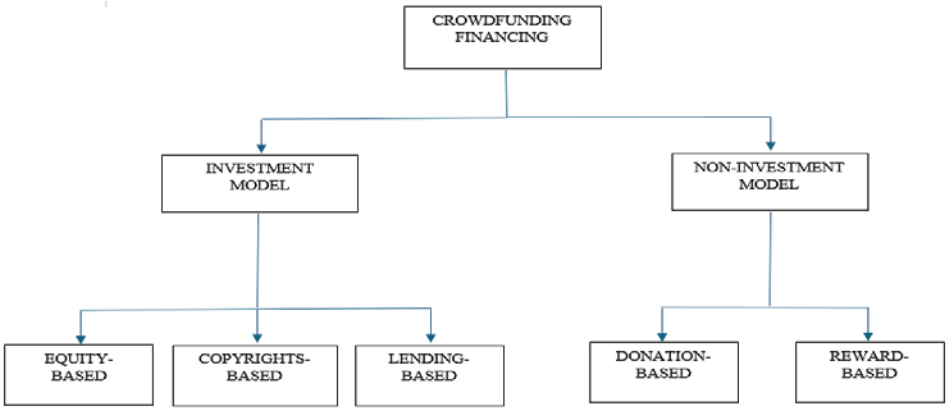
Source: Eurostat (2025)

ENERGY CROWDFUNDING

In 2008, the development of crowdfunding significantly accelerated amidst the financial crisis, largely due to the scarcity of traditional financing options such as venture capital, business angels and bank loans, combined with the rise of Web 2.0 technologies that enhanced the communication and interaction among users (Đurđenić, 2017; De Broeck, 2018; Krok, 2019). Crowdfunding represents a digital transformation in finance, whereby products, ideas or projects are funded through the collective contributions of many individuals via the Internet on various crowdfunding platforms (Ninčević Pašalić and Pepur, 2022). It forms part of a broader alternative finance market (Bergmann et al., 2021). According to Shala (2022), the crowdfunding market volume is anticipated to reach $300 billion by 2025, surpassing traditional investments from business angels and venture capitalists. Crowdfunding platforms are internet websites, which do not borrow, lend, or aggregate money for themselves; instead, they enable backers to invest directly (Hariwibowo, 2024). Backers are seen as novel investors who invest small amounts of money in different projects (Mukherjee et al., 2024). Crowdfunding models can be (Wanchuk,

2021) a donation CF, reward CF, peer to peer CF, equity CF, or share based CF. According to Ninčević Pašalić and Pepur (2022), crowdfunding models can be divided into investment and non-investment models (Figure 2).

Figure 2. Crowdfunding classification



Source: Ninčević Pašalić and Pepur (2022)

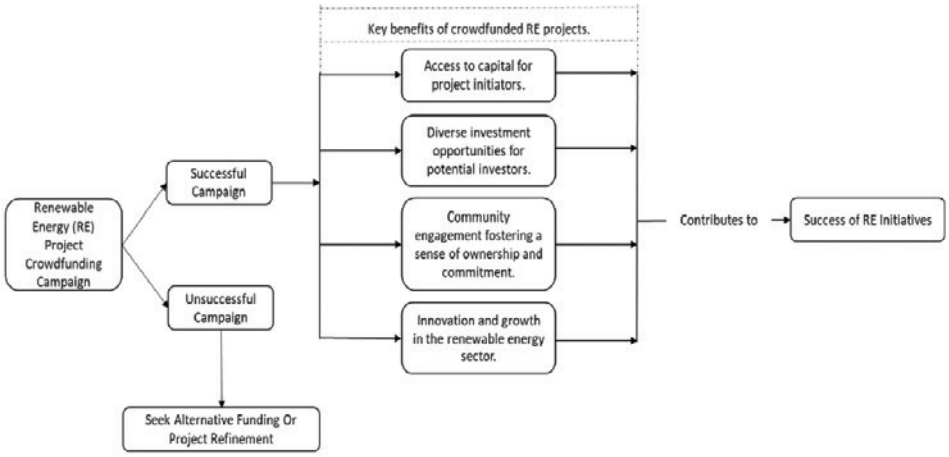
In the early development stages of sustainable energy and other green initiatives, particularly during the ideation and prototyping phases, donation-based and reward-based crowdfunding emerged as especially appropriate financing instruments due to the pronounced need for seed capital (Adhami et al., 2017; Yin et al., 2024). In light of this, the literature generally distinguishes two core forms of green crowdfunding (Yang et al., 2019): donation-based campaigns, which are oriented toward non-profit activities focused on environmental protection and the promotion of a sustainable ecological environment, and reward-based campaigns, predominantly employed by entities that market environmentally friendly products or services. Green-oriented investments and projects span a broad array of domains (Stein, 2024; FasterCapital, 2024). They cover a wide range of activities, and renewable energy is one of the fields covered. It includes wind, solar, geothermal, hydro and biomass technologies. The improvement of energy efficiency and conservation, building greenhouses, smart grids and advanced energy storages is another field. Furthermore, organic farming, agroforestry, reforestation and afforestation are part of food systems and sustainable agriculture which also form part of green projects. Another field of green projects are sustainable transport solutions. They include public transit, electrical vehicles and alternative fuels.

Furthermore, they include recycling initiatives and waste management based on circular economy principles, waste-to-energy processes and various forms of pollution control. This classification illustrates the growth of green crowdfunding as a financing mechanism capable of supporting a wide spectrum of environmentally oriented projects and innovations.

The use of crowdfunding for RE projects has some benefits (Figure 3). Namely, it enables the following:

- Project initiators have access to necessary capital.
- Investors can invest in RE projects that they believe in.
- Broader community is engaged in RE initiatives.
- Growth and innovation occur in the RE sector.

Figure 3. Benefits of crowdfunding for RE projects



Source: Mukherjee et al., 2024

Even with this potential, a financing gap persists for renewable energy projects (REPs) funded via crowdfunding. According to Bergmann et al. (2021) in 2017, approximately €42.7 billion was invested in REPs through alternative finance channels, whereas only about €300 million was mobilized through crowdfunding. Conventional investors frequently refrain from supporting sustainable ventures because they perceive them as comparatively risky and less profitable, thereby confining crowdfunding to a complementary role in the capital structure of sustainable entrepreneurs (Tenner and Blöcker, 2021). At the same time, Bento et al. (2019) emphasize that existing research has yet to establish a robust theoretical or empirical consensus on the extent to

which a venture's sustainability orientation affects the probability of success in crowdfunding campaigns. Moreover, several important research and policy gaps remain in the field of green crowdfunding, particularly in developing and emerging economies. These include limited evidence on the social impact of equity-based crowdfunding, insufficiently developed regulatory frameworks and an underexplored understanding of how green crowdfunding can foster financial inclusion. Crowdfunding can nonetheless contribute to sustainable development in low-income countries by improving access to clean technologies. For this potential to be fully realized, policymakers are encouraged to mitigate perceived risks associated with sustainable projects, and to strengthen the dissemination of relevant information, thereby enhancing the overall effectiveness of crowdfunding for green initiatives (Caré et al., 2025).

Furthermore, it is necessary to point out that recent EU policy reports dating from September 2024, including the Draghi report and mission statements from the new European Commission leadership, underscore the priority of institutional investments, venture capital, and large-scale financial mechanisms to bolster European competitiveness and advance the green and digital transitions. While these strategies are indispensable, EUROCROWD (2025) posits that citizen-led investments, notably via crowdfunding, constitute a vital complementary mechanism to institutional finance. This approach promotes inclusive, resilient development with pronounced local impact. Moreover, for sectors that cannot obtain enough capital through institutional finance, crowdfunding is able to unlock the necessary capital. Additionally, while the Draghi report underscores the necessity of expanding institutional investments to realize Europe's growth imperatives, crowdfunding emerges as a distinctive antidote to the fragmentation inherent in Europe's capital markets. It delivers indispensable early-stage financing to start-ups, niche innovators, and regional entrepreneurs who are often excluded from conventional funding channels. By mobilizing citizens' savings, crowdfunding injects novel capital into the European investment ecosystem, thereby empowering ordinary individuals to contribute actively to wealth generation and the innovation pipeline.

Although citizen engagement in financial markets remains insufficiently harnessed, crowdfunding holds significant potential to redress this shortfall. Unlike institutional frameworks, it fosters direct individual involvement, affording participants a tangible interest in ventures that resonate with local priorities and the social economy.

Studies addressing the success factors of reward-based CF campaigns resulted in different factors and their significance. Some studies focused on the information description, some on the duration and goal, while some combined those two aspects (Mollick, 2014; Šimić Šarić and Musap, 2024; Corsini and Frey, 2023).

Predkiewicz and Kalinowska-Beszczyńska (2020) examined the key elements influencing the outcomes of environmental initiatives on eleven reward-style crowdfunding sites. Their findings highlighted that frequent updates and user comments, along with rewards offered, detailed profiles of teams or creators, and mentions of past achievements, all boost success rates. In contrast, aiming for a larger funding target tends to hinder these eco-focused efforts. Corsini and Frey (2023) explored how crowdfunding might drive progress in eco-friendly product development, while identifying success drivers for such ventures on platforms like Kickstarter and Indiegogo. From a pool of 200,000 campaigns, they pinpointed 3,082 sustainability-oriented ones – equating to only 1.5% of the total. Higher funding goals and extended campaign timelines emerged as major drags on success odds, therefore statistically speaking, raising failure risks. On the flip side, lengthier project descriptions packed with sustainability-focused keywords strongly correlated with better results, also holding statistical weight. Meanwhile, Yin et al. (2024) scrutinized 720 nature-themed campaigns on GoFundMe, factoring in elements like runtime, funding targets, location, title length, intro text volume, common phrasing, emotional tone in descriptions, and images featuring human faces. Only the intro length, overall duration, and title brevity proved influential on outcomes, while the rest lacked clear statistical ties to performance. Yang et al. (2019) investigated a total of 1,389 eco-focused campaigns on China's Tencent Lejuan platform, employing a non-linear approach to forecast success based on goal levels, pledged amounts, and runtime. They stressed that campaign creators must weigh goals and duration thoughtfully, as the effects of these factors vary – sometimes boosting odds, occasionally dragging them down, or showing no clear sway.

Yao (2025) delved into Indiegogo projects to gauge the "green premium" for sustainable ones compared to conventional efforts. Key metrics included backer counts, comments, description word counts, image numbers, and creators' prior crowdfunding history, with controls for goals, length, updates, and pricing tiers. Findings revealed non-sustainable projects boasting more images, feedback, supporters, and experienced leads, yet shorter text. Sustainable counterparts featured steeper goals, prolonged runs, fewer pricing choices, and reduced updates. Caré et al. (2025) added that supporters of green initiatives often chase motives transcending pure financial gains.

Siebeneicher et al. (2022) analyzed a dataset of 434 crowdfunding campaigns from Germany and Austria. According to them, the success of a campaign is not only connected to the sustainable orientation of the campaign. Moreover, there is no effect of duration on the campaign success.

Figure 6 summarizes the determinants that influence the fundraising outcomes, however the focus on sustainable and eco projects is still rare in the literature.

Figure 6. Determinants influencing crowdfunding outcomes

Paper	Factors
de Larrea et al. (2022)	Images Communication with donors Title length Description length
Ho et al. (2021)	Title Project description length Location Visual presentations
Mollick (2014)	Personal networks Project quality Geography
Rossolini et al. (2021)	Campaign information structure Environmental protection purposes Goal size
Salahaldin et al. (2019)	Duration
Yuan (2016)	Textual content Topical feature

Source: Yin et al, 2024., p. 3

Due to all of the abovementioned, the following three hypotheses where set:

H1: The number of backers positively affects the success of energy crowdfunding campaigns from EU countries.

H2: The project goal negatively affects the success of energy crowdfunding campaigns from EU countries.

H3: The duration of a campaign negatively affects the success of energy crowdfunding campaigns from EU countries.

METHODOLOGY

DATA COLLECTION

The analysis of the success determinants of energy crowdfunding campaigns from European countries was performed using the Kickstarter cam-

paigns data provided by Webrobots.io in CSV format. The data included crowdfunding campaigns in the period from the beginning of 2010 to the end of 2024. The campaigns of interest were extracted using Python programming language and the following three criteria:

- Keywords in campaign blurb and slug included: “energy”, “solar”, “wind”, “renewable”, “hydro”, and “biofuel”.
- Campaign location was in one of the EU countries.
- Campaign state: successful or failed.

After the usage of the Python extraction script, additional manual filtering was performed to exclude campaigns not related to energy crowdfunding. In total, 60 campaigns were detected and used to apply descriptive statistics and logistic regression.

MEASURES

For the analysis of success determinants for energy CF campaigns from Europe, campaign success was set as a binary dependent variable, and the three predictors included the number of backers, project goal, and duration of the campaign. Table 1 summarizes the description of those three predictors.

Table 1. Predictors and their description

Predictors	**Description**
Number of backers	The number of backers represents the number of campaign supporters (funders/investors). Project creators create and present promotional materials to encourage potential backers to invest.
Project goal	The project goal is the target amount that the project creator plans to raise with a crowdfunding campaign. Project costs should be calculated carefully to set an adequate goal. Setting a low target amount increases the risk of project failure, while a high target amount decreases the campaign’s success probability. In addition, in order to run a better media campaign, it is necessary to set a satisfying project goal.
Duration of the campaign	Duration is determined before campaign launch by setting the end date. It is related to the time required for campaign promotion, and therefore, it should not be too short. On the other hand, long duration can indicate the founder’s uncertainty regarding his/her own project. A campaign can be stopped before the deadline if it failed or if multiple target amounts were achieved. In relevant research, it has been shown that campaign duration is a significant determinant of campaign success, where successful campaigns have shorter duration.

Source: authors

The previously described predictors were chosen because they represent the fundamental economic and psychological mechanism of crowdfunding. The number of backers measures the demand and represents a signal of campaign credibility in the information asymmetry environment (Mamaro, 2025). It is related to herding behavior, where a high number of existing backers motivates new potential backers to support a campaign. The project goal represents the financial requirement and acts as a signal of campaign risk and ambition. A high project goal can signal to the potential backers that a campaign is overambitious, leading to campaign failure (Mollick, 2014). Campaign duration includes a temporal dimension enabling the regression model to distinguish campaigns raising the same amount, but in time intervals of different duration. Shorter campaigns create the impression of urgency that motivate backers, while longer campaigns can indicate a lack of momentum, which is related to marketing fatigue experienced by backers.

Table 1 presents the descriptive statistics for observed variables. According to the data, the mean value for the number of backers who supported the campaigns is 117.8, i.e. nearly 120 backers per campaign. The maximum value equals to 1121 backers, while the minimum number of backers who supported a campaign equals to 0. The data show a large range in the number of backers per campaign. The mean value for the project goal is $34956.24, with a minimum value of $50 and a maximum value of $400000. The standard deviation amounts to $66598.12. The average value of campaign duration is 35.60 days, with a minimum value of 7.26 days and a maximum value of 60.04 days.

Table 2. Descriptive statistics

Variable	Mean	Standard Deviation	Min	Max
Number of backers	117.8	231.28	0	1121
Project goal ($)	34956.24	66598.12	50	400000
Duration (days)	35.60	12.59	7.26	60.04

Source: authors

DATA ANALYSIS AND RESULTS

Logistic regression analysis was applied to the model relation between binary dependent variable campaign success and the three predictors: number of backers, project goal and campaign duration. Before applying logistic regression, multicollinearity and heteroscedasticity were tested. The VIF values in

Table 3 indicate that no multicollinearity exists between the predictors, while the p-value of Breusch-Pagan Test equal to 0.125 shows that there is no statistically significant evidence of heteroscedasticity.

Table 3. VIF results for logistic regression model

Variables	VIF (model 1)
Number of backers	1.05
Project goal	1.22
Duration	1.21
Constant	9.38

Source: authors

The results presented in Table 4 show that the number of backers and project duration are statistically significant at the 5% level. However, the effect of these predictors is opposite: while a higher number of backers increases the success probability, longer duration negatively affects the chance of fundraising. The project goal is only marginally significant at the 10% level, and it also exhibits a negative effect. Negative effects of longer campaign duration and higher funding goals correspond to the findings presented in Corsini and Frey (2023). Furthermore, the LLR p-value indicates that the model is statistically significant, while the values of Pseudo R-squared and Naglekerke's coefficients suggest that the chosen predictors have a strong correlation with project success.

Table 4. Logistic regression results

Variables	Model 1
Number of backers	0.0299** (0.014)
Project goal	--3.787e-05* (1.97e-05)
Duration	-0.0595** (0.027)
Constant	-0.5109 (0.597)
LLR p-value	7.863e-08
Pseudo R-squared	0.4316
Nagelkerke's pseudo R-squared	0.6004

Standard errors are shown in parentheses **p<0.05; *p<0.1

Source: authors

Despite the fact that due to a small number of observations the logistic regression model was limited to three predictors, this was sufficient for the baseline model because the predictors cover three basic elements required for market transaction: price (project goal), demand (number of backers) and time (campaign duration). Since the dataset was small, other relevant variables, such as creator's experience, number of updates and comments, sentiment of textual description etc., were excluded.

CONCLUSION AND IMPLICATIONS

Energy transformation from the use of fossil fuels to renewables is one of the most important goals for EU countries. Namely, the climate goal is to reduce the greenhouse gas emissions by 55% until 2030, as well as to increase the use of energy from renewable sources such as wind, solar, biomass, etc. The main reason for these actions is to reduce or to slow down the temperature rise, since Europe is the fastest warming region in the world. In order to achieve these goals, huge capital is necessary. Considering the limited resources available from different institutional investors such as banks, venture capital etc., policymakers must find additional sources of capital. In this light, crowdfunding appears as a viable solution. Crowdfunding represents an important method of financing energy-related projects that face challenges such as lack of traditional financing options, risk perception, and policy and technology uncertainty, information asymmetry between investors and entrepreneurs, regulatory and policy support, lack of financial literacy and investor awareness, low rates of return, etc. According to the obtained results, the number of backers and duration are statistically significant, but have opposite effects. The probability of success increases with a higher number of backers, whereby longer duration leads to a lower probability of success. Furthermore, if the set goal is higher, then the probability of success is lower. The obtained results are in line with the results described in theory.

Regarding the financing of energy projects, policymakers and institutions should provide more in-depth information about the necessity of financing these kinds of projects, as well as raise awareness among citizens about it. Furthermore, young people in schools and universities should be more educated about the use and importance of utilizing renewable sources.

The main limitations of the study lie in the small number of campaigns. A higher number would enable a deeper analysis and more complex conclusions. Furthermore, more in-depth analyses of individual EU countries would provide a better understanding of the energy transition, due to the high differences

among countries. An additional limitation also relates to the use of the variable number of backers as exogenous, although it simultaneously functions as both an outcome and a signal.

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CLUSTER ANALYSIS OF THE EUROPEAN UNION PASSENGER CAR MARKETS: ELECTRIFICATION PROGRESS AND STRUCTURAL TRANSITION PATTERNS

Tomislav KOROTAJ *

The passenger car markets in the European Union (EU) are undergoing a period of profound transformation. Regulatory pressures linked to the EU's green transition agenda, alongside the accelerated electrification of vehicles, have intensified both academic and policy debates. The European Green Deal introduced some of the most ambitious mobility-related climate targets in the world, including the requirement that new cars emit zero carbon dioxide by 2035. Assessing the feasibility of these goals requires continuous monitoring of market developments, as well as an integrated understanding of the structural factors that influence national transition trajectories. The purpose of this paper is to examine the extent to which passenger car markets across EU Member States exhibit similar or divergent characteristics, and to identify the degree of heterogeneity that underlies the green transition process. Particular attention is also given to identifying Croatia's position relative to the other EU Member States. In order to construct a comprehensive picture, the study analyses a sample of 24 EU countries using the most recent fully available data for 2023, sourced from the European Automobile Manufacturers' Association (ACEA). Six variables capturing structural, technological, environmental and infrastructural dimensions of the passenger car market were selected: average age of the passenger car fleet, motorization rate, share of electrified cars (battery electric, plug-in hybrid and hybrid electric vehicles), share of diesel-powered cars in the total fleet, average carbon dioxide

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emissions from new passenger cars, and number of public charging points per 1,000 passenger cars. Since the variables were measured on different scales, all data were standardized prior to analysis. A multivariate approach combining hierarchical and non-hierarchical clustering techniques was employed. In the first stage, several dendrograms were generated using different algorithms, with Ward's method and squared Euclidean distances yielding the most meaningful structure. Among the solutions ranging from two to four clusters, a three-cluster configuration was identified as the most interpretable. In the second stage, this three-cluster solution served as the initial partition for a k-means clustering procedure. The k-means algorithm reproduced a cluster composition identical to the one obtained via Ward's method, indicating strong structural stability and robustness of the results. Cluster 1 comprises six countries (Austria, France, Germany, Italy, Slovenia, and Luxembourg) characterized by moderate electrified-vehicle uptake, intermediate charging-infrastructure density and mid-range emissions from new cars. Cluster 2 includes Croatia and twelve additional countries (Lithuania, Spain, Estonia, Ireland, Portugal, Hungary, Romania, Latvia, Czechia, Poland, Slovakia, and Greece) that collectively exhibit the lowest levels of electrification, the weakest charging infrastructure, higher emissions and older car fleets. Cluster 3 consists of five countries (Belgium, Denmark, Finland, the Netherlands, and Sweden) with the highest electrification levels, the densest charging infrastructure and the lowest emissions. Overall, the cluster profiles demonstrate that EU passenger car markets are structurally differentiated, and reflected markedly uneven progress toward low-carbon mobility in 2023.

Keywords: *passenger car market, European Union, electrification, carbon dioxide emissions, clustering*

JEL classification: *C38, L62, Q53, Q58*

INTRODUCTION

EU passenger car markets have faced substantial challenges over the past decade. The emissions scandal commonly referred to as "Dieselgate," which culminated in 2015 with accusations against the German automobile manufacturer Volkswagen Group, is widely regarded as the beginning of the decline of diesel-powered passenger cars in Europe. The manipulation of emissions tests resulted in financial penalties exceeding 30 billion euros for Volkswagen, and

marked a critical turning point for the European car markets (Kodjak, 2025). Following the scandal, passenger car markets entered a period of structural change, driven by stricter emissions regulations, new EU policy initiatives and targets, declining consumer demand for diesel vehicles, and a growing interest in electric mobility. Together, these developments signalled a clear shift for automobile manufacturers toward electrification and broader green transition.

The EU has continuously pursued policies aimed at achieving the objectives of the green transition in the passenger car market. To this end, several regulatory initiatives have been introduced, the most prominent being the European Green Deal, adopted in 2019. Among its key objectives, the Green Deal establishes an ambitious target of achieving zero carbon dioxide (CO2) emissions from newly registered passenger cars by 2035. A central instrument for implementing this objective is the "Fit for 55" legislative package, introduced in 2021 and further developed in 2023. In addition to reaffirming the 100% reduction target for 2035, the package sets an intermediate milestone for 2030, requiring a 55% reduction in carbon dioxide emissions from new cars relative to the 2021 limit of 95 g CO2/km (Erbach, 2023).

The decarbonisation of road transport represents a key political priority for the EU. Passenger cars alone are estimated to account for approximately 12% of the total EU carbon dioxide emissions (European Commission, 2022). Addressing this challenge relies primarily on technological progress and the increasing electrification of vehicles. In order to accurately assess the developments in this area, it is necessary to distinguish between electric vehicles (EVs) and internal combustion engine vehicles (ICEVs). EVs are powered by electric motors and rely on onboard batteries, whereas ICEVs use conventional fuels such as petrol, diesel, or gas. Fully electric vehicles are classified as battery electric vehicles (BEVs), while combinations of electric and combustion technologies are referred to as hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs). The key difference between these hybrid types lies in their charging mechanisms: PHEVs, like BEVs, require external charging infrastructure, whereas HEVs recharge their batteries internally through regenerative braking. In the context of this paper, the focus is placed on passenger car electrification in a broader sense, and consequently, BEVs, PHEVs, and HEVs are jointly considered as a single composite category representing electric vehicles.

The situation in EU passenger car markets is highly dynamic and therefore requires continuous measurement and monitoring. According to ACEA data for 2023, the average age of the passenger car fleet across EU countries is 12.5 years. Petrol-powered vehicles account for approximately half of all cars

on the road, while diesel vehicles represent a further 39.5%. Electric vehicles remain relatively limited, with a combined share of 7.1%, comprising 1.8% BEVs, 2.1% PHEVs, and 3.2% HEVs (ACEA, 2025a). Despite recent progress, the continued dominance of vehicles powered by fossil fuels remains evident. This raises important questions regarding the feasibility of the European Green Deal's targets for 2030 and 2035. It should be noted that these targets apply exclusively to new car registrations rather than to the entire vehicle stock circulating on European roads in the reference years. Nevertheless, recent assessments by ACEA (2025b), the most authoritative industry organization in this field, indicate that current demand projections and the existing ecosystem – including charging infrastructure, subsidy schemes, and battery value chain solutions – are not yet aligned with the pace implied by the EU policy objectives.

Under increasing pressure from several European automobile manufacturers, on 16 December 2025, the European Commission announced its intention to reconsider the existing ban on the sale of new ICEVs, HEVs, and PHEVs from 2035 onwards. Subject to approval by the European Parliament, the proposed revision would lower the emissions-reduction target for new passenger cars from 100% to 90%, thereby allowing up to 10% of newly registered vehicles to continue using diesel, petrol, or other combustion-based powertrains, including hybrid technologies. This flexibility would be conditional on compensatory measures by car manufacturers, potentially involving the use of climate-neutral e-fuels, biofuels, or low-carbon steel in vehicle production. However, the specific criteria and mechanisms for such compensations have not yet been fully defined (ICCT, 2025).

The purpose of this paper is to examine the extent to which passenger car markets across EU Member States exhibit similar or divergent characteristics, and to identify the degree of heterogeneity that underlies the green transition process. Specifically, the paper aims to classify passenger car markets in 24 EU countries by applying cluster analysis based on structural, technological, environmental, and infrastructural indicators. The central research question is whether the EU passenger car market is characterized by pronounced polarization or by multiple identifiable groups of countries with distinct transition profiles. In addition, particular attention is devoted to identifying the position of Croatia relative to the other EU Member States within the resulting cluster structure.

The paper is structured in five parts. Following the introductory discussion of the EU's green agenda, developments in the passenger car market, and the push toward vehicle electrification, the second part provides a concise over-

view of relevant recent literature on the topic. The third part describes the data used and outlines the research methodology, with particular emphasis on the applied cluster analysis methods and the sequence of data processing steps. The fourth part presents the empirical results, accompanied by their interpretation and discussion. Finally, the fifth part summarizes the key findings and conclusions of the study, highlights its contribution, discusses the limitations, and outlines the directions for future research related to the analyses of passenger car markets in the EU.

LITERATURE REVIEW

Recent literature highlights the substantial heterogeneity in the passenger car markets of the EU, particularly with respect to diesel dependence, electrification, and environmental performance. Studies on intra-EU vehicle trade indicate that dieselization remains largely an internal EU phenomenon, with Eastern European countries acting as major recipients of used diesel vehicles exported from Western Europe (Rosal, 2022). This suggests that stricter environmental policies in some Member States may lead to a geographical redistribution of high-emission vehicles rather than their complete elimination.

The environmental effectiveness of vehicle electrification has also been questioned. De Palma, Lindsey, & Riou (2025) argue that electrification imposes significant costs on consumers and manufacturers, while its environmental benefits may be weaker than expected due to trade effects involving electric and internal combustion vehicles. Similarly, Šoltés Brezina, & Pekár (2021) found no clear evidence that higher EV penetration has yet resulted in significant reductions in CO2 emissions at the EU level, largely because overall adoption remains limited.

Country-level studies further emphasize the role of policy and infrastructure. Research conducted in Norway highlights the importance of tax incentives in driving plug-in hybrid adoption, while also raising concerns about the long-term fiscal sustainability of such measures (Pfaffenbichler et al., 2024). In Germany, charging infrastructure availability has been shown to have a significant positive impact on EV uptake, particularly in densely populated areas (Sommer & Vance, 2021).

Several papers have applied classification approaches in order to capture cross-country differences in transition performance. Kraciuk et al. (2022) classify EU countries based on their adoption of innovative energy technologies in road transport, and identify a group of leading countries (including Finland,

Sweden, and the Netherlands) and a set of lagging markets in Southern and Eastern Europe (such as Greece, Hungary, Estonia, Latvia, Poland, and Romania). Scenario-based analyses further project divergent electrification pathways across EU countries up to 2035, with subsidy withdrawal identified as a key risk to BEV adoption (Möring-Martínez, Senzeybek, & Jochem, 2024). Countries such as Sweden and the Netherlands are likely to achieve complete electrification, while others, including Greece and Poland, remain far from meeting zero-emission targets.

Much of the recent literature focuses on newly registered passenger cars and their powertrain composition, while largely overlooking the overall structure of national car markets, which encompasses the entire vehicle stock in use. This paper contributes to the existing research by addressing this gap through a multivariate cluster analysis of EU passenger car markets, offering a more comprehensive perspective on electrification and structural differences across Member States.

DATA AND METHODOLOGY

For this study, publicly available data from ACEA (2024a, 2024b, 2025a) were used. The analysis refers to the year 2023, which represents the most recent period for which complete and comparable data are available for all observation units. The sample comprises 24 EU Member States – Bulgaria, Cyprus, and Malta were excluded due to a higher incidence of missing data.

The empirical analysis is based on six variables selected on the basis of a literature review and data availability. Together, these indicators capture the structural, technological, environmental, and infrastructural characteristics of national passenger car markets. The variables include: the average age of the passenger car fleet (*cars_by_age*), the motorization rate measured as the number of passenger cars per 1,000 inhabitants (*motorization*), the share of diesel-powered passenger cars in the total fleet (*cars_diesel*), the share of electrified passenger cars (including BEVs, PHEVs, and HEVs) in the total fleet (*cars_electrified*), the average carbon dioxide emissions from new passenger cars expressed in grams of CO2 per kilometre (*CO2_emissions*), and the number of public charging points per 1,000 passenger cars (*chargers*).

Table 1 presents the descriptive statistics for the selected variables. Substantial cross-country variation is evident across all indicators. The average age of the passenger car fleet ranges from 8 years in Luxembourg (the youngest fleet) to 17.5 years in Greece (the oldest). Motorization levels also vary considerably,

with the lowest value recorded in Latvia (381 passenger cars per 1,000 inhabitants), and the highest in Italy (694). Pronounced differences were observed in powertrain composition: the share of diesel-powered cars ranges from 8.4% in the Netherlands to 62.6% in Latvia, whereas the share of electrified vehicles ranges from 0.7% in the Czech Republic to 15.9% in Denmark. Environmental performance differs markedly as well, with average CO2 emissions from new cars ranging from 60.9 g/km in Finland to 137.6 g/km in Slovakia. Finally, charging infrastructure density exhibits the widest relative dispersion, from 0.3 public charging points per 1,000 cars in Poland to 15.34 in the Netherlands.

Table 1. Descriptive statistics of selected variables

Variable	N	Minimum	Maximum	Mean	SD
cars_by_age	24	8,00	17.50	12.85	2.42
motorization	24	381.00	694.00	526.04	75.95
cars_diesel	24	8.40	62.60	40.83	14.55
cars_electrified	24	0.70	15.90	7.03	4.54
CO2_emissions	24	60.90	137.60	108.87	24.10
chargers	24	0.30	15.34	2.89	3.58

Source: Author's calculation based on ACEA data (2023), performed in TIBCO Statistica.

The descriptive statistics confirm a pronounced heterogeneity among EU passenger car markets and substantial differences in measurement scales across variables. For this reason, all variables were standardized prior to applying the cluster analysis.

Given the paper's objective of classifying passenger car markets across EU countries based on multiple market characteristics, cluster analysis is an appropriate methodological approach. Cluster analysis is a multivariate statistical technique in which objects in a dataset are grouped into disjoint subsets, called clusters, based on selected variables (Hennig et al., 2016). In this study, the objects of analysis are 24 EU Member States, and the clustering is based on six indicators capturing structural, technological, environmental, and infrastructural aspects of national passenger car markets.

The methodological framework combines hierarchical and non-hierarchical clustering methods in order to identify a stable and interpretable cluster structure. Prior to clustering, all variables were standardized using z-scores to eliminate the influence of differing measurement units and scales. In order to

ensure the suitability of the selected indicators for multivariate analysis, multicollinearity was evaluated using variance inflation factors (VIFs). All VIF values were below 5, suggesting that the selected variables do not exhibit problematic levels of collinearity.

In the first stage, hierarchical clustering methods were applied to explore the underlying structure of the data. Several linkage algorithms were tested, including single linkage and complete linkage using Euclidean distances, as well as Ward's method using squared Euclidean distances. Cluster solutions were evaluated by visual inspection of the resulting dendrograms, with emphasis on interpretability and the presence of clearly distinguishable clusters. Among the tested methods, Ward's method produced the most coherent and interpretable structure, characterized by well-separated clusters and clear linkage distance jumps. Consequently, this method was selected for determining the final cluster configuration presented in the paper.

In the second stage, non-hierarchical clustering was performed using the k-means algorithm. The number of clusters was set equal to the final cluster solution identified by Ward's method. The k-means procedure was used to refine and validate the cluster assignment through an iterative partitioning process that minimizes within-cluster variance. The contribution of the used variables to the resulting clusters was assessed using the analysis of variance (ANOVA). In addition, cluster profiles were examined using a graphical display of standardized cluster means, and a cluster map was produced to visualize the spatial distribution of country groups within the EU.

Finally, based on their structural and environmental characteristics, each cluster was assigned a descriptive label reflecting the relative stage of the green transition in national passenger car markets in 2023. The cluster compositions derived from the hierarchical and non-hierarchical approach were compared in order to evaluate classification consistency and robustness.

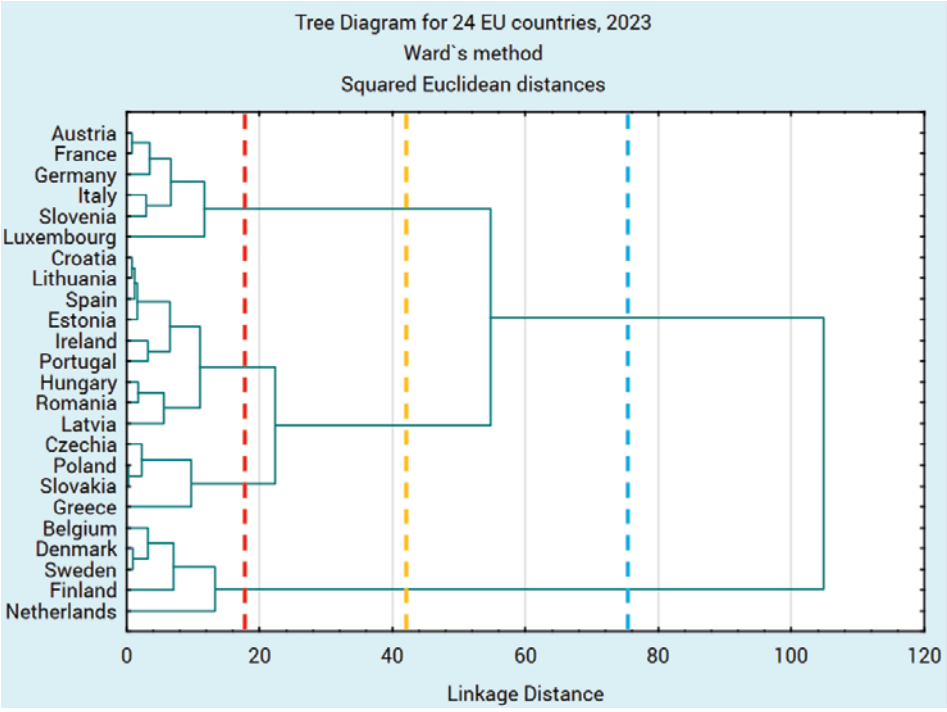
RESULTS AND DISCUSSION

The hierarchical cluster analysis conducted using Ward's method and squared Euclidean distances revealed a clear and interpretable structure in the EU passenger car market. Visual inspection of the dendrogram (Figure 1) indicates three possible cluster solutions, i.e. three potential cuts marked with dashed lines: (i) two clusters (blue line), (ii) three clusters (yellow line), and (iii) four clusters (red line). There is a pronounced increase in linkage distance when moving from three to two clusters, suggesting that a three-cluster solu-

tion provides the most meaningful balance between parsimony and explanatory power. This solution captures the major structural differences among national passenger car markets while avoiding excessive fragmentation of the sample.

The three-cluster configuration highlights the substantial heterogeneity across EU Member States in terms of electrification progress, infrastructure readiness, fleet characteristics, and environmental performance. The clusters are not randomly formed, but rather reflect coherent groupings of countries that share similar market structures and transition dynamics. This confirms that the EU passenger car market cannot be treated as a homogeneous entity in the context of the green transition, and rather, it comprises distinct groups of countries at different stages of transformation.

Figure 1. Dendrogram for 24 EU countries, 2023



Source: Author's calculation based on ACEA data (2023), performed in TIBCO Statistica.

The exact cluster membership for the selected three-cluster solution is presented in Table 2. The first cluster comprises five countries: Austria, France,

Germany, Italy, Luxembourg, and Slovenia. These countries represent mature passenger car markets characterized by relatively high motorization rates, moderate electrified-vehicle shares, intermediate charging infrastructure density, and mid-range CO2 emissions from new cars. While these markets have clearly moved away from a firm reliance on diesel technology, internal combustion engines still play an important role. Overall, this cluster can be interpreted as representing the "Mid-transition EV markets", where electrification is progressing steadily, but without the rapid uptake observed in the leading countries.

The second cluster includes thirteen countries: Croatia, Czechia, Estonia, Greece, Hungary, Ireland, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, and Spain. This group is characterized by the lowest levels of electrified-vehicle penetration, limited availability of charging infrastructure, higher average CO2 emissions from new cars, and comparatively older vehicle fleets. Diesel-powered vehicles remain particularly prominent in several of these countries, and fleet renewal rates are relatively slow. Despite internal heterogeneity within the group, these markets share common structural constraints that hinder rapid electrification, positioning them as the "Late-transition EV markets" within the EU.

The third cluster consists of five countries: Belgium, Denmark, Finland, the Netherlands, and Sweden. This cluster clearly represents the "EV leaders" in the EU passenger car markets. These countries exhibit the highest electrified-vehicle shares, the densest public charging infrastructure, the lowest diesel dependence, and the lowest average CO2 emissions from new passenger cars. Their relatively young vehicle fleets and well-developed charging ecosystems suggest a high level of readiness for further electrification. This cluster reflects advanced transition markets, in which policy support, infrastructure development, and consumer adoption are closely aligned with EU climate objectives. Moreover, it is the only cluster whose composition remains unchanged regardless of the chosen cluster solution.

Table 2. Cluster composition obtained using Ward's method

Cluster number	Countries	Cluster name
Cluster 1	Austria France Germany Italy Slovenia Luxembourg	"Mid-transition EV markets"
Cluster 2	Croatia Lithuania Spain Estonia Ireland Portugal Hungary Romania Latvia Czechia Poland Slovakia Greece	"Late-transition EV markets"
Cluster 3	Belgium Denmark Sweden Finland Netherlands	"EV leaders"

Source: Author

In order to compare and validate the hierarchical clustering results, a non-hierarchical clustering procedure was applied using the k-means algorithm. The number of clusters (k) was set to 3 based on the final solution obtained using Ward's hierarchical method. This two-step approach combines the strengths of both methods: hierarchical clustering to identify the appropriate number of clusters, and k-means to stabilize cluster membership through iterative reassignment (Rakhlin & Caponnetto, 2006).

The k-means algorithm (Table 3) produced exactly the same cluster composition as the hierarchical solution. All 24 EU countries were assigned to identical clusters under both approaches, indicating a high degree of consistency between the hierarchical and non-hierarchical methods. This result confirms the structural stability of the obtained cluster composition.

Table 3. Cluster composition obtained using the k-means method, and cluster distances from the respective cluster centre

Cluster number	Countries	Distances
Cluster 1 ("Mid-transition EV markets")	Austria	0.403420
	France	0.397489
	Germany	0.464694
	Italy	0.659396
	Luxembourg	0.902990
	Slovenia	0.584118
Cluster 2 ("Late-transition EV markets")	Croatia	0.391094
	Czechia	0.798920
	Estonia	0.414364
	Greece	1.190377
	Hungary	0.542827
	Ireland	0.873012
	Latvia	0.847129
	Lithuania	0.413590
	Poland	0.400164
	Portugal	0.731932
	Romania	0.504688
	Slovakia	0.307365
	Spain	0.394840
Cluster 3 ("EV leaders")	Belgium	0.492863
	Denmark	0.409766
	Finland	0.766789
	Netherlands	0.943488
	Sweden	0.391136

Source: Author's calculation based on ACEA data (2023), performed in TIBCO Statistica.

Additional support for the separation of the selected cluster solution was provided by the ANOVA results (Table 4). The contribution of individual variables to the differentiation of EU passenger car markets was assessed using F-values. The highest F-values were observed for charging infrastructure density (F = 27.64) and average carbon dioxide emissions from new passenger cars (F = 27.36), indicating that these dimensions play a particularly important role in distinguishing between clusters. The share of electrified cars and the average age of the passenger car fleet also contribute strongly to cluster separation. In contrast, the share of diesel-powered cars (F = 5.15) and the motorization rate (F = 10.38) provide additional, but less pronounced, discriminatory power.

Taken together, these results confirm that the selected variables collectively capture significant structural differences in passenger car markets across EU countries.

Table 4. Analysis of variance

Variable	Analysis of Variance					
	Between	**df**	**Within**	**df**	**F**	**signif. p**
cars_by_age	14.86272	2	8.13728	21	19.17823	0.000018
motorization	11.43151	2	11.56849	21	10.37566	0.000735
cars_diesel	7.56926	2	15.43074	21	5.15057	0.015133
cars_electrified	12.66991	2	10.33009	21	12.87830	0.000224
CO2_emissions	16.62072	2	6.37928	21	27.35691	0.000001
chargers	16.66765	2	6.33235	21	27.63752	0.000001

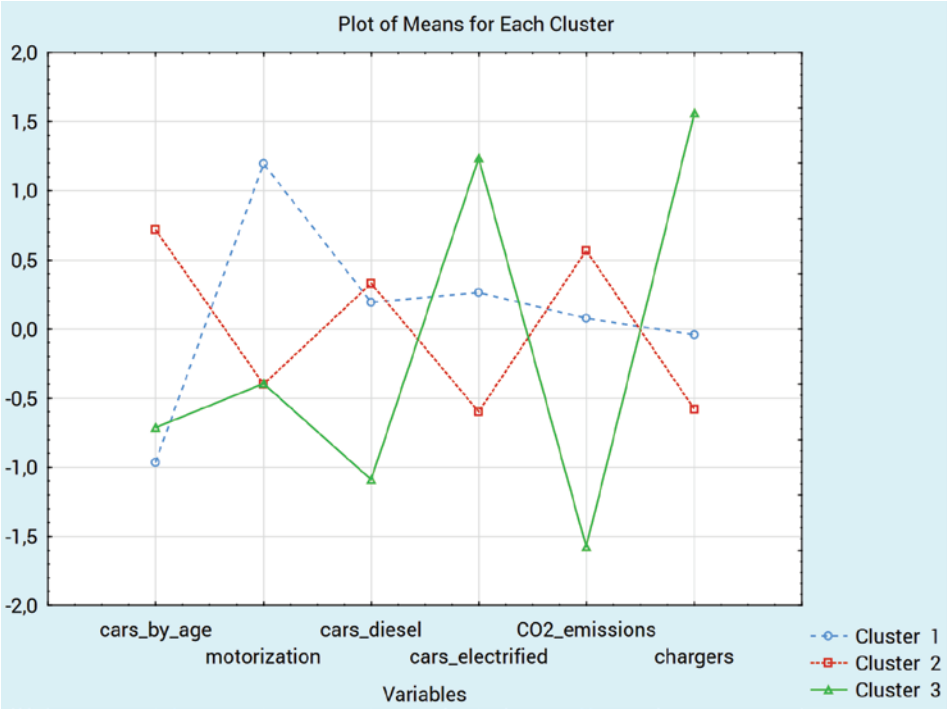
Source: Author's calculation based on ACEA data (2023), performed in TIBCO Statistica.

The standardized cluster means plot (Figure 2) further illustrates the distinct profiles of the three clusters. Each point represents the average standardized value of a given variable for all countries within a cluster, enabling direct comparison of cluster characteristics relative to the EU (sample) average.

Cluster 1 ("Mid-transition EV markets") is positioned close to the EU average on most indicators, but is distinguished by relatively high motorization levels. Cluster 2 ("Late-transition EV markets") exhibits below-average levels of electrification and charging infrastructure, alongside above-average carbon dioxide emissions and diesel shares. In contrast, Cluster 3 ("EV leaders") displays strongly positive values for the share of electrified cars and charging infrastructure, combined with markedly negative values for diesel dependence and carbon dioxide emissions, confirming its advanced stage of transition.

Overall, the alignment of results from Ward's method and k-means algorithm confirms the reliability and interpretability of the three-cluster solution. The consistency across methods strengthens the validity of the findings. It supports the conclusion that EU passenger car markets can be meaningfully classified into distinct groups reflecting different stages of progress toward electrification and decarbonization in 2023.

Figure 2. Standardized cluster means plot for a three-cluster solution



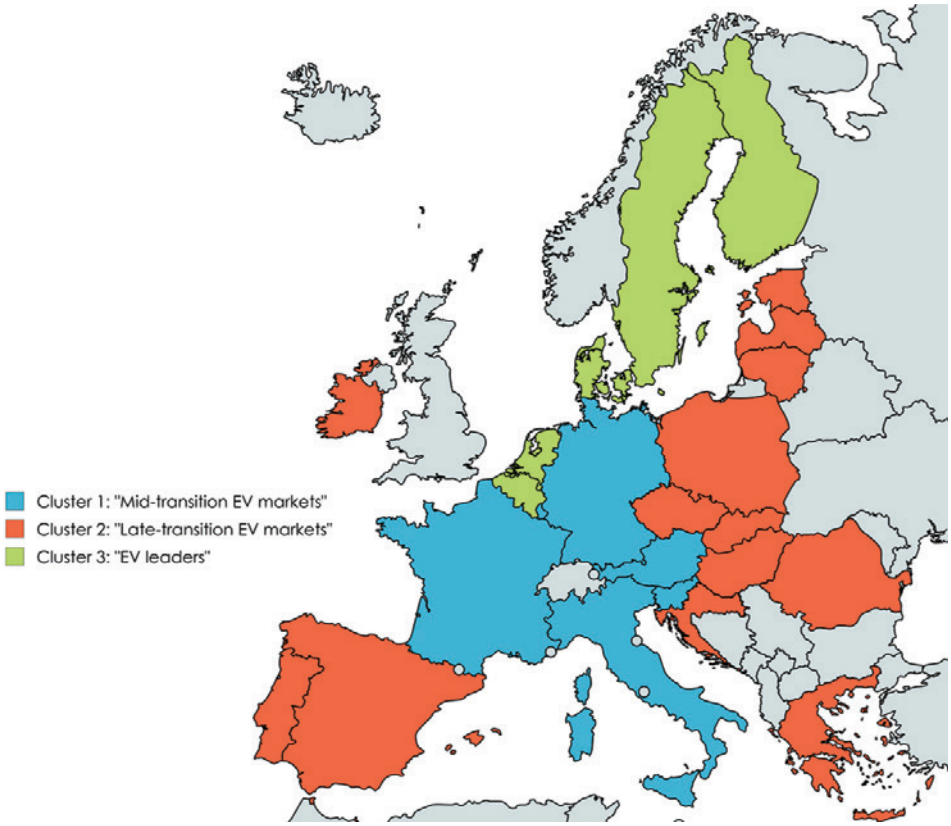
Source: Author's calculation based on ACEA data (2023), performed in TIBCO Statistica.

All things considered, the conducted cluster analysis reveals a clear spatial heterogeneity in the green transition of EU passenger car markets. This is evident in the cluster map of the final cluster solution presented in Figure 3. Only a limited group of countries can be identified as advanced "EV leaders", while most Member States in the sample fall into the "Mid-transition EV markets" or "Late-transition EV markets" cluster. This indicates that the overall pace of electrification remains uneven and modest. Notably, the "Late-transition EV markets" cluster accounts for more than half of the analysed countries (13 out of 24), suggesting that a large part of the EU still lagged in transition to low-carbon mobility in 2023.

Within the identified cluster structure, Croatia is classified as a "Late-transition EV market". This position is primarily driven by a low share of electrified cars, limited charging infrastructure, and a relatively old passenger car fleet. Croatia's values are close to the average of its cluster, indicating that it represents a typical, rather than an extreme case within this group. Compared

with mid-transition and leading markets, substantial gaps remain, particularly in charging infrastructure density and average carbon dioxide emissions from new cars. These findings suggest that Croatia's progress toward electrification is constrained by structural and infrastructure barriers, underscoring the importance of targeted policy measures to accelerate fleet renewal and expand charging infrastructure.

Figure 3. Cluster map for a three-cluster solution



Source: Author's calculation based on ACEA data (2023).

Note: Map visualization created using MapChart.

CONCLUSION

This paper examined the heterogeneity of passenger car markets across EU Member States in the context of the green transition. Specific focus was put on vehicle electrification and carbon dioxide emissions in 2023. Using a multivariate cluster analysis combining Ward's hierarchical method and the k-means algorithm, the study classified 24 EU countries into three distinct groups reflecting different stages of progress toward low-carbon mobility. The results demonstrate that EU passenger car markets are far from homogeneous, and that substantial structural differences persist despite a common regulatory framework.

The analysis identified a small group of EV leaders (Belgium, Denmark, Sweden, Finland, and the Netherlands) characterized by high shares of electrified vehicles, dense charging infrastructure, and low carbon dioxide emissions. At the same time, there is a large group of late-transition markets (thirteen countries, including Croatia) in which electrification remains limited and dependence on internal combustion technologies persists. Between these two extremes, mid-transition markets (Austria, France, Germany, Italy, Slovenia, and Luxembourg) display moderate electrification progress and average performance across most indicators. The strong consistency between hierarchical and non-hierarchical clustering results confirms the robustness and interpretability of the three-cluster solution.

Given the current pace of transition, the ambitious EU-wide decarbonization targets set for 2030 and 2035 appear increasingly challenging. Late-transition markets, including Croatia, are facing structural and infrastructure constraints that hinder faster electrification, underscoring the need for targeted support for fleet renewal and charging infrastructure expansion.

This paper contributes to the literature by providing a recent assessment of EU passenger car markets, using hierarchical and non-hierarchical clustering methods and the most recent available ACEA data. A key limitation is the reliance on data from a single year (2023) and the limited availability of data for some countries. Future research could improve the analysis by regularly re-evaluating cluster structures. It may also incorporate additional variables, refine existing indicators, compare different policy periods, and apply other clustering algorithms.

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THE REGULATORY ECONOMICS AND LAW OF CRYPTO-ASSETS: BALANCING INNOVATION, RISKS AND ENVIRONMENTAL HARM

Dominik VULETIĆ*

The emergence and rapid expansion of crypto-assets have challenged traditional regulatory frameworks and introduced various questions at the intersection of law and economics. This phenomenon has consequently led to specific regulatory developments in various jurisdictions. This paper examines how regulatory design can efficiently address the unique risks and market failures associated with alternative financial tools. Following on the author's previous normative research on crypto-assets, this paper continues with the analysis of competing regulatory approaches, with emphasis on environmental impacts. While crypto markets promise innovation, lower transaction costs, and heightened financial inclusion, they also exhibit features – such as extreme price volatility, asymmetric information, pseudonymity, and network-driven externalities – that complicate the application of classical regulatory tools. The negative impact of crypto-assets on the environment is frequently ignored. The infrastructure supporting crypto-assets uses a large amount of energy, the quantity of which rivals the energy consumption of certain small nations, as demonstrated by recent studies on the issue. The emissions of Bitcoin mining alone could be sufficient to push global warming beyond the Paris Agreement goals. This paper offers a systematic analysis of these challenges, using the principles of regulatory economics, combining insights from market structure theory, incentive regulation, and public interest rationales with evolving legal frameworks, with the emphasis on environmental impacts. The paper first identifies the key economic and legal characteristics of the

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crypto-asset markets, including high speculative demand, limited intrinsic valuation anchors, concentrated ownership patterns, underregulation, and the dual role of platforms as both market intermediaries and issuers. It demonstrates that these features generate predictable inefficiencies: information asymmetries leading to consumer protection failures; systemic risk transmission through interconnected platforms; market manipulation arising from low liquidity and fragmented exchanges; and negative externalities such as illicit finance and negative environmental externalities. The effective regulation of crypto-assets must balance innovation incentives against environmental and consumer harms, while minimizing regulatory arbitrage across jurisdictions. The central contribution of this paper is the identification of environmental harm as a structural regulatory blind spot in all permissive crypto-asset regimes. The research produces four general regulatory policy recommendations in addressing environmental harm arising from markets in crypto-assets.

Keywords: *Regulatory economics, crypto, impact on the environment, law and economics*

JEL classification: *K22, K24, L86, Q5*

1. INTRODUCTION

The rapid emergence and proliferation of crypto-assets have presented both opportunities and challenges to traditional regulatory frameworks. Although the idea of cryptocurrency as a peer-to-peer electronic cash system is widely perceived to have been established in the famous Satoshi Nakamoto paper from 2008 (Nakamoto, 2008), the origins of crypto-assets are in fact much older. In 1981, in his theoretical doctoral dissertation at the University of California, Berkeley, computer science pioneer David Lee Chaum introduced his proposal for a blockchain protocol (Sherman, Javani, Zhang & Golaszewski, 2019). At about the same time, David Chaum conceptualised the first framework for electronic cash (Chaum, 1983). Since this early groundbreaking development, there have been several proposals for the establishment of cryptocurrencies before Nakamoto's paper. However, not a single one of them was implemented due to the various shortcomings such as a lack of vulnerability to attacks and protection against double spending, and the need for centralised control. Bitcoin was implemented as an open-source code, released in January 2009, and it quickly became the world's first usable cryptocurrency (Vuletić, 2025).

As a starting point, we should explain the basic terminology: why is the notion of crypto-assets preferable and more correct than the term 'cryptocurrency', used by the wider public? Crypto-assets, except in the case of El Salvador where Bitcoin was introduced as legal tender in 2021, are currently not considered to be a currency. They can certainly be used as a means of payment for certain products and services in private transactions, but not in the form of a legal tender (except in El Salvador). This is a form of digitalised barter and not a payment in official currency. They are not digital money or e-money either. E-money, although it can share some of the technological attributes of crypto-assets, has official issuers such as central banking authorities, and has the status of a legal tender. The second argument for the primacy of use of the term 'crypto-assets' vs. 'cryptocurrency' is of a formal nature, and it derives from the European Union Law. The EU Law uses the term 'crypto-asset' exclusively (defined as digital representation of a value or of a right that is able to be transferred and stored electronically using distributed ledger technology or similar technology).

The technological basis for the large majority of crypto-assets is distributed ledger technology (DLT) that determines their decentralised nature. DLT is based on the concept of consensus mechanisms used to determine the state of the blockchain data, which replace centralised authorities or a single party as recordkeepers in centralised systems. The consensus mechanism is, therefore, a key component of every blockchain which ensures that participants are working based on the same ledger containing the same set of historical transactions and according to the same rules. In particular, new blocks are only added to the chain if the participants in the blockchain network have reached consensus over the validity of the transactions and their sequence. The consensus mechanisms incentivise and enable the participants of the blockchain network (nodes) to reach a common agreement, while preventing the participants from acting maliciously or prioritizing their own interests above those of the network (OECD, 2022).

The allure of crypto-assets lies in their potential to foster innovation, reduce transaction costs, and enhance financial inclusion. One of the foundational ideologies underpinning cryptocurrency is the rejection of centralised authority in favour of financial autonomy and user sovereignty (Stupak, 2025). However, these benefits are accompanied by significant market risks, including extreme price volatility, asymmetric information, and network-driven externalities. The pseudonymous nature of many crypto transactions further complicates the regulatory landscape, making it difficult to apply classical regulatory tools effectively. As regulatory bodies across various jurisdictions grapple

with these challenges, it is becoming evident that a more tailored approach is required to address the distinctive features of crypto markets.

This paper will first produce an analysis of the economic characteristics of the markets in crypto-assets using the principles of regulatory economics, and combining insights from market structure theory, incentive regulation, public interest rationales, and law and economics. This will be followed by a regulatory overview of the markets in crypto-assets, with emphasis on the European Law, and following on the author's previous normative research on crypto-assets (Vuletić, 2024 & 2025). The final part of the paper will address one of the most important and under-researched concerns associated with the rise of crypto-assets: their environmental impact. The conclusion will provide policy recommendations addressing the regulatory response to the environmental harm produced by the markets in crypto-assets.

2. REGULATORY LAW AND ECONOMICS OF CRYPTO-ASSETS: BALANCING INNOVATION AND RISKS

Regulatory economics provides a framework for understanding how government interventions can shape market outcomes. It examines the efficiency of regulation, the behaviour of firms under various regulatory regimes, and the implications for consumer welfare (Stigler, 1971). In the context of crypto-assets, regulatory economics has become increasingly relevant as governments worldwide grapple with how to manage these decentralized financial instruments. Owing to their decentralised structure and limited reliance on institutional intermediaries, crypto-assets are often portrayed as instruments well-suited for navigating the environments characterised by heightened uncertainty in traditional institutions. This perception underscores the importance of examining the economic conditions that shape the adoption patterns (Stupak, 2025).

Crypto-asset markets exhibit a combination of characteristics that distinguish them from traditional financial markets and complicate regulatory intervention. From an economic perspective, these markets are shaped by high speculative demand, limited intrinsic valuation anchors, strong network effects, and significant technological complexity. Together, these features can give rise to market failures. According to Iyer and Popescu (2023), crypto-asset markets can act both as a source of shocks or as an amplifier of overall market volatility. However, several studies (e.g. Koutrouli, Manousopoulos, Theal & Tresso, 2025) have demonstrated the existence of a correlation between tradi-

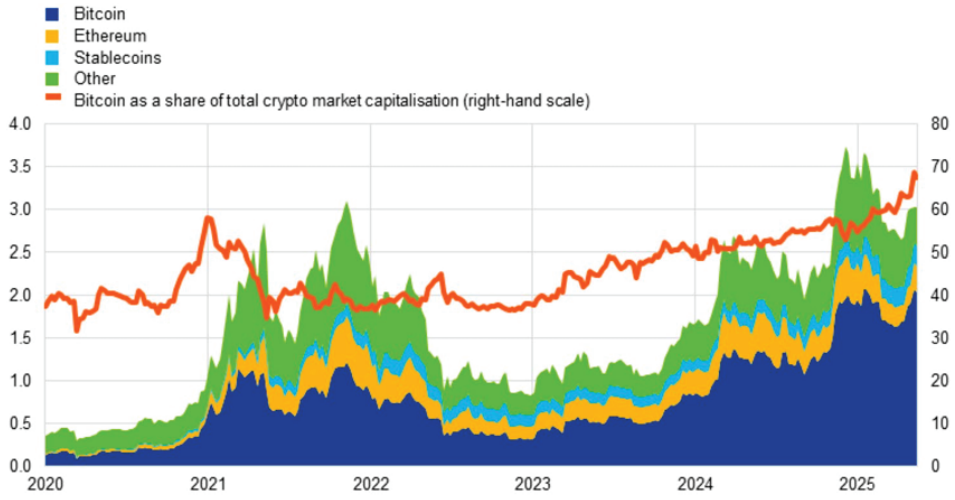
tional financial markets and markets in crypto-assets. Lahajnar and Rozanec (2020) have observed that, during favourable periods, the correlation between crypto-asset markets and financial markets tends to be lower compared to unfavourable periods. In other words, the presence of a strong correlation when the prices are falling can hinder the effective diversification of risk.

One of the defining characteristics of crypto-assets is extreme price volatility. Unlike equities or bonds, most crypto-assets lack cash flows or legally enforceable claims that could serve as a basis for fundamental valuation. The prices are, therefore, largely driven by expectations, narratives, and network adoption dynamics. This amplifies speculative behaviour and exposes the retail participants to significant losses, raising concerns about consumer protection and market integrity.

Information asymmetry also constitutes a major market failure that can be linked to crypto-assets. Issuers and developers of crypto-assets typically possess superior information regarding the technological design, governance structures, and risk profiles of their projects. Retail users, by contrast, often rely on incomplete or misleading information disseminated through white papers, social media, or online forums. The pseudonymous nature of many projects further exacerbates this asymmetry by weakening the reputational constraints and accountability mechanisms.

The economic significance of the global market in crypto-assets cannot be overstated: if treated like a country, it ranks between Germany and Japan or India in nominal GDP size. The cryptocurrency market has continued to expand significantly over the recent years (Figure 1), while Bitcoin keeps maintaining its market dominance. In Q3 2025, the total market capitalization of all crypto-assets had reached an all-time high of USD 4 trillion, while at the time of writing this paper, it had dropped to USD 3 trillion (European Parliament, 2025). Bitcoin remains the dominant asset, at a current market cap of USD 1.7 trillion at the time of writing this paper (CoinGecko, 2025).

Figure 1. Recent development of the market capitalisation of crypto-assets



Source: European Parliament (2025) and ECB Financial Stability Report based on CoinDesk data, IntoTheBlock and ECB calculations. January 2020-May 2025; left-hand scale: USD trillions, right-hand scale: percentages.

Network effects play a central role in crypto-asset markets. The value of a given crypto-asset often depends on the size and activity of its user base, leading to 'winner-takes-most' dynamics and high market concentration. While network effects can promote efficiency and standardisation, they also increase barriers to entry and may entrench inefficient or environmentally harmful technologies once they achieve sufficient scale.

Crypto-asset platforms frequently combine multiple economic functions, acting simultaneously as issuers, trading venues, custodians, and governance actors. This vertical integration creates conflicts of interest and challenges traditional regulatory distinctions between intermediaries. From a regulatory economics standpoint, such structures heighten the risk of opportunistic behaviour and complicate the allocation of liability.

Finally, crypto-asset markets generate negative externalities that are not reflected in market prices. These include the facilitation of illicit financial activities, pressures on financial stability, and, most notably, environmental harm associated with energy-intensive consensus mechanisms. Crypto assets have also been used as one of the most suitable investment instruments for tax evasion. The persistence of these externalities provides a strong economic justification for regulatory intervention.

3. REGULATORY OVERVIEW

3.1. THE EUROPEAN UNION LAW

The European Union has become the first jurisdiction in the world to have a fully specialised regulatory framework on crypto-assets with its Markets in Crypto-Assets Regulation, officially titled Regulation (EU) 2023/1114 of the European Parliament and of the Council of 31 May 2023 on markets in crypto-assets, which entered into legal force on 29 June 2023. The European Union regulators, the European Securities and Markets Authority ESMA and the European Banking Authority EBA, concluded in 2019 that the existing regulatory framework for financial markets could not be easily applied to crypto-assets (EBA, 2019). The Markets in Crypto-Assets Regulation (MiCA) consists of nine titles, six annexes and 149 articles. The MiCA entered into legal force on 29 June 2023, with titles III (asset-reference tokens) and IV (e-money tokens) applying as of 30 June 2024, and the rest of the legislation as of 30 December 2024.

The MiCA is based on the notion of crypto-asset defined in Article 3 as a digital representation of a value or of a right that is able to be transferred and stored electronically using distributed ledger technology or similar technology. Distributed ledger technology is defined as technology that enables the operation and use of distributed ledgers. Distributed ledger means an information repository that keeps records of transactions and that is shared across, and synchronised between, a set of DLT network nodes using a consensus mechanism. Consensus mechanism means the rules and procedures by which an agreement is reached, among DLT network nodes, that a transaction is validated. The MiCA classifies crypto-assets into three types: e-money tokens, asset-referenced tokens, and other crypto-assets, including utility tokens. Basically, all crypto-assets that fall under its scope are viewed as tokens, and tokens themselves could be viewed as DLT-based units (Maume, 2023). Thus, we can speak of a token-centric regulatory approach (Vuletić, 2025). Tokens that are financial instruments within the meaning of MiFiD II (Directive 2014/65/EU of the European Parliament and of the Council of 15 May 2014 on markets in financial instruments) fall outside the scope of the Regulation (Vuletić, 2025).

Beside the crypto-asset itself, the fundamental object of regulation in MiCA is crypto-asset service. Crypto-asset service includes providing custody and administration of crypto-assets on behalf of clients; operation of a trading platform for crypto-assets; exchange of crypto-assets for funds; exchange of crypto-assets for other crypto-assets; execution of orders for crypto-assets

on behalf of clients; placing of crypto-assets; reception and transmission of orders for crypto-assets on behalf of clients; providing advice on crypto-assets; providing portfolio management on crypto-assets; providing transfer services for crypto-assets on behalf of clients. The MiCA applies to natural and legal persons (and certain other undertakings) that are engaged in the issuance, offer to the public and admission to trading of crypto-assets, or that provide services related to crypto-assets in the EU. In particular, the Regulation lays down the following:

- transparency and disclosure requirements for the issuance, offer to the public and admission of crypto-assets to trading on a trading platform for crypto-assets ('admission to trading');
- requirements for the authorisation and supervision of crypto-asset service providers, issuers of asset-referenced tokens and issuers of e-money tokens (as well as for their operation, organisation and governance);
- requirements for the protection of holders of crypto-assets in the issuance, offer to the public and admission to trading of crypto-assets;
- requirements for the protection of clients of crypto-asset service providers;
- measures to prevent insider dealing, unlawful disclosure of inside information and market manipulation related to crypto-assets.

The regulatory framework set out in the MiCA, especially with regard to requirements towards crypto-asset service providers, is very similar to the traditional regulation of markets in financial instruments. The entire regime of rules on the authorisation and operating conditions is clearly a modification of the regime laid out in the MiFID II. At the EU level, the regulators are ESMA and ECB, while at the level of EU Member States, the competent authorities are national regulators that are practically the same as traditional regulators for markets in financial instruments. Some commentators speak of "regulating by analogy" or a "copy and paste" regulatory approach (Maume, 2023; Vuletić, 2025) of EU legislators. This regulatory framework is obviously not tailor-made for markets in crypto-assets.

3.2. OTHER JURISDICTIONS

Prior to 2025, the US lacked specialised regulations for crypto-assets at the federal level and applied the existing regulatory framework in all fields. One of the major regulatory issues is whether a certain crypto-asset falls under the scope of the Securities Act, like in the pending case of XRP / Ripple. An

essential component of SEC jurisdiction has been the 'Howey test', developed from the 1946 Supreme Court decision which declares a scheme to be an 'investment' contract under the Securities Act if it involves (a) an investment of money (b) in a common enterprise (c) with profits (d) to come solely from the efforts of others. If the Howey test is satisfied, it is immaterial whether the enterprise is speculative or non-speculative, or whether there is a sale of property with or without intrinsic value. Several US states, like New York and Wisconsin (Hallak & Salén, 2023), have enacted fragmented state-level legislation, in the absence of a federal regulatory framework.

The situation in the USA substantially changed in 2025 with the adoption of the landmark GENIUS Act, fully titled the Guiding and Establishing National Innovation for U.S. Stablecoins Act. It will come into effect in 2027. The GENIUS Act regulates only stablecoins, or in EU Law terminology, e-money tokens and asset-referred tokens. The rest of the market in crypto-assets is not covered by this Act. This new regulatory framework seeks to mitigate run risk and systemic contagion, drawing explicitly on lessons from bank regulations and money market fund reform. The Act establishes the rules for issuers, custody, and market participation, aiming to foster innovation while ensuring consumer protection, and anti-money laundering compliance. The Act establishes a dual supervisory model, allowing stablecoin issuers to be regulated either at the federal level or by approved state authorities, provided that the state regimes meet the minimum federal standards. The strict and prudent regulatory approach, besides the obvious purpose of bringing mainstream potential to digital assets, goes beyond mere financial stability and seems to enhance the preservation of the U.S. dollar reserve status. In a comparative perspective, the GENIUS Act aligns with the MiCA Regulation in its emphasis on authorisation and supervision, but diverges in its narrower scope and stronger reliance on the existing banking and payment law concepts.

The United Kingdom has gone further in the regulatory efforts on crypto-assets than the EU (Vuletić, 20025). The UK Money Laundering, Terrorist Financing and Transfer of Funds Regulation 2017, which became applicable to crypto-asset businesses in January 2020, provides a risk-based approach for applying customer due diligence, monitoring and reporting suspicious activities. The UK Financial Services and Markets Act (FSMA) was adopted in June 2023, and envisages the establishment of a financial market infrastructure (FMI) sandbox. The UK approach to testing the application of DLT technologies is channelled through the UK Financial Market Infrastructures sandbox, allowing the participating firms to test their technologies and products by letting the regulators temporarily suspend or amend laws, if not applying new

ones (Hallak & Salén, 2023). Under the current UK law, anti-money laundering (AML)/counter terrorist financing (CTF) rules already apply to crypto exchanges and wallet providers. The Bank of England, in the same line as the US GENIUS Act, has proposed a regulatory regime for sterling-denominated systemic stablecoins, focused on consumer protection, competition, and integrity of the financial system.

Table 1. Comparative overview of the crypto-asset regulations in the EU, UK and USA

Category	EU	UK	USA
Scope of regulation	Broad: issuance, public offers, trading, custody, market abuse, consumer protection	Gradual expansion: AML, promotions, custody; full market conduct regime forthcoming	Narrow: payment stablecoins only; other crypto-assets subject to fragmented oversight
Consumer protection	Extensive disclosure (whitepapers), liability rules, redemption rights	Currently limited; strengthened consumer protection planned	Strong redemption and reserve-protection rights for stablecoin holders
Environmental considerations	Mandatory disclosure of environmental impact of consensus mechanisms (no substantive limits)	No explicit environmental provisions	No environmental provisions
Risk of regulatory arbitrage	Low within EU due to harmonisation, medium to high outside the EU due to the overregulation	Medium during transition	High outside stablecoins due to fragmented regulation

Source: Author

The comparative overview of the regulatory framework in the analysed jurisdictions (the EU, USA and UK), divided in the categories of scope, consumer protection, environmental protection and risk of regulatory arbitrage, is shown in Table 1. In some other jurisdictions, e.g. Japan and Singapore, sector-specific regulation has been developing in a similar manner as in the UK. In the majority of other jurisdictions, such as the Russian Federation, the existing regulatory framework has been interpreted to be applicable to crypto-assets, with only specific AML and CFT rules. However, there is a group of jurisdictions that have introduced a formal ban on crypto-assets. The most notable example is the People's Republic of China, which has gone from being one

of the largest Bitcoin trading and mining hubs to imposing a complete ban on all crypto-assets. This case will be further elaborated in the next title of this paper, which addresses the environmental harm of the crypto-assets.

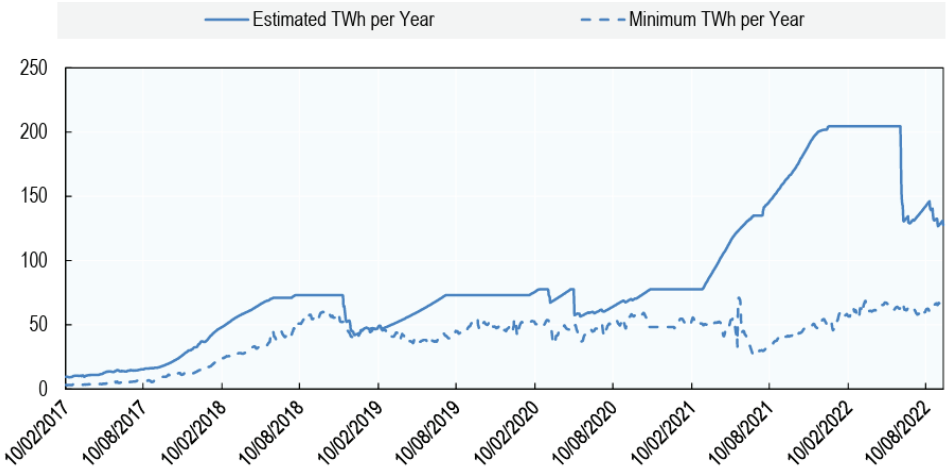
4. ENVIRONMENTAL RISKS: A REGULATORY BLIND SPOT

The infrastructure supporting crypto-assets uses an enormous amount of energy. This in particular relates to Bitcoin as a market dominant crypto-asset. Carbon emissions from the Bitcoin network have been described for some time as comparable with country-level carbon footprints (OECD, 2022). One important distinction that needs to be made is between energy consumption in crypto-asset function and energy consumption for crypto-asset creation, the so called 'mining': it is the mining process, and not the transaction validation, that consumes most energy in the Bitcoin network. Processing transactions requires a computational setup, which contributes to the network by solving the cryptographic puzzle. Subsequently, the contributor would receive a reward for this Proof-of-Work (PoW) operation which is known as mining. These computational units (miners) consume an intense amount of electrical power to operate. As the value of the received financial reward outweighs the costs of contribution, mining becomes economically viable, resulting in a significant growth in electricity consumption. Mining revenues consist of the sum of transaction fees paid to miners, plus the market value of newly minted coins awarded to miners who successfully compete to record transactions to the blockchain. Mining profit margins increase when the price of the underlying crypto-asset increases, and therefore mining activity – and the corresponding energy consumption – is expected to be greater when the price of the underlying crypto-asset increases (OECD, 2022).

According to a recent study from 2023, which was published in the Earth's Future journal, in the 2020–2021 period the worldwide BTC mining network consumed 173 TWh of electricity, which is 60% more than its electricity use during the 2018–2019 period (Chamanara, Ghaffarizadeh & Madani, 2023). Based on the CBECI (Cambridge Bitcoin Electricity Consumption Index) values, in 2021 and 2022, the annual electricity consumption for BTC mining across the globe exceeded 100 TWh per year. As of July 2023, according to the same study, global electricity consumption for BTC mining in 2023 was expected to be above 135 TWh (Cambridge Centre for Alternative Finance, 2023). Therefore, according to that estimation, if the Bitcoin network were a country, its energy consumption would have ranked it 27th in the world, ahead

of a country like Pakistan with a population of over 230 million people. An estimation of the total energy consumption of the Bitcoin network in the period 2017-2022 has been shown in Figure 2, along with the estimated levels and minimum possible levels of consumption.

Figure 2. Total energy consumption of the Bitcoin network



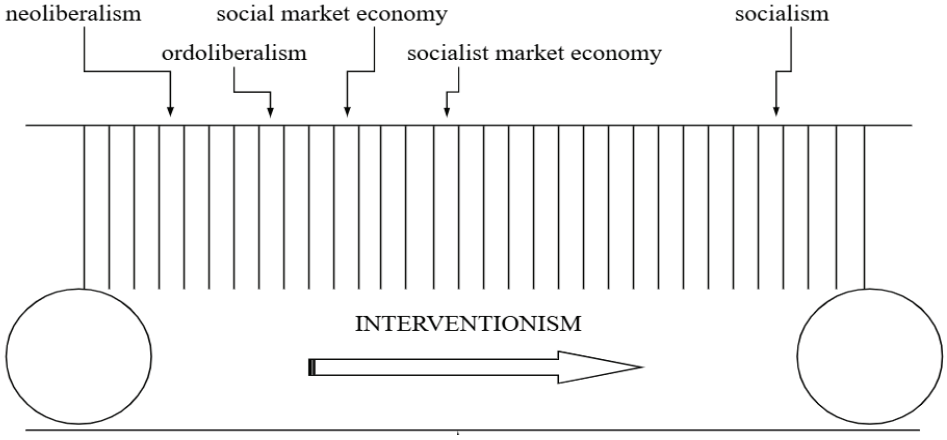
Source: OECD, 2022

The emissions of Bitcoin network mining alone, assuming that data from the Cambridge Bitcoin Electricity Consumption Index are correct or close to correct, could be sufficient to push global warming beyond the Paris Agreement goals. The regulatory response to the environmental harm presented by the markets on crypto-assets is extremely divergent. In the liberal democracies, regulatory response has been minimal. In the European Union's MiCA, there are provisions relating to the disclosure of effects on the environment, but no substantive limits on energy consumption or penalties for environmental harms have been established. The obligation to disclose information on the environmental impact of the consensus mechanism used is regulated in several places in the MiCA: in Art. 6. para. 1 subpara. 1 j) in relation to other crypto-assets); Art. 19 para. 1. subpara 1. h) in relation to asset-referenced tokens; Art. 51 para. 1 subpara. 1 g) in relation to e-money tokens, and in Art. 66 para. 5 in relation to activities of crypto service providers. The ESMA and EBA have established standards for the presentation of data in disclosure documents. In all the cited provisions, the MiCA only requires disclosure of information on the environmental impact, nothing more. In the USA GENIUS Act, there are

no environmental provisions. Virtually all jurisdictions that are permissive of crypto-assets have no substantial limits to crypto-asset energy consumption or specific provision on e-waste. This creates a huge regulatory blind spot.

The regulatory situation in the People's Republic of China is diametrically opposite. Once, a Bitcoin trading and mining leader (holding first global place in the Bitcoin mining activities with the USA holding the second place), in 2021 China radically intervened in the market and introduced a complete ban on crypto trading and mining, citing threats to national financial stability and energy preservation. The Chinese regulatory response was drastic: after the ban, mining activities moved from China to other countries, dominantly to Kazakhstan and the USA. This regulatory response is in line with the classification of economic constitutions or integration of legal rules in the economic orders developed by the author of this paper in his previous research (e.g. Vuletić, 2024). This classification is demonstrated in Figure 3 and can be used to explain the drastic divergence in regulatory response to the Bitcoin network electricity energy consumption.

Figure 3. The scale of anti-market interventionism



Source: Vuletić, 2024

However, none of the existing regulatory solutions create an adequate balance between enabling innovation and market growth on one side, and addressing the environmental harms on the other side. Thus, the regulatory blind spots remain. The People's Republic of China, as a socialist market economy, had the highest degree of regulatory intervention in the markets in crypto-assets and introduced the strictest measures. The European Union aim, defined

in Article 3 of the Treaty on European Union (TEU), is to have a highly competitive social market economy. A regulatory response of the EU in this case exists, but only in a form of disclosure requirements (this is in line with the definition of the EU economic order as a social market economy). Other liberal economies did not produce any regulatory response to the environmental risks produced by the markets in crypto-assets.

5. CONCLUSION AND REGULATORY POLICY RECOMMENDATIONS

This paper has examined crypto-assets through the combined lenses of regulatory economics and comparative legal analysis, with particular emphasis on environmental externalities as an under-regulated dimension of the crypto-asset markets. From an economic perspective, crypto-asset markets are characterised by extreme price volatility, limited intrinsic valuation anchors, strong network effects, vertical integration of platforms, and pronounced information asymmetries. A central contribution of this paper is the identification of environmental harm as a structural regulatory blind spot in all the permissive crypto-asset regimes. The energy consumption and carbon emissions associated with proof-of-work consensus mechanisms – most notably Bitcoin mining – constitute a textbook negative externality. These environmental costs are not internalised by the market participants, and are largely ignored or marginalised by the existing regulatory frameworks, e.g. in the US GENIUS Act. Disclosure-based approaches, such as those adopted under the European Union's MiCA, may reduce information asymmetry, but are insufficient to alter behaviour in the speculative, network-driven markets where price expectations dominate decision-making.

Based on this research, it is possible to formulate the four general regulatory policy recommendations that follow.

First, environmental externalities must be explicitly recognised as a justification for a regulatory intervention in crypto-asset markets. Legislators should acknowledge that energy-intensive consensus mechanisms generate social costs comparable to those of traditional heavy industries. This recognition should be reflected in the stated objectives of crypto-asset regulation, rather than being confined to ancillary sustainability disclosures.

Second, disclosure-based environmental regulation should be supplemented with incentive-compatible regulatory instruments. While transparency obligations under the MiCA represent a necessary first step, they do not internalise

environmental costs. Regulatory frameworks should move towards mechanisms that directly affect private incentives, including a differentiated regulatory treatment based on energy efficiency and environmental impact. Crypto-assets relying on low-energy consensus mechanisms could benefit from reduced compliance burdens or preferential access to regulated trading venues, while energy-intensive assets could face enhanced regulatory requirements.

Third, crypto-mining activities should be integrated into the general environmental and energy regulations. From an efficiency standpoint, price-based instruments such as carbon taxation or emissions trading schemes are preferable to outright bans. Subjecting mining operations to carbon pricing would internalise the environmental costs while preserving technological neutrality and allowing the market participants to determine the most cost-effective means of compliance. This approach avoids the rigidity and displacement effects observed in prohibition-based regimes.

Fourth, regulatory frameworks should explicitly address the risk of regulatory arbitrage arising from the mobility of crypto-mining activities. Unilateral national measures are likely to displace environmentally harmful activities to jurisdictions with weaker regulation, as evidenced by the post-ban relocation of mining activities from China. International coordination – whether through minimum standards, soft law instruments, or integration with global climate policy frameworks – is essential to prevent a regulatory race to the bottom.

The analysis, therefore, leads to a clear normative conclusion: an effective regulation of crypto-assets must treat environmental sustainability not as an ancillary disclosure issue, but as a core regulatory objective alongside innovation, consumer protection, and financial stability. Failure to do so risks undermining broader climate commitments, distorting competition between technologies, and allowing private gains to be achieved at a significant social cost.

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GREEN ECONOMY

THE ROLE OF EMOTIONAL AND COGNITIVE BIASES IN THE FINANCIAL DECISION-MAKING OF YOUNG INDIVIDUALS: A NEUROECONOMIC FRAMEWORK FOR GREEN REGULATION AND SUSTAINABLE POLICY DESIGN

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The transition toward a sustainable and climate-resilient economy increasingly depends on the financial choices made by younger generations, who are emerging as key participants in green consumption and sustainable investment markets. However, empirical evidence shows that these decisions are not purely rational, but are strongly shaped by emotional reactions, cognitive biases and perceptual shortcuts, which may limit the effectiveness of green regulatory policies. This paper develops a neuroeconomic theoretical framework in order to explain how emotional arousal, cognitive distortions and gaze-based visual attention jointly influence financial decision-making among young individuals, with a specific focus on their responses to sustainability-related financial products, environmental incentives and green regulatory measures. The purpose of the study is to provide behavioral and neurocognitive foundations that can support the design of more effective regulatory tools in the areas of green finance, environmental taxation, sustainable investment incentives and climate-related risk communication. The proposed model integrates insights from behavioral economics, neuropsychology and ecological economics to describe how biases such as present bias, overconfidence, the availability heuristic and social proof may discourage long-term sus-

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tainable investment, reduce responsiveness to green subsidies or distort the perception of climate-related financial risks. Although this paper does not include empirical testing, it outlines a methodological basis for future neuroeconomic experiments using eye-tracking and behavioral tasks that can measure real-time reactions to green financial information, eco-labels and regulatory messages. The findings imply that regulatory strategies promoting sustainable economic behavior must consider not only economic incentives, but also the underlying emotional and cognitive mechanisms that shape how young people process environmental information and evaluate green investment options. By identifying these mechanisms, the model can inform the development of targeted behavioral regulatory interventions – such as climate-focused nudges, improved sustainability disclosures, redesigned incentive structures and visually optimized green risk communication – that enhance the adoption of environmentally responsible financial decisions. The conclusion of the paper is that integrating neuroeconomic evidence into green regulatory design can significantly strengthen the effectiveness of sustainability policies and support a more behaviorally aligned transition toward a green and circular economy.

Keywords: *green investment behavior, environmental policy design, behavioral regulation, sustainability transitions.*

JEL classification: *D91, Q56, Q58, G41, D87*

INTRODUCTION

Young people today are facing a global economy that is quite unlike those encountered by the earlier age groups. Their monetary decisions are revealed in digital landscapes that are swayed by mobile investment tools, fractional investing sites, shifts in eco-friendly purchasing patterns, and the quick progression of sustainable finance products. A significant number of younger leaders view the distinction between traditional finance, behavioral metrics, and environmental values as increasingly unclear. These young people engage in monetary operations, expenditures, and reactions to regulations in ways that are profoundly linked to emotions, community involvement, and cognitive shortcuts. Consequently, comprehending the mechanisms through which young individuals interpret financial information has emerged as a pivotal subject not only within the scope of behavioral economics, but also within the realms of environmental and regulatory economics, where individual conduct

is acknowledged as fundamental to sustainable transitions. Economic theories of the past have often proposed that individuals look at information rationally and engage in behaviors aligned with their sustained goals. Despite this, numerous empirical papers illustrate that actual practices often contrast with this theoretical understanding, especially in settings influenced by doubt. This issue is strikingly apparent among younger people who frequently operate in dynamic, emotionally heavy environments, possessing a limited awareness of financial literacy and greater susceptibility to peer pressure. The interplay of present bias, overconfidence, availability heuristics, and social proof is a recurring theme in understanding financial behavior, with neuropsychology revealing how emotional responses and focus can alter risk judgments. These angles are fully embedded within the theoretical scaffolding that underlies this work, illuminating the interconnected roles of cognitive biases, emotional connection, and perceptual dynamics in the decision-making of young individuals. Simultaneously, modern policy dialogues increasingly emphasize the shift towards a green and climate-resilient economy. Around the world, authorities and regulatory organizations are enacting taxes in relation to ecological matters, promoting incentives to encourage sustainable investments, starting green consumer programs, and establishing disclosure standards to lead individuals towards decisions that support the environment. However, an increasing amount of findings reveals that the effectiveness of green regulatory frameworks cannot be fully achieved only via financial motivations or market systems. The approach individuals take towards sustainability data, their reactions to green labels, or their judgments concerning climate risks often rely more on emotional influences and mental frameworks than on financial reasoning. This comprehension is vital to the amended theoretical structure related to this inquiry, which asserts that the efficacy of environmental policies eventually depends on their psychological resonance with younger generations – encapsulating their ideals, anxieties, biases, and perceptual inclinations. The recent progressions have clarified the vital importance of exploring connections among behavioral economics, neuroeconomics, and environmentally oriented policy measures. The youth represent not merely prospective investors and consumers – they are pivotal actors in the shift towards low-carbon and circular economic paradigms. Should their financial decisions be consistently influenced by cognitive biases and emotional stimuli, then policy measures that fail to account for these mechanisms may prove to be less effective than anticipated. For example, a green subsidy might lack the capacity to inspire transformation if overshadowed by immediate salience effects or the dynamics of social influence. Likewise, disclosures regarding climate-related

risks could be disregarded if attention is redirected towards visually more engaging information. As a result, it is important to understand the behavioral and neurocognitive principles at play in these reactions so as to formulate regulatory approaches that genuinely correspond to human decision-making.

This paper is designed as a review-oriented and conceptually driven contribution that amalgamates prevailing scientific insights across these domains. It consolidates the current knowledge on the decision-making behaviors of young individuals, elucidates the interplay of emotional and cognitive mechanisms within financial environments, and investigates the significance of these mechanisms for the efficacy of green regulatory instruments. Concurrently, the paper establishes the conceptual groundwork for a more extensive research initiative titled Neuroeconomic Analysis of the Financial Behavior of Young People (NAUKO). Subsequent phases of this initiative will utilize sophisticated empirical methodologies – including eye-tracking technology, EEG recordings, and controlled behavioral experiments – to investigate in real-time how young individuals perceive sustainable financial offerings, interpret regulatory communications, and respond to environmental incentives.

By situating young individuals at the confluence of behavioral finance, neuroeconomic principles, and sustainability policy, this introduction aims to articulate the core research issue of the paper: comprehending not solely how young people make decisions, but also why they make the choices they do, and how these processes can inform the development of more efficacious and behaviorally attuned green regulatory strategies. The following segments expand on this structure by offering a comprehensive literature assessment and additional conceptual enhancement of the suggested neuroeconomic framework.

LITERATURE REVIEW

Research on the financial decision-making of young individuals has grown substantially in the last two decades, reflecting broader transformations in global financial systems, digital behavior and environmental policy landscapes. Young adults today inhabit an economic environment fundamentally different from those experienced by any previous generation. The acceleration of digital platforms, mobile trading applications, micro-investing ecosystems, sustainable consumption movements, and green financial innovations has created a financial world in which decisions are shaped by a combination of *cognitive complexity*, *emotional influence* and *environmental awareness* (Lusardi & Mitchell, 2014).

Lusardi & Mitchell (2014), for example, conducted a large-scale analysis demonstrating that financial literacy across young global populations remains significantly lower than expected, despite higher formal education levels. They argued that low financial literacy, combined with increased exposure to complex financial products, produces decision environments where cognitive biases flourish. This insight is crucial for understanding why younger individuals may be more vulnerable to behavioral distortions when making financial choices, particularly in the context of sustainability-oriented financial products.

Furthermore, Kahneman's seminal work *Thinking, Fast and Slow* (2011) revolutionized our understanding of decision-making by introducing the dual-system framework – System 1 (fast, intuitive) and System 2 (slow, deliberative). Kahneman's framework has become foundational to interpreting how young individuals make financial decisions in environments saturated with stimuli. His insights demonstrate that when individuals face information overload, emotional cues or time pressure, System 1 dominates, often leading to suboptimal and biased financial choices.

Environmental economic literature adds another essential dimension. As highlighted by Stern (2020) and Gowdy (2008), sustainability transitions rely not only on economic rationality, but also on behavioral tendencies, emotional responses to environmental risks and social norms. Stern (2020) argues that climate change is fundamentally a behavioral and coordination challenge – individuals must respond to long-term, probabilistic and abstract risks, which are precisely the types of risks that behavioral research shows humans struggle to evaluate.

Gowdy (2008) further emphasizes that climate-related decision-making cannot be separated from evolutionary psychology and cognitive bias; humans are not naturally equipped to prioritize long-term, collective environmental outcomes over immediate personal rewards. This insight is central to the research focus: young individuals must navigate sustainability-oriented financial decisions despite inherent cognitive and emotional limitations.

The project documents mirror these global trends, emphasizing that young individuals are particularly sensitive to cognitive biases, emotional triggers, and visual stimuli when interacting with financial information. The updated conceptual framework also highlights the growing need to understand how these mechanisms influence responses to green regulatory instruments, sustainable investment incentives and climate-related messages. This literature review, therefore, integrates research addressing behavioral economics, neuroeconomics, psychology, sustainable finance and environmental policy to establish a comprehensive foundation for analyzing how young individuals make financial decisions in the context of the green transition.

PRESENT BIAS AND TIME DISCOUNTING

Present bias is one of the most extensively documented behavioral tendencies affecting young adults. Laibson's (1997) model of hyperbolic discounting demonstrated that individuals systematically overweight immediate outcomes while heavily discounting future payoffs. Laibson's contribution is especially relevant because it shows through a mathematical approach why people procrastinate or avoid long-term beneficial behaviors.

Sutter et al. (2013) expanded on this by studying intertemporal choices across different age groups, and found that adolescents and young adults display significantly higher impatience and stronger present bias compared to older adults. Their study indicates that neurodevelopmental factors – specifically underdeveloped prefrontal control mechanisms – play a role in shaping time preferences.

This has major implications for sustainable finance:

- Green bonds and ESG funds often provide benefits that are long-term, uncertain or abstract.
- Young individuals may undervalue these distant payoffs due to present-biased decision-making.
- Environmental behaviors requiring upfront financial sacrifice (e.g. paying more for sustainable products) are disproportionately avoided.

Hardisty & Weber (2009) directly linked present bias to environmental outcomes, showing that individuals discount environmental benefits *even more steeply* than monetary benefits. This is critical: it means that sustainability suffers a double disadvantage – it is both long-term and abstract.

Thus, present bias contributes to the lower participation of young individuals in sustainable investment products and weak responsiveness to long-term environmental incentives.

OVERCONFIDENCE AND NOVICE INVESTOR BEHAVIOR

Overconfidence is one of the strongest predictors of financial mistakes among young individuals. In their landmark study, Barber and Odean (2001) found that overconfident investors trade more frequently, incur higher costs, and achieve lower returns. Their research also showed that men (especially young men) are particularly prone to overconfidence. Glaser & Weber (2007)

deepened this understanding by demonstrating that overconfidence comes in two forms:

1. **Overestimation of knowledge**, and
2. **Miscalibration of accuracy** (believing predictions are more accurate than they are).

Young individuals, who often begin investing through gamified mobile platforms, are particularly vulnerable to both forms.

The connection to sustainable finance is crucial:

- Many young investors believe they understand ESG metrics intuitively.
- They often rely on superficial indicators (e.g. labels, branding).
- Overconfident individuals are more likely to fall for greenwashing because they overtrust their judgement.

Recent research by Berg, Kölbel & Rigobon (2022) revealed that ESG ratings vary dramatically depending on methodology – demonstrating that the sustainability data young investors rely on is often ambiguous. Without understanding this complexity, overconfident young investors may make inappropriate decisions believing that they "know what is green." Hoffmann, Sias & Yu (2022) added that mobile trading apps, which emphasize quick decisions and dopamine-reward cycles, intensify overconfidence, especially among younger users.

AVAILABILITY HEURISTIC AND CLIMATE-RELATED INFORMATION

The availability heuristic, introduced by Tversky & Kahneman (1973), describes how individuals estimate likelihood based on how easily examples come to mind. Their original experiments showed that people rely on vivid memories rather than statistical reality. This heuristic becomes extremely powerful in climate-related financial decisions:

- The more frequently young people see climate disasters on social media,
- The more they believe climate risks are imminent and severe.

Mostafa (2021) found that exposure to climate imagery (floods, wildfires) increases emotional engagement and strengthens willingness to invest in sustainable financial products – but only in the short term. This highlights an important limitation: availability-driven effects decay quickly unless reinforced. On the other side, ESG controversies – highly visible scandals such as "greenwashing cases" can significantly reduce trust in sustainable investment products (Berg et al., 2022). This duality shows why the availability heuristic is essential for designing lasting green regulatory strategies.

SOCIAL PROOF, PEER INFLUENCE AND DIGITAL ENVIRONMENTS

Social proof operates when individuals look to others to determine appropriate behavior. Bursztyn & Yang (2022) reviewed dozens of studies and concluded that peer influence is one of the strongest behavioral forces in economics, particularly among young adults. Social proof affects sustainable finance in several ways:

- If peers are investing in green funds, young investors are more likely to follow.
- If peers mock or dismiss sustainable investing, engagement plummets.
- Sustainability influencers can dramatically shift investor sentiment – often more than official policy communication.

Evans et al. (2013) highlight that environmental behavior is significantly shaped by perceived social approval, and not only by environmental concern. In digital settings, these effects are amplified by the following:

- likes
- comments
- influencer endorsements
- visible trends in apps all acting as social cues that shape the perceived desirability of financial products.

EMOTIONS, AFFECTIVE STATES AND RISK PERCEPTION

THE CENTRAL ROLE OF EMOTION IN DECISION-MAKING

A large body of neuropsychological and behavioral research demonstrates that economic decision-making is not purely cognitive, but deeply intertwined with emotional processes. Antonio Damasio's influential work *Descartes' Error* (1994) fundamentally shifted scientific understanding by showing that emotion is not opposed to rationality, but essential to it. His somatic marker hypothesis proposes that emotional signals guide individuals toward or away from choices based on previous experiences. Without emotional feedback, people struggle to evaluate risks, anticipate consequences or make consistent decisions.

This has profound implications for young individuals:

- They may rely heavily on emotional evaluations in unfamiliar financial contexts.
- Their emotional responses can outweigh rational analysis, particularly under uncertainty.

- Emotional "shortcuts" are intensified in digital environments where stimuli are rapid and vivid.

Damasio's work is foundational because it demonstrates that emotional arousal is not a distortion to be eliminated – it is part of the architecture of decision-making itself.

Emotional Arousal and Market Behavior: Evidence from Neurofinance

Lo and Repin (2002) conducted one of the first empirical neurofinance studies by measuring physiological responses (skin conductance, heart rate) in traders during simulated market conditions. They discovered that strong emotional reactions were linked to risk-taking behavior, overreaction to market movements and inconsistent decision patterns.

Why is this relevant for young individuals?

- Youth exhibit stronger emotional reactivity than older adults.
- They often experience high-arousal market environments through mobile apps.
- Real-time notifications, chart movements and gamified features trigger intense emotions.

Their work validates the idea that emotional arousal can compromise rational evaluation, especially in fast-paced trading or sustainability-oriented choices where signals may be ambiguous.

EMOTIONS AND ENVIRONMENTAL RISK PERCEPTION

Environmental psychology research has shown that emotional responses play a central role in how individuals perceive climate risks. Van der Linden, Maibach & Leiserowitz (2015) developed an integrated model of climate risk perception showing that emotion – especially worry and concern – strongly predicts climate-related behavior, often more than objective knowledge. Their model demonstrates the following:

- Increased emotional concern → greater support for climate policies
- Reduced concern → lower engagement with sustainable choices

However, emotions must be carefully calibrated. O'Neill & Nicholson-Cole (2009) warn that fear-based climate messages can backfire. When individuals feel overwhelmed, they may disengage entirely or deny the message. For young individuals, who often consume climate content through emotionally charged social media platforms, this balance is delicate. Exposure to dramatic imagery increases initial engagement, but may not sustain long-term behavioral change unless paired with empowering messages.

POSITIVE EMOTIONS AND PRO-ENVIRONMENTAL BEHAVIOR

Research by Bamberg & Möser (2007) highlights that positive emotions such as pride, moral satisfaction and hope are strong motivators of sustainable behavior. Their meta-analysis shows that people are more willing to engage in environmental actions when they feel morally aligned with the behavior. Similarly, Schwartz et al. (2015) demonstrate that value-based emotional motivations predict willingness to invest in sustainable funds. This suggests that framing sustainable investments around collective identity and personal empowerment may be more effective than fear-based messaging.

In terms of green regulation, this means the following:

- Emotionally empowering communication works better than fear-inducing communication.
- Young individuals respond particularly strongly to messages involving identity and meaning.
- Emotional resonance is a necessary component of effective green financial policy.

IMPLICATIONS FOR THE NAUKO PROJECT

The project materials emphasize the centrality of emotional arousal and visual attention in shaping youth financial decisions. Eye-tracking and EEG technologies allow objective measurement of emotional and perceptual responses in real time. This aligns with the broader trend in behavioral research aiming to integrate physiological indicators for more accurate models of economic behavior.

NEUROECONOMIC EVIDENCE: ATTENTION, PERCEPTION AND INFORMATION PROCESSING

VISUAL ATTENTION AS A DETERMINANT OF CHOICE

Krajbich, Armel & Rangel (2010) provided groundbreaking evidence that attention, measured through eye fixations, directly influences choice. Their "gaze bias model" showed the following:

- People look longer at the option they prefer.
- The option that receives more visual attention becomes more likely to be chosen.

- Decision-making is not only based on evaluation, but on perceptual exposure.

This is crucial for sustainable finance because young people are highly sensitive to visual elements such as:

- green color schemes
- eco-labels
- logos
- icons
- influencer faces
- ESG badges
- simplified risk scales

The NAUKO project's planned eye-tracking experiments will directly leverage this literature to measure how young individuals visually process green financial information.

EEG AND THE NEUROSCIENCE OF FINANCIAL RISK

EEG research provides insight into neural activity during the evaluation of rewards and risks. Hajcak et al. (2006) identified neural signatures as follows:

- **FRN (Feedback-Related Negativity):** Error or negative outcome processing
- **P300 amplitude:** Attention, outcome evaluation, emotional engagement

These signals allow researchers to identify:

- whether young individuals perceive green investments as risky or rewarding
- how climate-related disclosures shape neural responses
- the strength of emotional reactions to sustainability cues

Young individuals often show more pronounced neural reactivity in economic contexts because their prefrontal regulatory systems are still developing.

PHYSIOLOGICAL INDICATORS IN DECISION SCIENCE

Figner & Murphy (2011) reviewed the role of physiological measures (heart rate, skin conductance) in predicting risk-taking. Their findings showed the following:

- Higher arousal → greater tendency toward risk
- Emotional overload → decision avoidance
- Calm states → more thoughtful decisions

This is essential for understanding youth responses to sustainability information.

Green policies that invoke either heightened excitement or excessive anxiety may unintentionally distort financial decisions.

PERCEPTUAL COMPLEXITY OF SUSTAINABILITY INFORMATION

Research on sustainability disclosures reveals that young investors struggle with:

- complex ESG metrics
- multi-layered taxonomy systems
- dense sustainability reports

Berg et al. (2022) argue that confusion caused by inconsistent ESG ratings erodes trust in green investments. Harbach & Hellwig (2020) demonstrate that simplified icons and visual summaries significantly improve comprehension for younger audiences.

This reinforces the need for behavioral and neurocognitive insights in designing green regulatory communication.

BEHAVIORAL ECONOMICS, GREEN REGULATION AND SUSTAINABLE FINANCE

BEHAVIORAL FOUNDATIONS OF GREEN POLICY

Environmental policies historically relied on economic incentives such as taxes, subsidies and price signals. However, behavioral economics reshaped this approach by demonstrating that:

- people do not respond optimally to incentives,
- messaging matters as much as monetary value,
- psychological barriers influence sustainable action (Sunstein & Reisch, 2014).

Gowdy (2008) argues that climate policy requires an understanding of evolutionary and psychological roots of behavior – humans are not naturally inclined to prioritize long-term ecological welfare. Stern (2020) reinforces this by framing climate change as "the greatest behavioral challenge humanity has faced". Therefore, policies must be designed with behavioral patterns in mind, not against them.

GREEN INVESTMENT BEHAVIOR AND BIASES

Multiple studies have shown that sustainable investment behavior is influenced by behavioral tendencies, as follows:

- Present bias reduces willingness to invest in long-term green portfolios (Hardisty & Weber, 2009).
- Availability effects shape climate-risk perception and investment intent (Mostafa, 2021).
- Overconfidence leads to misunderstanding of sustainability metrics (Berg et al., 2022).
- Social proof amplifies trends in sustainable investing (Evans et al., 2013).

Bolton & Kacperczyk (2021) empirically demonstrated that investors increasingly price carbon risk, but young investors often do so inconsistently due to behavioral distortions.

BEHAVIORALLY-INFORMED REGULATORY COMMUNICATION

Harbach & Hellwig (2020) found that simplified sustainability disclosures drastically improve comprehension and correct decision-making. Sunstein & Reisch (2014) argue that nudges – such as green default options, visual cues or behavioral prompts – can significantly improve policy uptake. This aligns with our conceptual framework, which emphasizes that emotional and cognitive biases should be incorporated into green regulatory design.

SOCIAL NORMS AND COLLECTIVE GREEN DECISION-MAKING

Allcott (2011) showed that social norm messages reduce household energy consumption more effectively than price incentives.

This may be applied to young investors as follows:

- Showcasing peer involvement in sustainable investment could amplify participation.
- Social comparison tools within investment apps may strengthen sustainable behaviors.
- Norm-based messaging could enhance regulatory impact.

PROPOSED NEUROECONOMIC CONCEPTUAL MODEL

The proposed neuroeconomic conceptual model seeks to explain how young individuals process sustainability-related financial information by integrating cognitive, emotional, perceptual and behavioral mechanisms into a single explanatory framework. Young people operate in digital environments filled with visual stimulation, persuasive messaging, social influence cues and complex sustainability labels, all of which interact with cognitive biases and emotional responses. A coherent model must, therefore, capture how these different processes combine to shape attention, evaluation and, ultimately, financial decision-making. The model begins with the informational environment in which young individuals are situated. Sustainability labels, green tax incentives, climate-risk disclosures and social norms embedded in digital platforms serve as external stimulation that initiates perceptual and emotional responses. Young people often encounter this stimulation in visually saturated contexts, such as investment apps or social media, making perception the first gateway through which sustainability information is filtered. Visual attention plays a central role in determining what information enters conscious processing. Eye-tracking research demonstrates that individuals tend to choose the option they visually attend to for longer, and that attention is shaped by salience, color cues, icons and emotional imagery. For young individuals who rely heavily on fast, intuitive processing, attention functions as a critical bottleneck: what they notice influences what they evaluate, and what they overlook rarely enters subsequent decision stages. Emotional arousal interacts closely with visual processing. When sustainability information evokes anxiety, hope, pride or excitement, emotional signals intensify or suppress attention and influence how risks and benefits are perceived. Emotional reactions can motivate young individuals to pursue sustainable investments, but they can also overwhelm them, causing avoidance or impulsive decisions. These emotional states are reflected in physiological responses such as changes in neural activation, heart rate and skin conductance, which together provide insight into the affective component of decision-making. Cognitive evaluation occurs once perceptual and emotional signals have shaped the information landscape. Here, cognitive biases, heuristics and pre-existing beliefs determine how sustainability information is interpreted. Present bias leads young individuals to undervalue long-term environmental benefits, overconfidence causes them to misjudge the complexity of ESG criteria, availability heuristics cause dramatic climate events to dominate judgment, and social proof drives conformity to peer behavior. These biases do not operate independent-

ly, but interact with emotional responses and attentional patterns, reinforcing interpretations of sustainability-related financial choices.

The decision environment or "choice architecture" further shapes the outcomes. The way information is framed, the order in which options are presented, the presence of default settings, the structure of digital platforms and the visual style of regulatory communication all have an influence on behavior. Even when individuals possess similar preferences, small changes in the decision environment can meaningfully shift their actions. Ultimately, behavioral outputs, such as choosing a green investment, responding to regulatory incentives or ignoring sustainability disclosures, emerge from the combined forces of perception, emotion, cognition and contextual structure. These decisions feed back into learning processes, influencing future expectations and biases. This conceptual model offers a holistic perspective for understanding how young individuals engage with sustainability-oriented financial environments, and provides a theoretical basis for designing the empirical research within the NAUKO project.

METHODOLOGICAL FRAMEWORK FOR THE NAUKO PROJECT

The methodological framework for the NAUKO project builds on the conceptual model by combining behavioral tasks, eye-tracking and EEG to capture the real-time processes that shape financial decision-making among young individuals. The aim of this methodological approach is not merely to record choices, but to observe the perceptual, emotional and cognitive mechanisms that precede and accompany them. By integrating multiple measurement techniques, the framework provides a multidimensional view of how young people process sustainability-related financial information.

The empirical design begins with the controlled presentation of sustainability-related stimuli, such as green financial products, ESG labels, climate-risk disclosures, tax incentives, social norm messages and conventional investment alternatives. Stimuli are designed to systematically manipulate visual salience, emotional tone, complexity and framing. Participants interact with these stimuli in a computer-based experimental environment that mirrors the interface of real financial platforms. Eye-tracking is used to record gaze patterns, fixation durations, areas of interest and attention shifts. These measures provide insight into which aspects of the information attract attention, how long participants examine sustainability indicators, and whether certain cues prompt increased or decreased engagement.

Simultaneously, EEG is used to capture neural responses associated with emotional arousal, attention allocation and risk evaluation. Neural markers such as the P300, feedback-related negativity and theta-band activity allow researchers to infer cognitive effort, uncertainty processing and emotional salience. Physiological signals such as heart rate variability or skin conductance may also be integrated to measure affective intensity. Together, these measures provide a more complete picture of decision processes than behavioral data alone.

Participants then complete a series of financial decision tasks involving choices between sustainable and conventional investment options under varying levels of risk, complexity and regulatory framing. These tasks reveal behavioral tendencies such as risk-taking, preference for sustainability, susceptibility to emotional framing and responsiveness to green incentives. Survey instruments complement physiological and behavioral measures by capturing individual differences such as environmental attitudes, financial literacy, personality traits and value orientations.

Data analysis integrates information across modalities. Eye-tracking data identify attentional patterns, EEG reveals underlying neurocognitive processes, and behavioral choices indicate preference structures. Multilevel statistical models and machine-learning algorithms are used to examine how attention, emotion and cognitive biases jointly predict sustainable financial behavior. This framework enables the identification of behavioral profiles and neurocognitive signatures that explain why young people respond differently to sustainability-related financial information.

DISCUSSION AND FUTURE RESEARCH DIRECTIONS

The integration of behavioral, cognitive and neurophysiological evidence offers important insights into how young individuals make sustainability-related financial decisions. The findings emerging from the NAUKO model and methodological framework underscore the limitations of traditional assumptions of rationality in environmental and financial policy. Young individuals frequently rely on cognitive shortcuts, emotionally driven heuristics and visually guided attention patterns, which can either support or undermine sustainable financial behavior. Understanding these mechanisms is essential for improving the design of green regulatory tools, sustainable finance products and educational interventions.

One major implication of this work is that green regulation must account for behavioral constraints. If policymakers expect individuals to interpret

complex sustainability metrics, understand climate-risk disclosures or evaluate long-term environmental benefits using purely analytical reasoning, policy uptake will remain limited. Regulatory communication must, therefore, be redesigned with a behavioral lens, incorporating insights from eye-tracking and neuroeconomics to ensure that the most important information captures attention, evokes appropriate emotional engagement, and is cognitively digestible.

Future research should explore the heterogeneity among young individuals. Different psychological profiles, environmental identities, cultural backgrounds and social influences may shape responses to sustainability information in distinct ways. Machine-learning methods applied to neurophysiological data could help classify behavioral subgroups, enabling the development of personalized or segmented policy interventions. Additionally, longitudinal research is needed to examine how exposure to sustainability information and green financial products influences attitudes and behaviors over time. Another important direction involves studying how digital platform design affects sustainable investment behavior. The architecture of trading apps, financial dashboards and social financial networks may amplify biases or promote more sustainable choices depending on their design.

The NAUKO project also provides an opportunity to examine emotional and attentional responses to misinformation and greenwashing, a growing concern in sustainable finance. Understanding how young individuals detect or fail to detect misleading sustainability claims may enhance the integrity of green markets.

CONCLUSION

This analysis combines results from behavioral economics, cognitive psychology, neuroscience, and environmental policy to develop an insight into the ways in which young people make financial choices concerning sustainability. The existing literature indicates that decision-making processes within this domain are influenced by cognitive biases such as present bias, overconfidence, availability heuristics, and social proof, as well as emotional reactions tied to risk, identity and moral imperatives, and perceptual filters that dictate the information subjected to conscious scrutiny. Individuals in their youth stand at a pivotal point where financial advancements and environmental care converge, yet they deal with psychological and intellectual hurdles that shape their reactions to sustainable finance and policies intended for environmental conservation. The neuroeconomic framework we are discussing artfully

weaves together the complex relationships among visual focus, emotional involvement, mental evaluation, and the surrounding context, thereby offering a unified model that showcases the ongoing dynamics of how decisions are made. The methodological strategy in the NAUKO project operationalizes this framework by merging behavioral tasks with eye-tracking and electroencephalography (EEG), enabling researchers to examine the neurocognitive underpinnings of financial decision-making. This integrated method boosts our grasp of scientific ideas and offers significant insights necessary for crafting policies. The outcomes emphasize the value of guidelines based on behavioral understanding. Effective sustainability initiatives must consider how young individuals perceive information, what draws their focus, the emotional resonance of climate-related risks, and how cognitive biases shape their understanding of long-term advantages. By matching regulatory frameworks with genuine human decision processes, lawmakers can stimulate the acceptance of sustainable investment practices and enable the larger transition to a green and circular economy. This investigation forms a scaffold for upcoming analyses that will clarify the economic patterns affecting young individuals. By integrating cognitive, emotional, and neurophysiological dimensions, the NAUKO project promotes a more nuanced, human-centric model of sustainable economic decision-making – one that recognizes both the constraints and the capabilities of young individuals as pivotal agents in the ecological and economic transformations that lie ahead.

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DIGITAL MARKETING AND CAMPING TOURISM: WEB PERFORMANCE AS A COMPETITIVE ADVANTAGE IN THE CONTEXT OF THE BLUE ECONOMY

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With the accelerating digital transformation of the tourism industry and the growing focus on sustainability, digital marketing and optimised websites are playing an increasingly important role in strengthening the market presence of camping tourism. As a form of special interest tourism closely connected to nature, sustainability, and local resources, camping has significant potential to contribute to the blue economy, particularly in coastal regions such as Split-Dalmatia County. In this context, the quality and technical optimisation of campsite websites become not only communication tools, but also instruments that may help raise the visitors' awareness with regard to environmentally responsible behaviour.

The purpose of the study is to explore the role of technically optimized websites in promoting sustainable camping tourism, and to examine their relationship with the principles of the blue economy. The study aims to analyse how the digital infrastructure of campsites may be associated with ecological efficiency, resource management, and the competitive position of camps that promote sustainable practices.

The research methodology is based on a quantitative analysis of official campsite websites in Split-Dalmatia County. Using reliable analytical tools, website performance was evaluated through Core Web Vitals (CWV) metrics to assess loading speed, interactivity, and server response.

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The findings were compared with international standards for digital accessibility and sustainability in order to assess the degree of digital advancement of campsites. The results indicate that many campsite websites do not meet the recommended technical standards for loading speed and server response time, although interactivity generally meets expectations. While the study does not directly measure sustainability outcomes, it suggests that website optimisation may be related to a more efficient use of digital resources and the communication of environmentally responsible practices. By linking digital optimisation with sustainable development through the concept of the digital circular economy, the study provides empirical insights into the technical quality of campsite websites and highlights its potential relevance for sustainable tourism, the blue economy, and the long-term development of coastal communities.

Keywords: *Digital marketing, camping tourism, sustainable development, blue economy, website optimisation*

JEL classification: *L84, O33, Q56*

INTRODUCTION

Camping tourism is one of the fastest-growing segments of the European tourism industry, particularly important for destinations with valuable natural resources, indented coastlines, and rich cultural heritage (Camping statistics, 2024). In a competitive market characterised by evolving tourist preferences, a strong digital presence is essential for campsites to promote and differentiate their offerings (Mikulić et al., 2017), particularly given their dispersed, nature-based locations and smaller size, which limit traditional marketing opportunities (Lindgren, 2025). For campsites, online tools uniquely enable real-time bookings, capacity management, and the promotion of nature- and sustainability-focused experiences, enhancing competitiveness, attracting environmentally conscious visitors, and supporting sustainable tourism development (Fikri, F. & Ikhsan, 2025). Most visitors search for information, compare options, and make reservations online, making website quality and digital marketing highly important determinants of visibility, reputation, and business performance (Halkiopoulos & Giotopoulos, 2022; Jaković et al., 2014), with technical website quality emerging as a fundamental factor in digital presence effectiveness. Consistently, technical website quality, measured by indicators such as Core Web Vitals (CWV), plays an important role in shaping user ex-

perience, engagement, trust, and, ultimately, booking decisions (Dobbala & Lingolu, 2022; Li et al., 2022).

In tourism, even minor delays in website performance can cause user dissatisfaction and result in lost customers, emphasising the importance of technically optimised websites as a core element of digital marketing strategies (Pencarelli, 2020). Beyond their economic and promotional functions, digital channels can also support broader strategic goals related to sustainable development and the blue economy (Lee et al., 2020). Such research indicates that digital tools can promote environmentally responsible practices, improve resource efficiency, enhance transparency, and increase visitor awareness of the preservation of coastal and marine ecosystems (Lee et al., 2020; Gutierrez et al., 2025; Zaeri, 2025). However, this study does not directly measure these relationships, but rather considers them at a conceptual level in the context of the technical performance of websites.

The main objective of the study is to assess the technical performance of campsite websites in Split-Dalmatia County using Core Web Vitals and related metrics, and to explore their potential relevance for digital competitiveness, sustainable tourism, and the blue economy. Specifically, the study aims to: (1) evaluate website performance of the analysed websites in terms of loading speed, interactivity, and visual stability; (2) identify key technical weaknesses and optimisation opportunities; and (3) discuss the potential implications of digital performance for user experience, competitiveness, and sustainability-oriented tourism development.

THEORETICAL OVERVIEW

DIGITAL MARKETING, ONLINE PRESENCE, AND COMPETITIVENESS IN TOURISM

Digital marketing in tourism comprises a set of interrelated strategies, techniques, and digital tools that enable tourism entities to communicate effectively with target markets, manage their brand, and stimulate bookings across online channels (Afren, 2024). In the contemporary tourism environment, characterised by widespread digitalisation and changing consumer behaviour, tourists increasingly search for information, compare options, and make booking decisions online, making digital channels crucial for shaping the customer journey (Veseli et al., 2025; Jayakody et al., 2025). In camping tourism, a holistic digital approach – integrating content marketing, search engine optimisa-

tion (SEO), social media, and paid campaigns – not only increases visibility, but also communicates sustainable, authentic, and experience-oriented values that appeal to modern "conscious travellers" (Holmberg, 2022; Arantes et al., 2025). This digital presence, which includes websites, social media profiles, booking platforms, reviews, visual identity, and overall online reputation, signals quality, professionalism, and reliability (Nemyrovska & Ievseitseva, 2024; Cruz & Karatzas, 2024; Kromidha & Robson, 2021).

Systematically developing a digital presence enables campsites to strengthen brand perception, differentiate from competitors, and build trust among users (Qazi, 2024; Lindgren, 2025). It also provides a strategic platform to showcase unique features such as natural surroundings, certified sustainable practices, high-quality infrastructure, and local experiences, thereby increasing both competitiveness and relevance in tourism markets focused on sustainability (Aussawariyathipat & Khajorntridech, 2025; Abad & Velasquez, 2025; Sukenda et al., 2025).

While a strong digital marketing strategy and a well-developed online presence are essential for competitiveness in tourism, their effectiveness ultimately relies on the technical quality of the website, making Core Web Vitals (CWV) a core factor in shaping user experience and business performance.

TECHNICAL WEBSITE QUALITY AND CORE WEB VITALS (CWV)

In the digital environment, websites are a primary interface between organisations and their users, often shaping initial brand perceptions. A well-designed and technically optimised website can provide a significant competitive advantage by enhancing user experience, fostering engagement, and contributing to overall business performance. As a result, an increasing number of organisations systematically monitor measurable performance indicators, among which CWV have become a central standard for evaluating website performance (Dobbala, & Lingolu, 2022; Gaddam, 2025).

CWV, developed by Google (Wehner et al., 2022), are a set of objective metrics designed to measure real user experience. Unlike traditional metrics such as total page load time, CWV more accurately reflect how users perceive the speed, responsiveness, and visual stability of a website (Walton, 2020; Dobbala, & Lingolu, 2022; Edgar, 2024a). They comprise the following core indicators: Largest Contentful Paint (LCP), which assesses content rendering speed (Edgar, 2024b); Interaction to Next Paint (INP) which replaced FID in 2024 and measures responsiveness (Edgar, 2024c); and Cumulative Layout Shift (CLS), which tracks visual stability. Additionally, First Contentful Paint

(FCP) is often used as a supplementary indicator of the early loading phase (Edgar, 2024d), as well as Time to First Byte (TTFB) which indicates the speed of the server's initial response to a user request (Edgar, 2024e).

Research confirms that optimising these five core metrics increases user satisfaction, session duration, engagement, and conversion rates, thereby significantly contributing to business performance (Sikder, 2023). In tourism, where booking decisions are often made quickly, impulsively, and with minimal tolerance for technical disruptions, website performance optimisation directly affects user retention and revenue generation (Foris et al., 2020). In light of the above, it is evident that CWV metrics are not merely technical indicators, but key dimensions of real user experience that directly influence the perceived quality of a website and overall business performance. Table 1 integrates the CWV indicators, phases of perceived user experience (Perceptual UX phase), performance thresholds (Thresholds, P75), and the status within the CWV (SEO status/evaluation framework).

Table 1. CWV indicators and associated metric, UX phases, thresholds (P75), and SEO status

Indicator	Measure aspect	Perceptual UX phase	Thresholds (P75)	CWV / SEO status
Largest Contentful Paint (LCP)	Main content load time	Sense of "readiness" of the main content.	≤2.5 s good; 2.5–4.0 s needs improvement; >4.0 s poor	Official CWV; strong impact on SEO and UX.
Interaction to Next Paint (INP)	Responsiveness to user actions	Perceived responsiveness throughout the entire visit.	≤200 ms good; 200–500 ms needs improvement; >500 ms poor	Official CWV (since 2024, replaced FID).
Cumulative Layout Shift (CLS)	Visual stability	Sense of predictability and reliability.	≤0.1 good; 0.1–0.25 needs improvement; >0.25 poor	Official CWV; stability builds trust.
First Contentful Paint (FCP)	First content visibility	Signal that the page is loading.	≤1.8 s good; 1.8–3.0 s >3.0 s poor	Not an official CWV; supplementary indicator.
Time to First Byte (TTFB)	Server response speed	Influences overall page loading performance.	< 200 ms good; 200–500 ms needs improvement; > 500 ms poor	Not an official CWV; supplementary indicator.

Source: Authors' own research, adapted from Edgar (2024) and Gaddam (2025)

In line with the existing literature (Moreno & Martínez, 2013), Core Web Vitals metrics were supplemented by additional Google Lighthouse scores, which capture further dimensions of website quality – namely Performance, Accessibility, Best Practices, and SEO – providing a more comprehensive assessment of website optimisation. Their related Google Lighthouse scores range from 0 to 100, with scores between 90 and 100 indicating good performance, scores from 50 to 89 indicating a need for improvement, and scores below 50 indicating poor optimisation (Web.dev, 2025).

Beyond technical performance and user experience, a tourism entity's digital presence can also promote sustainability goals and support the development of a digital circular economy within the sector.

SUSTAINABLE DEVELOPMENT AND DIGITAL CIRCULAR ECONOMY IN TOURISM

The concept of the digital circular economy extends traditional circular economy principles into the digital domain by emphasising the efficient use of data, energy (Bressanelli et al., 2022), and digital infrastructure throughout their lifecycles (Patwa et al., 2025). It seeks to minimise digital waste, optimise data flows, and reduce the environmental impact of information and communication technologies, while enhancing value creation (Cheah et al., 2022). In tourism, digital systems are increasingly recognised not only as operational tools, but also as strategic enablers of sustainability, supporting responsible resource management, transparency, and process optimisation across the value chain (Aransyah et al., 2025; Padash & De Tombe, 2025). Digital solutions improve environmental efficiency by reducing material consumption, particularly in paper-based processes, and enable rapid, personalised visitor education through applications, interactive maps, and information systems (Chakraborty, 2024; Zhang & Deng, 2024). They also enhance resource use through smart energy and water management systems, and increase the visibility of local environmental initiatives, contributing to more sustainable operational practices (Aksin-Sivrikaya & Bhattacharya, 2017).

In camping tourism, where infrastructure is closely integrated with natural environments, digital tools help reduce ecological pressures, improve environmental performance, and enhance competitiveness for nature-oriented and environmentally conscious visitors (Aussawariyathipat & Khajorntridech, 2025; Rodrigues et al., 2023). Websites and other digital channels are essential for communicating these values in an engaging and interactive way, influencing visitors' perceptions and supporting the market positioning of sustainable

campsites (Llodrà-Riera et al., 2015; Brochado & Brochado, 2019). Extending the focus on sustainability, digital tools also enable coastal destinations to advance the blue economy by supporting efficient resource use and sustainable tourism practices.

THE BLUE ECONOMY AND DIGITAL TOOLS IN COASTAL DESTINATIONS

The blue economy promotes the sustainable management of marine and coastal resources, aiming to balance economic growth, ecosystem conservation (Shekhar, 2024), and social well-being. In tourism, this approach is reflected in reducing environmental impact, protecting biodiversity, and implementing innovative technological and organisational solutions that support responsible resource management (Spalding, 2016; Anjum et al., 2025). As tourism is one of the most intensive economic activities in coastal areas, it plays a key role in creating a synergy between economic benefits and the preservation of marine ecosystems.

Digitalisation has become an essential mechanism for operationalising blue economy principles, enabling transparent, data-driven, and adaptive governance frameworks for coastal and tourism systems (Verma & Sharma, 2025). Core applications include: monitoring marine and coastal environments through IoT-based sensing systems (Miller et al., 2025); tracking resource consumption and waste streams to optimise energy, water, and material use (Sankar & Ilangovan, 2025); enhancing maritime safety with digital navigation and crisis communication tools (Casareale, 2019); applying advanced analytics to manage tourism carrying capacities sustainably (Wrisberg et al., 2002); and promoting visitors' environmental awareness through interactive digital content (Kiraz & Danju, 2025).

In camping tourism, integrating digital solutions guided by blue economy principles offers a competitive advantage. It enables campsites to demonstrate sustainability, enhance the perceived environmental value of the destination, and strengthen long-term competitiveness and resilience in a market increasingly driven by environmentally responsible tourism practices.

INTEGRATION OF CONCEPTS: DIGITAL PRESENCE AS A DRIVER OF SUSTAINABLE AND COMPETITIVE DEVELOPMENT

The theoretical review above shows that digital presence and the technical quality of websites go beyond their primary marketing function, contributing

more broadly to sustainability, operational efficiency, and the protection of coastal resources. In the contemporary digital ecosystem, technologically optimised websites enable faster and more reliable communication with visitors, provide clear guidance on sustainable behaviour in natural environments, and improve transparency in capacity and resource management. As a result, digital business elements are effectively integrated into the strategic framework of sustainable tourism and the blue economy, where rational resource use, environmental responsibility, and long-term resilience are central priorities.

EMPIRICAL RESEARCH DESIGN

Building on a theoretical framework that highlights the importance of digital presence and website technical quality in contemporary camping tourism, the empirical part of this study examines the Core Web Vitals (CWV) performance of campsite websites in Split-Dalmatia County. Metrics such as LCP, INP, and CLS, along with FCP and TTFB, reflect loading speed, interactivity, and visual stability, enabling an objective assessment of technical optimisation and the identification of limitations affecting user experience, digital visibility, and the sustainability of digital presence. On this basis, the study addresses the following research question:

To what extent are the websites of campsites in Split-Dalmatia County aligned with the recommended Core Web Vitals (CWV) metric thresholds?

Answering this question enables a systematic evaluation of website performance, identification of campsites achieving optimal values, and detection of areas requiring further optimisation, providing an empirical basis for understanding digital readiness and potential improvements in user experience, sustainability, and overall digital competitiveness.

SAMPLING

The study focused on coastal campsites in Split-Dalmatia County that have official websites. The sample was compiled from publicly available sources, including tourism organisation databases, regional tourism portals, and online booking platforms. A total of 30 websites were included, representing nearly 65% of all campsites in the county and providing a representative overview of the camping tourism segment.

INSTRUMENTS AND MEASUREMENT

Website technical quality was assessed using Core Web Vitals (CWV) and aggregated Google Lighthouse scores, covering Performance, Accessibility, Best Practices, and SEO. Metrics were analysed descriptively through charts, with interpretations highlighting their impact on user experience and priorities for optimisation. All measurements were conducted using Google PageSpeed Insights and Lighthouse to ensure standardised and comparable data.

ANALYTICAL APPROACH

The collected data were analysed descriptively, and individual metrics were categorised into three performance levels according to Google Lighthouse thresholds (Edgar, 2024; Gaddam, 2025; Web.dev, 2025):

- **Good** – highly optimised
- **Needs Improvement** – moderate performance, with scope for optimisation
- **Poor/Bad**[1] – significant deficiencies requiring corrective action

This classification highlights the overall performance trends, differences among campsites, and potential technical limitations affecting user experience, digital visibility, and the communication of sustainable practices.

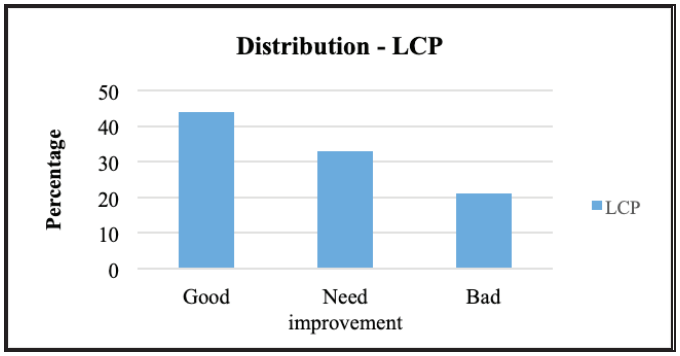
RESEARCH FINDINGS

This section presents the empirical findings on CWV performance across campsite websites, highlighting technical strengths and weaknesses. The first metric examined is LCP, which measures the time required for the largest visible element on a webpage – typically a large image, video, or prominent text block – to load.

LCP values for the analysed websites are shown in Chart 1.

[1] The term "bad" is equivalent to "poor" and has no difference in meaning; it is simply a terminological choice and does not affect interpretation.

Chart 1. LCP indicator (N=30)

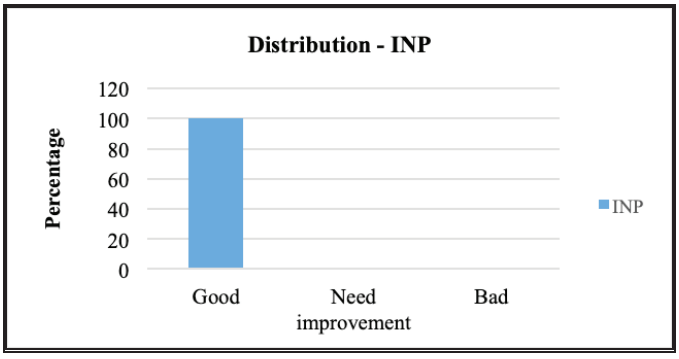


Source: Author(s)

The chart for the LCP metric indicates a generally satisfactory situation, though there is clear room for improvement. Approximately 44% of the websites load their main content within the recommended 2.5 seconds, giving users a positive first impression. However, 33% of the websites fall into the "needs improvement" category (2.5-4 seconds), where the user experience is average and comparatively slower than that of their competitors. Of particular concern is that 21% of the websites are classified as "poor," with loading times exceeding 4 seconds, which significantly increases the likelihood of page abandonment. Overall, the results show that more than half of the analysed websites do not meet optimal standards, indicating substantial potential for further optimisation.

Furthermore, INP – the metric that measures the responsiveness of a webpage to user interactions – underscores the importance of performance.

Chart 2. INP indicator (N=30)

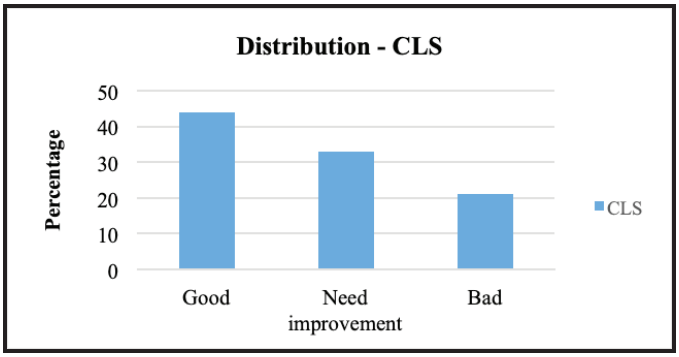


Source: Author(s)

According to the results shown in the chart presenting the INP metric (Chart 2), 100% of the analysed websites fall into the "good" category, with response times below 200 ms. This indicates that users – whether browsing glamping or camping websites – can expect very fast and smooth interactions, without delays, lag, or frustration. None of the websites are classified in the "needs improvement" or "poor" categories, confirming a high level of technical optimisation and consistently strong responsiveness.

In contrast, the CLS metric measures the visual stability of a webpage during loading, specifically capturing unexpected layout shifts of elements such as images, text, or buttons.

Chart 3. CLS indicator (N=30)



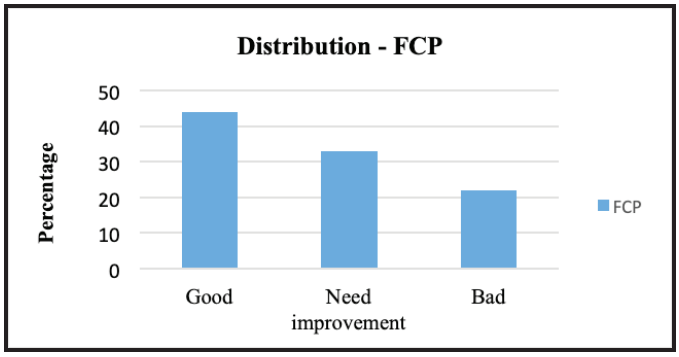
Source: Author(s)

The distribution chart for the CLS metric (Chart 3) indicates that visual stability among the analysed websites is highly inconsistent. Forty-four percent of the websites fall into the "good" category, meaning that nearly half provide a stable experience without significant element shifts. However, 33% of the websites are classified as "needs improvement," where content shifts are occasionally noticeable and may disrupt the smoothness of user interaction.

Of particular concern is that 21% of the websites fall into the "poor" category, exhibiting pronounced element shifts that can lead to misclicks and a sense of unreliability. Overall, more than half of the websites require optimisation, primarily by defining multimedia dimensions, reserving space for advertisements, and optimising font loading.

Regarding the FCP metric, it marks the moment when the first content appears on the screen.

Chart 4. FCP indicator (N=30)

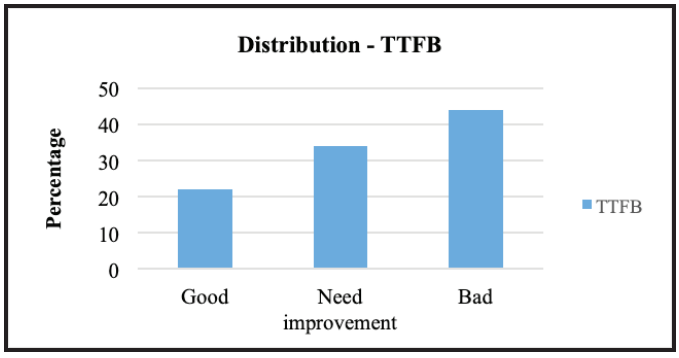


Source: Author(s)

The distribution chart for the FCP metric (Chart 4) shows divided results among the analysed websites. In total, 44% of the websites achieve "good" values, with the first content displayed within the recommended 1.8 seconds, providing users with a quick initial visual cue. However, 33% of the websites fall into the "needs improvement" category (1.8–3 seconds), where loading is still perceived as acceptable but not optimal. The greatest challenge is represented by 22% of the websites classified as "poor," where the first content appears only after 3 seconds, often perceived by users as slow and causing frustration. Overall, more than half of the websites do not meet the recommended standards, indicating a need for optimisation, for example, by reducing Cascading Style Sheets/JavaScript (CSS/JS) file sizes or optimising images.

The TTFB metric further reflects the server speed.

Chart 5. TTFB indicator (N=30)

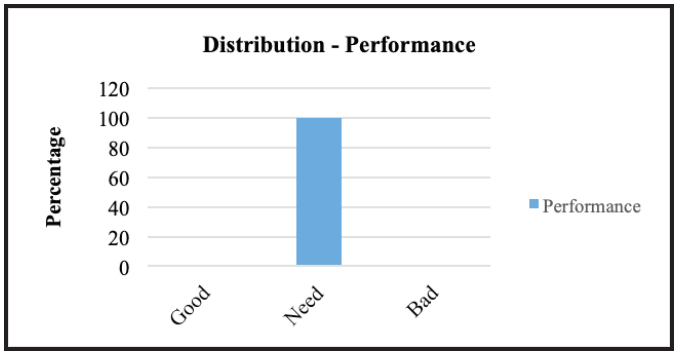


Source: Author(s)

The TTFB distribution chart (Chart 5) shows that most of the analysed websites experience issues with server response speed. Only 22% of the websites achieve good results, with a time to first byte under 200 ms, representing a relatively small proportion. The largest group, 44%, falls into the "poor" category, where TTFB exceeds 500 ms, creating a perception of slowness immediately upon page load. The remaining 34% are classified as "needs improvement" (200-500 ms), which is acceptable but far from optimal. Overall, more than three-quarters of the websites fail to meet the recommended standards, making TTFB one of the weakest performing metrics. Slow server response is often caused by unoptimised databases, lack of caching systems, reliance on external services, or significant physical distance between users and the server. Potential improvements include optimising server-side logic, implementing caching tools, reducing external resource calls, and utilising a content delivery network (CDN) for faster content delivery.

The next chart (Chart 6) shows the distribution of the Performance score, which consolidates several metrics related to loading speed and technical optimisation. This indicator offers a concise overview of how fast a website is and how effectively it delivers a quality user experience.

Chart 6. Performance (N=30)

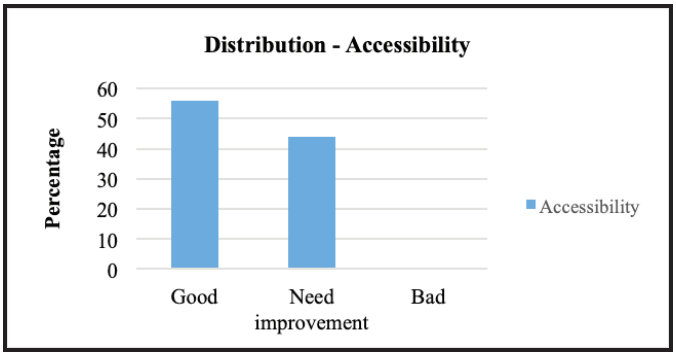


Source: Author(s)

The distribution results show that 100% of the websites fall into the "needs improvement" category. None of the websites achieved a "good" rating, but none were classified as "poor" either. This indicates that all the analysed websites provide an average user experience; they are not critically slow, but their performance is far from optimal. These results highlight a clear potential for improving technical optimisation and speed to meet the recommended standards.

The following chart (Chart 7) presents the distribution of the Accessibility score, an indicator that evaluates how accessible websites are to all users, including individuals with various disabilities. Factors considered include colour contrast, availability of alternative text for images, logical page structure, and the ability to navigate using a keyboard.

Chart 7. Accessibility (N=30)

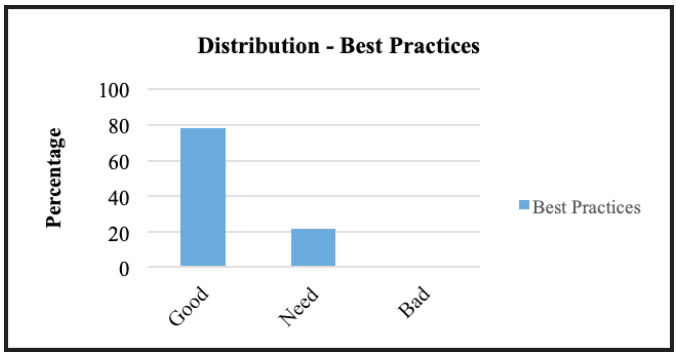


Source: Author(s)

The distribution results show that 56% of the websites fall into the "good" category, while 44% are classified as "needs improvement". No websites were rated as "poor". This indicates that more than half of the websites meet the basic accessibility standards, while nearly half still have shortcomings that may hinder usability for certain user groups. Overall, accessibility is not critically deficient, but there is significant room for improvement to ensure that all websites are fully inclusive and aligned with best practices.

The next chart (Chart 8) presents the distribution of the Best Practices score, an indicator assessing the extent to which websites adhere to modern web development security and technical guidelines. The factors considered include the use of HTTPS protocols, secure and up-to-date libraries, and the implementation of technologies that ensure a reliable and safe user experience.

Chart 8. Best Practices(N=30)

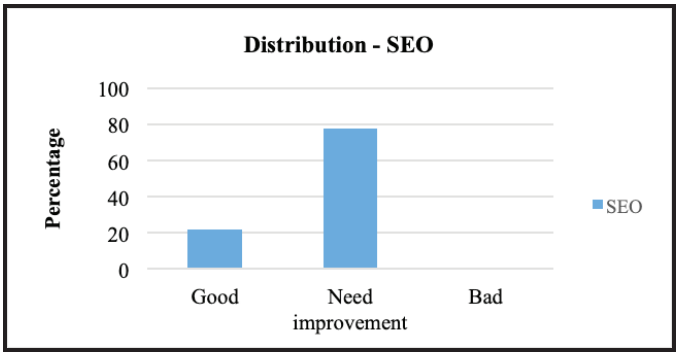


Source: Author(s)

The distribution results show that 78% of the websites fall into the "good" category, while 22% are classified as "needs improvement". No websites were rated as "poor". This indicates that the vast majority of the websites meet the modern security and technical standards, which is a positive outcome. However, the presence of a small proportion of websites in the "needs improvement" category suggests that not all are fully aligned with the recommended best practices, which may pose risks or limitations for further development and maintenance.

The next chart (Chart 9) shows the distribution of the SEO score, an indicator that measures the level of search engine optimisation of the websites. The analysis evaluates technical elements such as meta tags, mobile responsiveness, HTML structure, loading speed, and other factors that affect the visibility and ranking of websites in search engine results.

Chart 9. Analysis of SEO practices (N=30)



Source: Author(s)

The results show that 78% of the websites fall into the "needs improvement" category, while only 22% are classified as "good". No websites were rated as "poor". This indicates that most websites have certain deficiencies in SEO optimisation; although not critical, they are not fully aligned with the best practices that would enable better search engine visibility. The main potential for improvement lies in optimising the meta tags, enhancing mobile responsiveness, and maintaining a consistent content structure.

CONCLUDING REMARKS

DISCUSSION

The findings show that a significant proportion of campsite websites in Split-Dalmatia County do not meet the recommended technical performance standards, particularly regarding loading speed and server responsiveness. Metrics such as Largest Contentful Paint (LCP), First Contentful Paint (FCP), and Time to First Byte (TTFB) reveal key bottlenecks related to delayed content rendering and slow server communication, which negatively impact perceived speed and overall user experience. These shortcomings are also reflected in the performance and SEO scores, which mostly fall within the "needs improvement" category.

In contrast, relatively favourable results for Interaction to Next Paint (INP) and Cumulative Layout Shift (CLS) indicate that interactivity and visual stability are generally satisfactory. This suggests that many campsite websites provide a functional and stable user interface, offering a solid foundation for further optimisation. However, the observed variation in performance across websites highlights uneven levels of digital maturity and points to structural inefficiencies, particularly in backend processes and content delivery systems. These differences may significantly influence the user perception, engagement, and ultimately the digital visibility and competitiveness of campsites. The results further underline the importance of addressing performance-related issues through systematic technical optimisation.

Improvements in server response times, efficient content delivery, and the reduction of render-blocking resources can substantially enhance overall website performance. In practical terms, this involves implementing content delivery networks (CDNs), optimising server-side logic, compressing and standardising multimedia content, and reducing reliance on external scripts. Continuous monitoring using tools such as Google Lighthouse and PageSpeed Insights can support the identification of performance bottlenecks and guide

ongoing optimisation efforts. In the broader context of tourism digitalisation, the findings suggest that technical website quality plays a critical role in shaping online user experience and influencing competitive positioning.

In environments characterised by increasing digital dependence and user expectations of fast, seamless interactions, even minor performance delays can cause user dissatisfaction and potential loss of demand. Ensuring high technical performance is, therefore, not only a matter of operational efficiency, but also a strategic priority for tourism stakeholders, especially in highly competitive and environmentally sensitive coastal destinations.

As no previous studies are available for direct comparison, these findings address an important research gap and provide novel insights into the technical performance of campsite websites, while also highlighting the need for further research. They further indicate that optimising website performance enhances competitiveness and supports digital circular economy principles by reducing data processing and energy use (Bressanelli et al., 2022; Cheah et al., 2022; Patwa et al., 2025), with broader implications for sustainable digital development in camping tourism.

SCIENTIFIC CONTRIBUTION

This study contributes to the literature by integrating concepts from digital tourism, website technical performance, and sustainable development within the framework of the digital circular economy. Methodologically, it shows that the combined use of Core Web Vitals metrics and Google Lighthouse tools enables a multidimensional assessment of the digital infrastructure of tourism websites. In doing so, the study advances the theoretical understanding of the relationship between technical website quality and sustainable tourism, although it does not establish a direct causal link. Furthermore, it opens space for interdisciplinary research at the intersection of digital performance, sustainability, and the blue economy – areas that have so far received limited attention in tourism research.

PRACTICAL CONTRIBUTION

From a practical perspective, the study addresses a research gap in the analysis of technical website quality within niche tourism segments, particularly camping tourism, where comparable studies are scarce. The empirical

analysis provides insights into the digital infrastructure of the campsites in Split-Dalmatia County, identifies the structural weaknesses in content loading speed and server responsiveness, and offers concrete recommendations for improving digital competitiveness. These include server-side optimisation, content compression, the use of content delivery networks (CDNs), reduction of external resources, and continuous performance monitoring.

LIMITATIONS AND FUTURE RESEARCH

This study has several limitations that should be considered when interpreting the findings. The analysis is geographically limited to campsite websites in Split-Dalmatia County, which may restrict the generalisability of the results to other regions and tourism contexts. Furthermore, the study relies exclusively on technical performance indicators (Core Web Vitals), which, although providing objective insights into website quality, do not directly measure sustainability outcomes, user behaviour, or actual resource consumption. Consequently, the relationship between website optimisation and sustainable tourism remains indicative rather than empirically confirmed. The focus on official websites also excludes other relevant digital channels, such as mobile applications, booking platforms, and social media.

Future research should address these limitations by incorporating broader and more diverse samples, including cross-regional and international comparisons, as well as integrating direct sustainability indicators and user-based data through mixed-method approaches. Longitudinal studies and a more comprehensive analysis of digital ecosystems in tourism would further contribute to understanding the role of digital optimisation within sustainable development and the blue economy.

CONCLUSION

This study examined the technical quality of campsite websites in Split-Dalmatia County using Core Web Vitals and related performance metrics, aiming to explore their potential relevance for sustainable tourism and the blue economy. The findings show that, while interactivity and visual stability are generally satisfactory, significant shortcomings remain in loading speed and server responsiveness, which may negatively affect user experience, digital visibility, and competitive positioning.

Although the study does not directly measure sustainability outcomes, it highlights the potential importance of digital infrastructure as a supporting element in more efficient and transparent tourism systems. In this context, technically optimised websites may contribute to improved resource efficiency and the communication of environmentally responsible practices, although these relationships require further empirical validation.

By integrating digital performance metrics with sustainability and blue economy perspectives, this research offers both conceptual and empirical insights into an underexplored area of tourism studies. Finally, the results raise awareness and underscore the importance of prioritising technical website quality within broader digital transformation strategies in tourism, particularly for environmentally sensitive coastal destinations.

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GREEN BANKING DISCLOSURE: COMPARISON BETWEEN CROATIA AND FRANCE

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Background: The banking sector is increasingly recognizing its own role in supporting the environmental policies and green transition, primarily by financing initiatives and technologies that help reduce the effects of climate change. This change in attitude was driven by several global initiatives, which started a complete paradigm shift in the banking industry towards green financing and the emergence of green banking. The notion of green banking involves promoting environmental awareness, encouraging employees and customers to adopt environmentally friendly behaviors, and providing products and services that address environmental risks. Banks, as key agents in the financial system, should structure their credit management to prioritize supporting industries that invest in environmentally friendly activities and implement technologies for green environmental management. Previous research indicates that many factors influence the scope of green banking activities and, consequently, disclosure practices. This study contributes to understanding the differences in green banking practices and disclosure between banks operating in Croatia and those in a country with a long-standing tradition of addressing sustainability issues, such as France.

Purpose: This study aims to identify the green banking practices in Croatia and France. The main hypothesis is that banks in France disclose more information on green practices, such as having a climate-related

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strategy, green lending, fossil fuel policy, and climate risk management. Furthermore, online disclosure by banks in France is expected to align more closely with the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD).

Method: Empirical research is based on the analysis of non-financial information disclosure of 19 banks operating in Croatia and 19 banks operating in France. The research was conducted in March and April 2025, and in this period the data were collected from publicly available sources. The collected data were analyzed using a non-parametric statistical method, specifically Fisher's Exact Test, which supported all the proposed hypotheses.

Conclusion: Empirical research has confirmed that banks in France disclose a significantly broader range of green banking practices in their non-financial reports than banks in Croatia. While this study focuses on country-specific regulation, it does not examine all the potential drivers of disclosure practices. It provides a basis for future research to expand the analysis and explore several additional factors influencing banking disclosure practices across diverse European banking systems. Moreover, as the analysis is based on a cross-sectional sample from 2023, it does not track the pace of ongoing changes in disclosure practices or regulations. Future research could build on this study by including longitudinal comparisons or extending the research to additional EU Member States.

Keywords: *Green banking, ESG disclosure, sustainability reporting*

JEL classification: *G21, M41, Q56*

INTRODUCTION

In today's world, climate change has become one of the most urgent and complex challenges, with profound consequences for the environment, global economy, and society. Banks are uniquely positioned to address climate change by managing the carbon footprint of their operations and evaluating the environmental impacts of their loan portfolios and financial activities. The urgency of mitigating climate change has highlighted the importance of transparent communication by banks with regard to climate-related information (Raimo, Fraccalvieri, Vitolla, & Bussoli, 2025).

Previous studies (Mahoney, Thorne, Cecil, & LaGore, 2013; Rogošić, 2014; Lee, Kim & Bae, 2024) have examined the determinants of Corporate Social

Responsibility (CSR) and Environmental, Social, and Governance (ESG) reporting in the banking sector. Kundid Novokmet & Bilić (2016) noted that image and public reputation improvement are often the main drivers of corporate social responsibility achievements in the banking sector. During the voluntary stage, sustainability reporting focused primarily on CSR, but gradually shifted to the ESG concept.

This study explores the differences in green banking disclosures between Croatia and France within the context of institutional theory, which states that formal and informal institutional frameworks influence banking behavior in different countries. A previous study (Rogošić, 2014) confirmed that CSR reporting in banks is country-specific, with banks in Croatia more likely to disclose this information than those in Bosnia and Herzegovina or Montenegro.

Using Fisher's Exact Test, we analyzed non-financial disclosure data from 19 banks in Croatia and 19 banks in France. Findings indicate that there are significant differences in green banking and climate-related information disclosure between those two banking systems.

The remainder of this paper is structured as follows: the next section defines green banking and provides an overview of most of its important instruments. The third section is about ESG reporting practices, with a summary of the corresponding EU regulations. The hypotheses are then formulated, followed by an explanation of the methodology. Lastly, the results are summarized, and the concluding remarks are made.

GREEN BANKING: CONCEPT, FINANCIAL INSTRUMENTS AND ECONOMIC EFFECTS

One of the key focus points of the ongoing development in the banking sector is how the banks can effectively improve their operational efficiency while considering sustainable development (Chen, Lin, Chiu, & Yang, 2024). The 17 Sustainable Development Goals (SDGs), adopted by the United Nations General Assembly in 2015 as part of the 2030 Agenda for Sustainable Development (United Nations General Assembly, 2015), have become benchmarks for sustainable development across industries, including banking. Several SDGs, such as SDG 13, focus on environmental issues and thus play a vital role in the emerging field of green banking.

Despite growing interest and research, there is no single, universally accepted definition of green banking (Alexander, 2016). Various studies, such as the one conducted by Paluszak & Wiśniewska-Paluszak (2016), provide over-

views of the different definitions proposed in the literature. Given the lack of consensus on its definition, green banking can be defined as a subset of the broader concept of green finance. It is also identifiable through its key characteristics outlined by Paluszak & Wiśniewska-Paluszak (2016).

One of the key challenges in examining green finance and green banking is defining what is considered "green". For instance, the term 'clean coal' has largely fallen out of use in European countries, while the Chinese Green Bond Endorsed Projects Catalogue removed the category of "clean utilization of coal" less than ten years ago (Zhang, Zhang, Li, & Liu, 2024). Different international organizations, governments and financial institutions tend to adopt their own specifications based on specific goals. Consequently, as in the case of green banking, a unique and widely accepted definition of green finance does not exist.

In order to clarify the concept, UNEP (2016) presents several definitions of green finance by relevant global organizations, governments and central banks, such as the OECD and the German government. For example, the OECD defines green finance as finance aimed at achieving economic growth while reducing pollution and greenhouse gas emissions, minimizing waste and improving efficiency in the use of natural resources (UNEP, 2016). In contrast, the German government, in GIZ (2011), describes it as a strategic approach to incorporate the financial sector in the transformation process towards low-carbon and resource-efficient economies, and in the context of adaptation to climate change. Furthermore, different organizations sometimes use the terms 'green', 'climate' and 'sustainable finance' interchangeably.

Based on the framework of the Paris Agreement and the SDGs, Berrou, Dessertine, & Migliorelli (2019) distinguish between these terms. Green finance refers to the financial stocks and flows aiming to support environment-related SDGs. In comparison, climate finance is a narrower subset of green finance, focusing specifically on climate-related SDGs, whereas sustainable finance is broader, encompassing stocks and financial flows mobilized to achieve all SDGs.

Accordingly, as a subset of green finance, green banking broadly refers to the incorporation of all environmentally friendly and climate-related banking activities that support the achievement of the environment-related SDGs. These activities, and consequently green banking, play a key role in mitigating adverse ecological impacts, consistent with SDG 13 on climate action (Muchiri, Erdei-Gally, & Fekete-Farkas, 2025). In recent years, research has shown that among the 17 SDGs, SDG 13 has become one of the primary areas of focus within the global banking industry. Sengupta, Pramanik, Datta, Dutta, Dasgupta, & Kirtania (2023) examined bank sustainability disclosures across

the globe, finding a strong focus on SDG 13 along with moderate to high levels of progress toward achieving SDG 13 targets, according to SDG Index 2021.

Miah, Rahman, & Mamoon (2021) conducted a country-level analysis of Omani banks' initiatives to reduce their carbon footprint. They found that day-to-day initiatives are largely limited to increased recycling and reduced paper and energy consumption. While these findings suggest a relatively narrow scope of green activities, broader cross-country research and literature reviews present a more optimistic picture. Muchiri et al. (2025) identified a wide range of "green" activities commonly prioritized by banks. Their review shows that digital banking activities, such as paperless transactions and online banking, are the most frequent green activities. They are followed by green loans/sukuk products, green services and green infrastructure. Saeedi & Ashraf (2024) examined the role of emerging technologies, such as machine learning (ML) and artificial intelligence (AI), and reported that their use can significantly improve risk assessment and stimulate the creation of new green financial products.

One of the primary green financial products within the field of green banking are green loans. Golubeva (2024) identified six major factors that impact the introduction of green loans: profitability and sustainability goals of the bank, green balance sheet, public policies, market mechanisms, the needs of the society, and development of science and technology. Additionally, Shang & Niu (2023) highlighted the relationship between green loans and digital banking in China, reporting that digital transformation facilitates green loans, with the effect being more pronounced in state-owned and larger banks.

In order to clearly distinguish green loans from other lending products, the Loan Market Association (LMA) outlined the Green Loan Principles (GLP) and categories of eligible projects in LMA (2025). Additionally, the European Union (EU), through the European Green Deal and EU Taxonomy, addresses the classification of green loans. Golubeva (2024) noted that under the EU Sustainable Finance Taxonomy green loans can be defined as debt provided to borrowers who generate revenue from green economic activities. Using syndicated loan data matched with EU Taxonomy, Gilchrist, Yu, & Zhong (2021) estimated that green loans accounted for approximately USD 480 billion in 2017, representing about 55% of the syndicated loan market in their international sample.

In part, the green loan market was developed to provide financing opportunities for smaller companies and environmentally friendly projects that are too small to qualify for the issuance of green bonds. As one of the pioneering green financial instruments, green bonds remain the most important type of green securities. ICMA (2025) outlines the Green Bond Principles (GBP),

voluntary guidelines that define green bonds and their types. These guidelines, initially developed and published in 2014, have become one of the leading frameworks with regard to green bonds (Berrou et al., 2019). According to GBP, green bonds are used exclusively to fund green projects, such as renewable energy or clean transportation. While the largest issuers of green bonds are governments and international organizations, banks typically participate in this market as underwriters. Since the first issue in 2007, the green bond market has grown substantially. Based on a sample of 75 issuers from multiple regions worldwide analyzed in the Climate Bonds Initiative (2025), approximately USD 672bn in green bonds was issued between 2020 and 2023, with the three largest issuers—EU, World Bank, and Caisse d'Amortissement de la Dette Sociale (CADES)—each issuing more than USD 100bn.

While green banking has the potential to help mitigate environmental issues in the long term, climate change also shapes banks' risk management. Regarding the effect of regulation and climate-related policies on the banking system, Battiston, Mandel, Monasterolo, Schütze, & Visentin (2017) found that the timing of climate policy matters, with an early and orderly transition reducing potential systemic distress. Furthermore, PRA (2018) identifies physical and transition risks as the main types of climate-related risks and as primary sources of climate-related credit, market, and operational risks. Similarly, Radzewicz-Bak, Vacher, Anderson, Gori, Harb, Korniyenko, Ma, Malak, Nampewo, & Sakha (2024) classified physical and transition risks as two key sources of climate change risk that may affect banking sector stability. Physical risks arise from extreme weather events and climate change (NGFS, 2019). They can influence financial institutions by affecting their underwriting activity, lending and portfolio holdings (International Monetary Fund, 2020). On the other hand, transition risks include changes in technology, regulation and climate-related policies required for the transition to a low-carbon economy (Radzewicz-Bak et al., 2024). Given that the transition to a low-carbon economy may require radical changes, a large range of assets, such as fossil-fuel related assets, may be revalued, leading to higher credit exposure for the banking sector (Park & Kim, 2020). Considering the differences between physical and transition risks, Chalabi-Jabado & Ziane (2024) investigated their effects on bank performance and loan growth using a sample of 147 international banks across 37 countries. They found that physical risks are associated with lower performance and loan growth, whereas transition risks are linked to higher performance and loan growth.

Similarly, beyond financing environmentally friendly projects, green loans and bonds also affect banks' profitability and competitiveness. Istudor, Nites-

cu, Dumitru, & Anghel (2022) investigated the relationship between sustainability, performance and competitiveness in the US, Chinese and European banking systems. They concluded that, in the short term, investment in sustainable products and green energy increases competitiveness but decreases profits, whereas in the medium and long term, a higher share of green investments leads to higher profitability. Empirical evidence from diverse settings broadly supports the positive impact of green policies on profitability. Bătae, Dragomir, & Feleagă (2021) found that reductions in carbon emissions are associated with higher measures of financial performance, such as increased ROA. Bressan (2025) took the opposite approach by investigating the relationship between environmental damage costs, as a share of revenue, and performance. The results showed a negative connection with profitability and equity market returns. In a related context, Tian, Wang, & Wu (2025) investigated the connection between green credit performance and market valuation in China. Their results showed that banks with superior green-loan performance experience higher abnormal returns when announcing a new loan. Finally, Bose, Khan, & Monem (2021) focused on green banking in the Bangladeshi banking system, showing its positive association with financial performance.

Muchiri et al. (2025) highlighted policy issues, awareness issues and investors' lack of confidence in green bonds as some of the key challenges of green banking in developing countries. They also found regional differences, with developed countries facing credibility issues such as greenwashing. As the public has become more interested in environmental issues and responsible behavior, some banks have engaged in greenwashing by presenting themselves as environmentally responsible while continuing to finance environmentally damaging projects (Elliott & Löfgren, 2022 – as cited in Galletta, Mazzù, Naciti, & Paltrinieri, 2024). Schücking, Kroll, Louvel, & Richter (2011) provided a clear example by examining the public statements of 104 banks and the amount of funding they provided to the coal industry. They found that all 20 banks that provided the most funding also made strong public commitments regarding climate change.

Overall, green banking incorporates a wide range of environmentally friendly banking activities, including green infrastructure, green services, and various innovative financial products. Among the most important instruments are green loans, which are used to finance green projects of different sizes, and green bonds, which typically support large-scale infrastructure projects such as renewable energy investments. Beyond influencing the banks' role as lenders, green banking practices also affect banks' risk management, competitiveness, and financial performance. At the same time, growing concerns

regarding greenwashing highlight the need for clear standards and transparent disclosure of green banking practices.

SUSTAINABILITY-RELATED DISCLOSURES IN THE BANKING INDUSTRY

Reporting on CSR, as well as sustainability reporting on the environmental, social and governance (ESG) impacts of organizational activities, encompass climate-related issues. ESG reporting succeeded CSR reporting in practice. Chang & Cheng (2025) point out that CSR can be considered as a base for corporate sustainability, but differs in its ethical background and normative application, as CSR emphasizes moral responsibilities and accountability, whereas corporate sustainability embraces a systems-based and empirically driven approach entrenched in systems theory and the United Nations Sustainable Development Goals (SDGs). CSR and ESG reporting were voluntary, thus companies used creative methods of disclosure. Therefore, a lack of consistent and comparable data was observed. Subsequently, various ESG reporting guidelines have emerged to define the content and procedures considered legitimate for sustainability information disclosure (Darnall, Ji, Iwata, & Arimura, 2022). Standards and frameworks for sustainability reporting and accounting were developed, with the most prominent being the Global Reporting Initiative (GRI). Some standard setting boards like the Sustainability Accounting Standards Board, the International Integrated Reporting Council, the International Accounting Standards Board, the Task Force on Climate-related Financial Disclosures (TCFD), the Carbon Disclosure Standards Board, and CDP (formerly known as the Carbon Disclosure Project) also offer guidelines for climate-related disclosures. The EU Commission issued a supplement to the Non-Financial Reporting Directive (NFRD) in June 2019 to provide guidance on reporting climate-related information. These guidelines apply to companies within the scope of the NFRD, including large listed companies, banks, and insurance companies with over 500 employees. The guidelines on reporting climate-related information integrate the recommendations of the TCFD while being in line with the EU Taxonomy that entered into force on 12 July 2020. Regulation 2019/2088 of 27 November 2019 on sustainability-related disclosures in the financial services sector sets out the ground rules for classifying and reporting on sustainability and ESG criteria in the EU. The Sustainable Finance Disclosure Regulation (SFDR) represents a significant step forward in the process of enhancing transparency and sustainability in the financial

industry by requiring financial market participants to disclose the ESG factors associated with their investment decisions, including the consideration of both "green" and "brown" assets. Furthermore, aligning banking disclosure practices with SFDR standards can facilitate the identification and mitigation of systemic risks associated with climate change, thereby enhancing financial stability (Relano, Paulet, & Mavoori, 2024). In order to reduce climate risk and improve overall EU sustainability, a recent EU regulation was introduced. The Corporate Sustainability Reporting Directive (CSRD) was adopted by the European Commission on 14 December 2022, followed by the adoption of the European Sustainability Reporting Standards (ESRS) on 31 July 2023 (EU Commission, 2023). The CSRD significantly expands the scope, sustainability disclosures, and reporting requirements of its predecessor – the NFRD – with the aim of harmonizing sustainability reporting and increasing corporate transparency. The first large companies subject to the CSRD were required to report for the 2024 financial year, with reports to be published in 2025.

HYPOTHESES

Banks are expected to play a dual role in supporting corporate sector sustainability. Internally, they do so through their own operations, as other firms do, while externally, they incorporate ESG risks into their lending and investment decisions (Buallay et al., 2021). Prior studies in the banking sector indicated that the presence of women on the board (Octavio and Setiawan, 2024; Raimo et al., 2025), foreign board members, foreign ownership, public attention (Octavio and Setiawan, 2024), board expertise, and bank size (Mou and Ma, 2023; Raimo et al., 2025) positively influence the level of climate-related disclosures. A recent study on the 30 largest European banks revealed significant compliance with global frameworks such as GRI, ESRS, and TCFD, indicating that banks are increasingly aligning their climate strategies and disclosures with financial imperatives and societal expectations (Brescia, Degregori, Chmet, & Secinaro, 2025).

Caby, Ziane, & Lamarque (2020) stated that country-level and bank-level characteristics are valid predictors of banks' commitment to voluntary carbon disclosure initiatives and environmental scores. Liaqat, Floerani, & Naseer (2025) revealed that the stability-enhancing effects of ESG performance in banking are fundamentally shaped by institutional and cultural contexts. Drawing on institutional theory, which asserts that organizational behavior is shaped by pressures from the institutional frameworks defining the economic

and social environments in which companies (including banks) operate, the following hypotheses were formulated:

H_1: Banks in France disclose more non-financial information on green banking practices than banks in Croatia.

$H_{1.1}$: Banks in France are more likely to use the TCFD and EU Taxonomy frameworks in their reports than banks in Croatia.

$H_{1.2}$: Banks in France are more likely to disclose their climate strategy than banks in Croatia.

$H_{1.3}$: Banks in France are more transparent about climate risks than banks in Croatia.

$H_{1.4}$: Banks in France are more likely to report on climate risk management than banks in Croatia.

$H_{1.5}$: Banks in France are more likely to report on green lending and fossil fuel policy than banks in Croatia.

$H_{1.6}$: Banks in France are more likely to disclose direct and indirect GHG emissions than banks in Croatia.

METHOD

In this study, content analysis techniques were used to gain insights into green banking practices on a sample of 19 banks operating in Croatia (whole population) and 19 banks from France, using a purposive sampling technique. The relevant non-financial information was collected from the 2023 annual non-financial reports of banks, which were available on their official websites during March and April 2025. The French banking industry had 388 banks in 2023 (ECB, 2025), while only 19 banks operated in Croatia at that time (HNB, 2025). Banks in Croatia operate as universal banks, offering a wide range of retail and business banking products and services, including savings products, current accounts, payment cards, and consumer and business loans. Large banks in Croatia have developed investment-banking services. On the other hand, banks in France offer services across various segments, including retail, corporate, and investment banking. Among all the non-financial information reported, our research focused on climate-related topics and green banking practices, as these are more pressing global issues. The collected data were used as nominal variables for Fisher's Exact Test (suitable for small samples), conducted in the IBM SPSS program.

RESULTS

Non-financial information in the banking industry has been disclosed in various ways, primarily within the annual reports or as a stand-alone document, such as an ESG or sustainability report. Only 6 banks operating in Croatia (32%), and 17 out of 19 (nearly 90%) observed banks in France disclosed their ESG strategy. The same banks operating in France were transparent about their ESG policies compared to 7 banks in Croatia. Analyzing the official websites of the observed banks, we found that 14 banks in France (74%) and only 4 in Croatia (21%) followed the EU Taxonomy framework while reporting their sustainability related activities. Two banks in Croatia (11%) and 13 banks in France (68%) followed the recommendations of the TCFD. The first auxiliary hypothesis was tested using Fisher's Exact Test (Table 1 and Table 2 in the Appendix). The results presented in Table 1 and Table 2 confirm the first hypothesis, as Fisher's Exact Test is statistically significant in both cases (p-value less than 0.05). Institutional theory explains how organizations become more homogeneous due to coercive, mimetic, and normative pressures. A study of 10 banks in France (Autorité des marchés financiers, 2020) found that all the observed banks followed the TCFD framework, although their approaches varied. The French regulatory body, Autorité des marchés financiers, actively promotes the TCFD, therefore banks in France, particularly the listed ones, follow this framework to enhance transparency regarding climate-related risks and opportunities in governance, strategy, and risk management.

Cucinelli, Nieri, and Piserà (2026: 1172) defined banks' climate change and environmental strategy as the way in which banks manage climate-related risks, promote sustainable finance, integrate environmental criteria into decision-making, advocate environmentally responsible practices, disclose climate-related information transparently, improve internal operations to reduce their environmental footprint, and invest in capacity building and research to address climate risks effectively. Banks that take more substantive action still combine it with symbolic activities, which may support the strategic change process. Without diligent analysis on climate strategy outcomes, we simply detected that 7 banks operating in Croatia and 17 banks in France disclosed their climate strategies. The second auxiliary hypothesis was validated using Fisher's Exact Test (Table 3 in the Appendix).

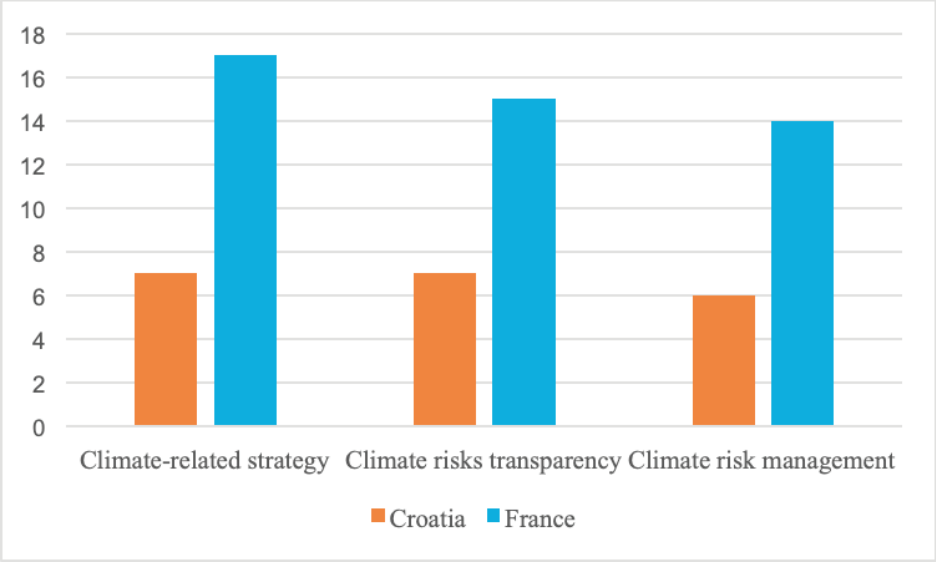
Climate risk refers to the potential impact of climate change on financial performance, as exposure to climate-related effects can have serious financial consequences for organizations. There are two types of climate-related risks in the banking industry: physical risks, which arise from direct climate im-

pacts caused by extreme weather events and gradual climate changes, including environmental degradation such as air, water and land pollution, water stress, biodiversity loss and deforestation; and transition risks, which refer to financial loss that may result, directly or indirectly, from the adjustment to a lower-carbon, more environmentally sustainable economy. Transition risks arise from policy, legal, technological, and market changes required to shift to a low-carbon economy.

In our sample, 7 (37%) banks in Croatia and 15 in France (nearly 80%) were observed as transparent regarding their climate risks, and the difference between these countries is statistically significant (Table 4 in the Appendix) – which validates our third auxiliary hypothesis.

Climate risk management can be described as a framework that employs strategies to assess and manage risks associated with climate change, thus enabling climate-resilient decision-making. Effective climate risk management and sustainable economic development require the full participation of the financial system, especially in countries with a well-developed banking sector and high vulnerability to climate change (Toma & Stefanelli, 2022). Six banks in Croatia (32%) and 14 in France (74%) report on their climate risk management practices. In order to test our fourth auxiliary hypothesis, we performed Fisher's Exact Test (Table 5 in the Appendix), which was statistically significant (p-value = 0.022).

Figure 1. Comparison of the disclosure of climate-related strategy and climate-related risks



Green loans were detected as one of the most common green banking activities, followed by green services and green infrastructure (Muchiri et al., 2025). On the other hand, a lack of clear commitment to financing fossil fuels is evident (Elliott and Löfgren, 2022). The comparison between the two countries in terms of green banking activities shows that banks in France report more frequently on green lending (17 banks, compared to 7 in Croatia) and fossil fuel policy (14 banks, compared to 6 in Croatia). These findings support the fifth auxiliary hypothesis, as the results of Fisher's Exact Test yielded a p-value below 0.05 (Table 6 and Table 7 in the Appendix).

Bowman (2010) stated that banks play a significant role in reducing GHG emissions. As creditors, investors, advisers, and heads of supply chains, banks can influence the business practices and GHG-emitting behavior of other corporate actors. GHG emissions can be direct or indirect, and are commonly classified as Scope 1 (direct GHG emissions from sources owned or controlled by the bank), Scope 2 (indirect GHG emissions from the generation of purchased and consumed electricity, steam, heat, or cooling), and Scope 3 (all other indirect GHG emissions that occur in the value chain of the reporting bank, including both upstream and downstream emissions). Banks in France disclose more frequently on direct and indirect GHG emissions than banks in Croatia, as Scope 1 and Scope 2 are disclosed by 17 banks in France compared to 5 banks in Croatia, while Scope 3 is disclosed by the same banks in France compared to only 4 in Croatia. This difference between the two countries is statistically significant (Table 8 and Table 9 in the Appendix), which confirms our sixth auxiliary hypothesis.

All the empirical results above support the main hypothesis that banks in France disclose more green banking and climate-related information than banks in Croatia. We believe that, in addition to the greater development of the banking sector in France compared to Croatia, this difference is also due to mandatory non-financial reporting for large listed companies, which has included social, environmental, and societal aspects since 2001 in France. Thus, when non-financial disclosure is considered, country-specific regulations, and even non-mandatory frameworks, can cause differences in the content of banks' sustainability reports across countries.

CONCLUSION

The banking sector has a prominent role in mitigating the effects of climate change, which raises the importance of the disclosure of climate-related

efforts. Although all EU countries have developed banking systems, there are significant differences in the frequency and quality of non-financial reporting. Empirical results confirm the substantial gap between Croatia and France regarding green banking practices and their disclosure. In spite of the fact that this study included only two banking systems observed for only one period, it provides a confirmation of the hypotheses. In addition, the results provide the basis for future research that should encompass more countries and a wider range of factors influencing green banking disclosure. Additionally, future studies should include a longitudinal comparison in order to gain further insights. The main limitation of this study lies in binary coding, as it reduces complex, nuanced data to two rigid categories. Therefore, future research should adopt a more granular approach.

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APPENDIX

- The banks operating in Croatia (in 2023) were the following: Addiko Bank d.d., Agram banka d.d., Banka kovanica d.d., Erste & SteiermärkischeBank d.d., Hrvatska poštanska banka d.d., Imex banka d.d., Istarska kreditna unija Umag d.d., J&T banka d.d., Karlovačka banka d.d., KentBank d.d., OTP banka d.d., Partner banka d.d., Podravska banka d.d., Privredna banka Zagreb d.d., Raiffeisenbank Austria d.d., Samoborska banka d.d., Slatinska banka d.d., Zagrebačka banka d.d., and Jadranska banka d.d.
- The banks in France included in our sample were the following: BNP Paribas, Crédit Agricole, Société Générale, Groupe BPCE, Crédit Mutuel Group, La Banque Postale, Crédit Industriel et Commercial (CIC), Banque Kolb, Banque Popularie, Le Crédit Lyonnais (LCL), Arkéa, Banque Palatine, HSBC France, BRED Banque Populaire, Caisse d'Épargne, Banque de Savoie, Rothschild Martin Maurel, Banque Courtois, and SG Tarneaud.

Table 1: Chi-Square Tests – TCFD as a framework for disclosure

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	13.328[a]	1	.000	.001	.000	
Continuity Correction[b]	11.014	1	.001			
Likelihood Ratio	14.497	1	.000	.001	.000	
Fisher's Exact Test				.001	.000	
Linear-by-Linear Association	12.977[c]	1	.000	.001	.000	.000
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 7.50.

b. Computed only for a 2x2 table

c. The standardized statistic is 3.602.

Table 2: Chi-Square Tests – EU Taxonomy as a framework for disclosure

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	10.556[a]	1	.001	.003	.001	
Continuity Correction[b]	8.550	1	.003			
Likelihood Ratio	11.116	1	.001	.003	.001	
Fisher's Exact Test				.003	.001	
Linear-by-Linear Association	10.278[c]	1	.001	.003	.001	.001
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 9.00.

b. Computed only for a 2x2 table

c. The standardized statistic is 3.206.

‚Table 3: Chi-Square Tests – climate strategy disclosure

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	11.310[a]	1	.001	.002	.001	
Continuity Correction[b]	9.161	1	.002			
Likelihood Ratio	12.221	1	.000	.002	.001	
Fisher's Exact Test				.002	.001	
Linear-by-Linear Association	11.012[c]	1	.001	.002	.001	.001
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 7.00.
b. Computed only for a 2x2 table
c. The standardized statistic is 3.318.

Table 4: Chi-Square Tests – climate risks transparency

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	6.909[a]	1	.009	.020	.010	
Continuity Correction[b]	5.290	1	.021			
Likelihood Ratio	7.163	1	.007	.020	.010	
Fisher's Exact Test				.020	.010	
Linear-by-Linear Association	6.727[c]	1	.009	.020	.010	.009
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 8.00.
b. Computed only for a 2x2 table
c. The standardized statistic is 2.594.

Table 5: Chi-Square Tests – climate risk management

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	6.756[a]	1	.009	.022	.011	
Continuity Correction[b]	5.172	1	.023			
Likelihood Ratio	6.974	1	.008	.022	.011	
Fisher's Exact Test				.022	.011	
Linear-by-Linear Association	6.578[c]	1	.010	.022	.011	.009
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 9.00.
b. Computed only for a 2x2 table
c. The standardized statistic is 2.565.

Table 6: Chi-Square Tests – green lending

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	11.310[a]	1	.001	.002	.001	
Continuity Correction[b]	9.161	1	.002			
Likelihood Ratio	12.221	1	.000	.002	.001	
Fisher's Exact Test				.002	.001	
Linear-by-Linear Association	11.012[c]	1	.001	.002	.001	.001
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 7.00.
b. Computed only for a 2x2 table
c. The standardized statistic is 3.318.

Table 7: Chi-Square Tests – fossil fuel policy

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	6.756[a]	1	.009	.022	.011	
Continuity Correction[b]	5.172	1	.023			
Likelihood Ratio	6.974	1	.008	.022	.011	
Fisher's Exact Test				.022	.011	
Linear-by-Linear Association	6.578[c]	1	.010	.022	.011	.009
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 9.00.

b. Computed only for a 2x2 table

c. The standardized statistic is 2.565.

Table 8: Chi-Square Tests – Scope 1 and Scope 2 disclosure

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	15.545[a]	1	.000	.000	.000	
Continuity Correction[b]	13.063	1	.000			
Likelihood Ratio	17.040	1	.000	.000	.000	
Fisher's Exact Test				.000	.000	
Linear-by-Linear Association	15.136[c]	1	.000	.000	.000	.000
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 8.00.

b. Computed only for a 2x2 table

c. The standardized statistic is 3.891.

Table 9: Chi-Square Tests – Scope 3 disclosure

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson's Chi-Square	17.989[a]	1	.000	.000	.000	
Continuity Correction[b]	15.328	1	.000			
Likelihood Ratio	19.914	1	.000	.000	.000	
Fisher's Exact Test				.000	.000	
Linear-by-Linear Association	17.515[c]	1	.000	.000	.000	.000
N of Valid Cases	38					

a. 0 cells (0.0%) have an expected count lower than 5. The minimum expected count is 8.50.

b. Computed only for a 2x2 table

c. The standardized statistic is 4.185.

WHAT SHAPES ATTITUDES TOWARDS GREEN FINANCE? A PILOT STUDY AMONG CROATIAN STUDENTS

Ana KUNDID NOVOKMET[*], Matej ALILOVIĆ[**]

Green finance is an umbrella term for financial services that address climate change, support the recovery of natural resources from environmental degradation, and aim for a positive impact on biodiversity. These financial products are crucial for sustainability transformation, with the market for green financial services having grown rapidly in recent years. However, its future development largely depends on the acceptance of such services by young financial consumers, who bear the responsibility for driving positive societal change. In order to understand the long-term prospects of the green financial transition, it is important to gain insight into their knowledge, attitudes, and propensity towards green finance. This paper explores the perceptions of Croatian students regarding green finance, and examines their attitudes towards financial knowledge, green values, pro-environmental behaviour, and general awareness of green financial products, with the aim of identifying the most influential drivers. There have been few comparable studies on this topic so far, and none of them have focused on Croatia. Approximately 100 online questionnaire responses were collected, mainly from students attending the two largest universities – the ones in Zagreb and Split. About 90% of the respondents were under 25 years old, while 72% studied social or technical sciences. The level of financial knowledge among the respondents is modest, as only 12% of the students answered all the questions about basic financial terms correctly. Almost 60% of the respondents presented an intermediate level

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of green values, while 42% presented the same level of pro-environmental behaviour. Therefore, there is a disparity between green attitudes and green actions. Furthermore, there is no difference in pro-environmental behaviour between genders, although women expressed a higher level of compliance with green values. However, students have very poor awareness of green finance, the Paris Agreement, and the European Green Deal. Multiple linear regression analysis was employed to determine the importance of financial knowledge, green values, pro-environmental behaviour, awareness of green finance terminology, and gender for attitudes towards green finance. Interestingly, neither green nor mainstream financial knowledge was observed to be related to differences in green finance attitudes. However, being female, having stronger green values, and engaging in pro-environmental behaviour led to more positive attitudes towards green finance. Approximately 22% of the students plan to adopt at least one green financial service. Positive attitudes towards green finance have a favourable influence on such intentions. In summary, enhancing green values and promoting the necessity of pro-environmental behaviour through formal education and other educational policy tools might be effective in shaping positive attitudes towards green financial services and their subsequent adoption. In this way, environmental literacy should become one of the key skills for policymakers to rely on in order to achieve sustainable development goals.

Keywords: *green finance, sustainability transformation, sustainable finance literacy, young financial consumers, questionnaire.*

JEL classification: *G10, D12, Q01*

INTRODUCTION

Green finance is an important area of sustainable finance that refers to financial decision-making based on environmental considerations. It includes climate finance, which involves financial methodologies and risk mitigation techniques associated with climate change, but additionally extends to other environmental and ecological aspects of financial decisions. Green financial instruments are necessary to achieve environmental sustainability and support the transition to green economy (Bhatnagar & Sharma, 2022). They include various financial innovations that reduce environmental degradation in the long run (Afzal, Rasoulinezhad, & Malik, 2022) and lower CO_2 emissions

(Khan, Akbar, Nasim, Hedvičákova, & Bashir, 2022). Conversely, financial constraints are associated with a 3.340% increase in carbon emissions at the listed firm level in the United States (Rehman, Shahzad, Hanif, Arshad, & Sergi, 2024). Green finance excludes financial instruments that directly tackle social welfare by reducing poverty, social exclusion, or inequalities, and by enhancing the well-being and opportunities of individuals worldwide, which differs them from sustainable finance.

Sustainable finance addresses social, environmental, and economic matters in financial activities, including investments, lending, and capital allocation, with the aim of promoting sustainable development and generating positive long-term societal and environmental impacts which are aligned with the United Nations' Sustainable Development Goals (SDGs) (Yucel, Celik, & Jilmaz, 2023). It can particularly contribute to the achievement of SDG 8 (inclusive and sustainable economic growth), SDG 7 (affordable and clean energy), and SDG 13 (climate action) (Lanciano, Previati, Ricci, & Santilli, 2025). Thus, sustainable finance seeks to balance economic growth with environmental preservation and societal well-being through various financial instruments such as green bonds, sustainability bonds, social bonds, green loans, and sustainability-linked loans, as well as by influencing corporate accountability or ESG (Environmental, Social, Governance) stance. In addition to supporting an environmentally responsible future, it promotes accessible healthcare, education, and affordable housing (Yucel et al., 2023).

Understanding what motivates retail financial consumers to choose sustainable financial products may be crucial for sustainability transformation, and has therefore become an important topic of research (e.g. Anderson & Robinson, 2022; Bethlendi, Nagy, & Póra, 2022; Yucel et al., 2023; Filippini, Leippold, & Wekhof, 2024; Lanciano et al., 2025). Awareness, knowledge, and preferences are usual complements when choosing among various available products or services, alongside other frequently used profiling variables such as socioeconomic characteristics, behavioural patterns, and psychographics. In this study, we focus on green financial awareness, general financial knowledge, green values, and pro-environmental behaviour of young financial consumers, specifically students in Croatia, to assess their significance in shaping attitudes and, consequently, the acceptance of green financial products. The importance of socially responsible banking in Croatia from the students' perspective was previously examined (Kundid Novokmet & Bilić, 2016), while Borgonovi et al. (2022a) reported that 15-year-old students in Croatia were slightly below the OECD and EU averages when it came to their environmental values and pro-environmental behaviour. We specifically targeted green financial products,

as evidence from transition countries (e.g. Gedvilaitė et al., 2022, for Estonia, Latvia, and Lithuania) often reveals a greater inclination towards social rather than environmental issues, even among young respondents who are typically more aware of environmental challenges. Altogether, the aim of this study was to examine which factors – financial knowledge, sustainable finance knowledge, green attitudes, or behaviour – are more important.

We expected environmental preferences to be the key determinant of positive attitudes towards green financial products. In the literature, their importance for the acceptance of sustainable financial products is complemented by general financial literacy (Anderson & Robinson, 2022; Bethlendi et al., 2022) and/or sustainable finance literacy (Filippini et al., 2024). Nevertheless, mixed results indicate that the determinants of sustainable or green finance investments are ambiguous and require further exploration, especially given the ongoing debate about which type of knowledge is more important (general finance, environmental, or sustainable finance) and questioning whether knowledge itself drives action – in this case, the adoption of more sustainable financial products. Although many researchers have demonstrated the beneficial effects of financial literacy and sustainable finance literacy, there is also evidence of negative effects of higher financial literacy on sustainable investments (Rossi, Sansone, Van Soest, & Torricelli, 2019; D'Hont, Merli, & Roger, 2022). In general, financial literacy and environmental sustainability competences are highly correlated, but according to Borgonovi et al. (2022b), young people with higher financial literacy are less likely to exhibit pro-environmental behaviour. Moreover, knowledge about sustainability issues or opportunities might not lead to sustainability-related activities, as these may be more closely linked to attitudes, norms, and perceived behavioural control (Heeren et al., 2016), or to cost-benefit considerations, that is, being cost- (Kent, Beckwith, Shah, & Wood, 2024) or price-driven (Gedvilaitė et al., 2022). Finally, sustainable finance decisions may be context-driven, therefore gaining insight into economies not covered by previous research is valuable.

The originality of this pilot study lies in identifying the size of latent demand for green financial products in Croatia, as well as their most influential factors. Our approach was to define what drives attitudes, as we assume that attitudes subsequently drive behaviour. By focusing on students, we could examine the weight of knowledge, values, and behaviour on attitudes towards green finance without the need to control for numerous socio-demographic variables.

GREEN FINANCIAL PRODUCTS – PROSPECTS FOR RETAIL FINANCIAL CONSUMERS

There is plenty of empirical research on the determinants of socially responsible investments, while the number of studies dedicated to the determinants of sustainable finance investments, particularly from the perspective of retail financial consumers, has been increasing only over the past decade, that is, since the establishment of the Paris Agreement and the UN's Sustainable Development Goals, which are to be achieved by 2030. Research focused specifically on green finance acceptance is even less common, but has increased following the Covid-19 pandemic – more precisely, after the 2021 National Recovery and Resilience Plans adopted by European countries to foster the green transition of the economy and the society (Lanciano et al., 2025). Therefore, our literature review focuses mainly on the most inspirational studies addressing the drivers of sustainable finance, following the micro-level, questionnaire approach.

Anderson and Robinson (2022) surveyed approximately 4,000 Swedish households and concluded that pro-environmental attitudes and behaviour are not sufficient for holding green investment portfolios. Namely, those with strong pro-environmental preferences (e.g. recycling more than neighbours and being willing to pay more for green products) are usually less financially active, uninterested in financial matters, or even financially disengaged. However, higher financial literacy increases the chances for their green financial engagement.

Similarly, on a data sample of 2,500 Hungarian respondents, Bethlendi et al. (2022) documented that having positive attitudes towards green finance and practising sustainability in consumer decisions is not enough to choose green financial products. They summarise that the potential customer of green financial products is younger, male, more educated, lives in larger settlements, and has favourable life circumstances, as well as higher financial and sustainability knowledge. Therefore, they advocate the joint promotion of financial and eco-literacy, as well as subsidy policy (e.g. tax benefits, price subsidies) in order to increase the demand for such products.

Yucel et al. (2023) reported their results for Turkey, or to be more precise, 254 residents of its capital, Ankara. In addition to the positive effect of sustainable finance literacy, they highlighted the importance of a positive perception of the advantageous environmental effects of sustainable finance instruments for sustainable finance attitudes. Furthermore, a higher income level and knowledge of the risk diversification potential of sustainable finance investments explain the greater propensity towards sustainable finance acceptance.

According to the study conducted by Filippini et al. (2024) among more than 3,000 Swiss respondents, 26.7% own sustainable financial products. The most important factors for their acceptance are wealth, previous donations (for pro-environmental and pro-social activities), and university education. Additionally, investors in sustainable finance products tend to be risk-lovers and prioritise mitigating climate change. Financial and sustainability literacy were not influencing variables, in contrast to sustainable finance literacy and sustainable finance awareness, where each additional point on the score increases the probability of owning a sustainable finance product by 2.8% and 5%, respectively.

In contrast, Lanciano et al. (2025) examined 5,000 Italian households and confirmed that higher financial literacy is associated with greater knowledge about sustainable finance, and both have a positive impact on sustainable finance investments. They found that only 4% of the respondents owned sustainable investment products, while 14% expressed the intention to own such products in the future, and 18% expressed some interest in them. According to their results, financial advisory is positively related to sustainable investments. High income, high education, being female, and being older than 65 additionally explain favourable sustainable investment outcomes (future intention or personal interest in these products).

Quite different from the previous studies, Kent et al. (2024) conducted an in-depth, multi-methodological examination of young adults' perceptions and behaviour regarding climate change and green finance in Australia. The respondents were between 18 and 40 years of age. Upon tracking all the banking transactions of 70 participants over a period of six-months, followed by in-depth qualitative interviews, they drew the following conclusions: 1) the respondents have strong pro-environmental attitudes, with 70% worried about climate change; 2) 60% face severe financial barriers to consuming green products and therefore perceive these products as luxury goods; 3) they expect a greater role from financial institutions and government in climate action and are concerned about greenwashing. Finally, they often suffer from climate anxiety, as they are concerned about environmental challenges, but feel powerless to contribute meaningfully to climate action. Similarly, a global survey of around 860 finance experts from academia, the finance industry, finance-oriented regulators, and economists in public institutions indicated that carbon taxes, pressure from institutional investors, and government subsidies are the top three driving forces in reducing climate risk exposures and the carbon footprints of corporations, with the influence of customers and their changing preferences ranking as fourth (Stroebel & Wurgler, 2021). In addi-

tion, Bhatnagar and Sharma (2022) identified ten enablers of green finance development, the majority of which were in the macroeconomic, regulatory, and institutional-setting domains. These conclusions are important, as views about the relevance of the institutional framework for enabling the green transition may be even more pronounced in less developed countries.

In summary, most results support the importance of financial and/or environmental knowledge for positive attitudes or acceptance of sustainable finance investments. Our research extends in the direction of literacy as a practical skill, as we include attitudes (values) and behaviour into the students' propensity towards making sustainable financial decisions.

EMPIRICAL STRATEGY AND RESULTS

QUESTIONNAIRE DESIGN, DESCRIPTIVE STATISTICS AND CONSTRUCTION OF COMPOSITE VARIABLES

The main goal of this study was to identify the factors that shape positive attitudes towards green financial products and their association with adopting such products. Our focus was on young financial consumers – to be more precise, the student population – as we expect them to be leaders in positive societal changes, such as greening the financial sector. The data were collected via Google Forms in the second half of 2023. Over a one-month period, we collected exactly 102 voluntary and anonymous online responses. In addition to basic socio-demographic questions, our questionnaire examined the following elements:

- Elementary financial knowledge (five questions in total about compounding, inflation, diversification, long-term savings, and bond pricing, as found in Anderson and Robinson, 2022)
- Green values (using a Likert scale from 1 to 5 to indicate the level of agreement or disagreement with six statements taken from the OECD's Programme for International Student Assessment – PISA, as reported by Borgonovi et al., 2022a: 19, where 1 means "strongly disagree with the statement" and 5 means "strongly agree with the statement")
- Pro-environmental behaviour (four questions in total about the frequency of acting in an environmentally sustainable way, taken from the OECD's Programme for International Student Assessment – PISA, as reported by Borgonovi et al., 2022a: 34-35, with answers ranging from "never" to "always")

- Awareness of green finance terminology (six questions in total about the Paris Agreement, the European Green Deal, green stocks, bonds and investment funds, with answers ranging from "I have never heard of the term" to "I am well aware of the term")
- Attitudes towards green finance (using a Likert scale from 1 to 5 to indicate the level of agreement or disagreement with six statements adopted from or inspired by Anderson and Robinson, 2022, where 1 means "strongly disagree with the statement" and 5 means "strongly agree with the statement")
- Adoption of at least one green financial service (three questions in total regarding past experience, current state, and future prospects, with "yes", "no", and "I do not know / I am not sure" answers)

The questionnaire was composed in the Croatian language. More detailed insight into it is available upon request. Each student answered every question, and no missing responses were reported.

The sample consisted of 56 females (55%) and 46 males (45%), most of whom were up to 25 years old (almost 90%). Only 10 students were in the 26–28 year range, and one was 37. Approximately 57% of the respondents studied at the University of Zagreb, 38% at the University of Split, and 5% were affiliated with other universities across the country. Students of social sciences made up 46% of the sample, followed by those from technical sciences (25.5%), humanities (15.7%), and natural sciences (9.8%), while students from medical sciences were underrepresented (3%). The majority of the students were enrolled in graduate study programmes (65%), while the remainder were at the undergraduate level.

Elementary financial knowledge was assessed using the five ("Big-5") financial literacy questions:

1. *Suppose you had $100 in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow?* 74.5% of the students answered correctly: "more than $102".
2. *Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money in this account?* 63.7% of the students answered correctly: "less than today".
3. *Buying a single company's stock usually provides a safer return than a stock mutual fund*. 56.9% of the students answered correctly that this statement is false.
4. *Suppose you were given $10,000 as a gift and wanted to double the amount by saving the money for ten years without having to touch it*.

What interest rate would you require to achieve this goal? 42.2% of the students answered correctly: "about 7% annual interest rate".

5. *If interest rates fall, what should happen to bond prices?* 26.5% of the students answered correctly: "they will rise".

The respondents were asked to select one answer from the provided options. Each correct answer earned 1 point, while incorrect answers received zero points. By summing the points for each question, the financial knowledge variable was constructed, with a minimum theoretical value of 0.00 points for those with all incorrect answers and a maximum theoretical value of 5.00 for those with all correct answers. Both the theoretical minimum and maximum were confirmed empirically. Namely, 15 students did not record any correct answers in the financial knowledge category, while 12 students answered all the questions correctly. The majority of the students (26 students or 25.5%) achieved a total of 4 points, 20 students had 3 points, while 16 had two correct answers, and 13 had only one correct answer. The mean value of the financial knowledge variable was 2.6373, with a standard deviation of 1.61545.

The descriptive statistics for statements indicating green values are presented in Table 1.

Table 1. Descriptive statistics – green values

Statement	Mean	Std. Deviation	Minimum	Maximum
Looking after the global environment is important to me.	4.03	0.884	2	5
When I see the poor conditions that some people in the world live under, I feel a responsibility to do something about it.	3.63	0.984	2	5
I think my behaviour can impact people in other countries.	2.95	1.075	1	5
I think of myself as a citizen of the world.	3.37	1.062	1	5
It is right to boycott companies that are known to provide poor workplace conditions for their employees.	4.10	0.873	1	5
I can do something about the problems of the world.	3.05	0.999	1	5

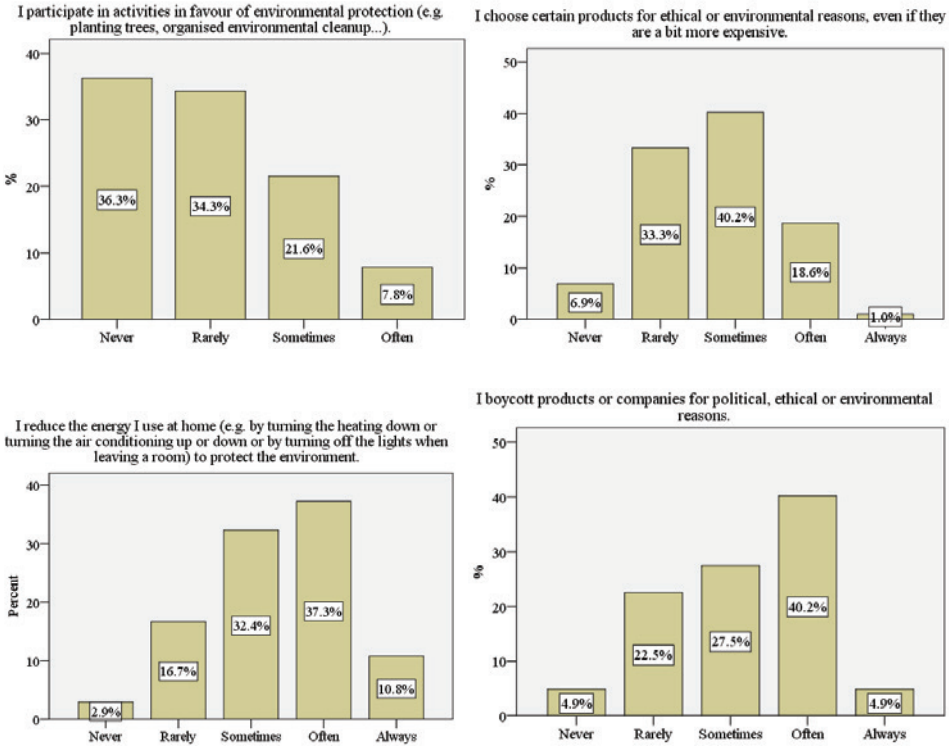
Source: Authors' calculation

The students were most in favour of the statement about "the rightness of boycotting companies that are known to provide poor workplace conditions

for their employees" (mean=4.10, or 79.4% agree or strongly agree with this statement) and "the personal importance of looking after the global environment" (mean=4.03, or 76.4% agree or strongly agree). However, they expressed doubt that their "behaviour can impact people in other countries" (mean=2.95, or 35.3% agree or strongly agree) and that they "can do something about the problems of the world" (mean=3.05, or 36.3% agree or strongly agree).

Regarding pro-environmental behaviour (Graphs 1-4), the students most frequently engage in energy efficiency activities (48.1% do them often or always) and in boycotting products or companies for political, ethical, or environmental reasons (45.1% do this often or always). However, 70.6% never or rarely participate in activities in favour of environmental protection, while 40.2% rarely or never choose more expensive, but more ethical and environmentally friendly products.

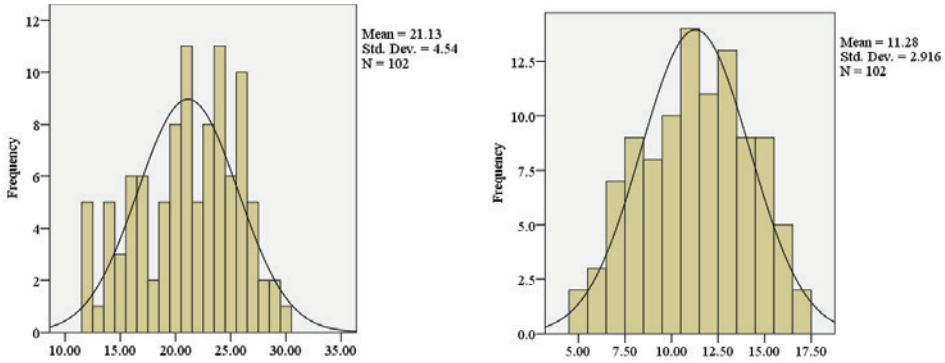
Graphs 1-4. Frequencies of pro-environmental activities



Source: Authors' calculation

From these responses, we constructed two new composite variables: green values and pro-environmental behaviour. Both variables represent the sum of points assigned to each answer. For green values, we used a Likert scale ranging from 1 to 5 points. Thus, the green values variable could have a minimum of 6 points (if a respondent strongly disagreed with each of the six statements) and a maximum of 30 points (if a respondent strongly agreed with each statement). The minimum empirical value was 12, while the maximum matched the theoretical maximum. The mean value was 21.1275, with a standard deviation of 4.53953. Regarding pro-environmental behaviour, there were four questions, with a scale from "never" to "always". We scored "never" as one point and "always" as five points, following the previous Likert scale logic. In this way, the theoretical minimum is 4 (if respondents answered "never" to every question), while the maximum is 20 (if "always" was the response to every question). The empirical minimum matched the theoretical minimum, while the empirical maximum was 17. The mean value for this composite variable was 11.2843, with a standard deviation of 2.91591. The frequencies of each of these composite variables are presented in the following histograms.

Graphs 5-6. Histograms for green values and pro-environmental behaviour



Source: Authors' calculation

Awareness of green finance terminology or green financial knowledge was assessed using the following six questions:

1. *Are you familiar with the term "green finance"?*
2. *Are you familiar with the existence and content of the Paris Agreement?*
3. *Are you familiar with the existence and content of the European Green Deal?*

4. *Are you familiar with the existence of and the term "green stocks"?*
5. *Are you familiar with the existence of and the term "green bonds"?*
6. *Are you familiar with the existence of and the term "green investment funds"?*

Nearly 60% of the students have never heard of the term "green finance", almost 14% have some level of familiarity with the term, while the remainder have heard of the term, but are not familiar with its meaning. These results are worse than those reported for Chinese undergraduates by Zhu, Zhu, Fang and Pan (2017), where 43% had never heard of green finance. Even more unfavourable results were recorded for specific financial products such as green stocks, green bonds and green investment funds, which approximately 67%–68% of the respondents had never heard of. Better awareness was recorded for the Paris Agreement and the European Green Deal. A total of 27% of the students are familiar with the Paris Agreement, and 17% with the European Green Deal. Moreover, 54% of the students have heard of, but are not familiar with the existence and content of the Paris Agreement, while approximately 58% gave the same response for the European Green Deal. Around 18% and 25% of the respondents have never heard of the Paris Agreement and the European Green Deal, respectively.

On the basis of these responses, we created another composite variable – awareness of green finance terminology, or, in short, green financial knowledge. Each "I have never heard of the term" answer was scored with one point, "I have heard, but I am not familiar" counted for two points, while "I am familiar with the term" and "I am well aware of the term" were given three and four points, respectively. This counts up to six points for the theoretical minimum, and 24 points for the theoretical maximum. However, the empirical maximum amounted to 21. The mean value for green financial knowledge was 9.9412, with a standard deviation of 3.26949.

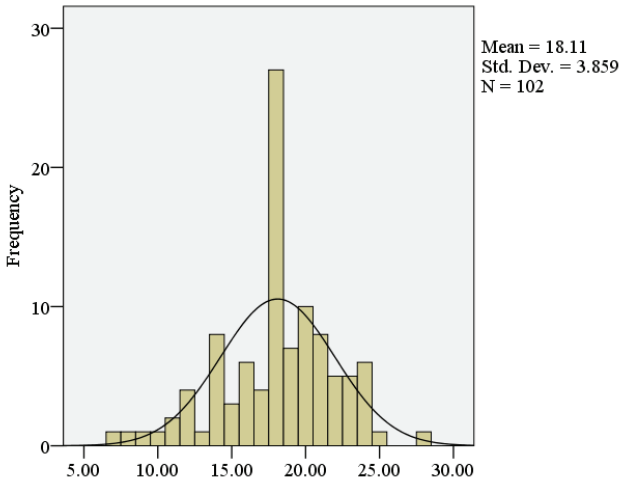
Furthermore, we examined the attitudes towards green finance. The descriptive statistics of the six statements that aimed to capture these views are included in Table 2. The students have a positive view of green finance (mean = 3.26), and prioritise a clean planet over financial welfare (mean = 3.22). However, it was observed that the ecological awareness of a bank is not an important criterion when choosing a bank (mean = 2.66).

Table 2. Descriptive statistics – green finance attitudes

Statement	Mean	Std. Deviation	Minimum	Maximum
Green finance has the key role in environmental protection.	3.03	0.710	1	5
If I invested, rather than being conventional, I would prefer green financial services.	3.01	0.906	1	5
A clean planet is more important for me than financial welfare.	3.22	1.224	1	5
It is worth paying higher fees for a mutual fund that only makes environmentally sustainable investments.	2.93	0.812	1	4
Ecological awareness of the bank is an important criterion in my process of bank selection.	2.66	0.939	1	5
I have a positive view of green finance.	3.26	0.717	1	5

Source: Authors' calculation

Graph 7. Histogram of green finance attitudes



Source: Authors' calculation

In order to depict the attitudes towards green finance more broadly, we constructed a composite variable by summing the points for all responses. The theoretical minimum was 6 and the maximum was 30. However, these were

not reached, as the empirical minimum and maximum amounted to 7 and 28, respectively. The mean value amounted to 18.1078, with a standard deviation of 3.85866. Graph 7 contains the histogram for this variable.

At present, most respondents do not use any green financial services (80%), or are unsure about their green aspect (20%). In the past, 71% did not use any green financial products, while 28% do not know if they used them. However, the future may be more promising, as 21.6% of the respondents are certain they will adopt at least one green financial service (compared to 41% of Chinese students according to Zhu et al., 2017). A total of 20.6% are certain they will not use green financial services, while 58% are undecided.

RESEARCH RESULTS AND DISCUSSION

In this section, we evaluate the importance of the composite variables: financial and green financial knowledge, green values, and pro-environmental behaviour on the composite variable of green finance attitudes. A dummy variable for gender (1 for females, 0 for males) was also included. Multiple linear regression was performed, and the results are presented in Tables 3 and 4.

The correlation between the model variables (R) and the model representativeness, that is, the coefficient of multiple determination (R Square), is slightly lower than 0.8 for R and around 58% for R Square (Table 3). The Durbin-Watson test is around 2, indicating no problem of autocorrelation of residuals. The estimated model is statistically significant (F = 26.118; sig. = 0.000). Since the tolerance was always greater than 20% and the variance inflation factor (VIF) was lower than 5, we can conclude that there is no multicollinearity problem (Table 4).

Table 3. Linear regression – model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.759[a]	0.576	0.554	2.57618	2.101

Source: Authors' calculation

Table 4. Linear regression with green finance attitudes as dependent variable

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	**4.074**	1.497		2.722	**0.008**		
Financial knowledge	-0.047	0.181	-0.020	-0.260	0.796	0.767	1.304
Green values	**0.321**	0.080	0.378	4.015	**0.000**	0.499	2.004
Pro-environmental behaviour	**0.535**	0.124	0.404	4.322	**0.000**	0.504	1.984
Green finance knowledge	0.071	0.087	0.060	0.818	0.416	0.809	1.236
Gender	**1.148**	0.546	0.149	2.101	**0.038**	0.881	1.136

Source: Authors' calculation

According to the estimated coefficients, pro-environmental behaviour (0.535) and green values (0.321) are more important for shaping green finance attitudes than financial knowledge or green finance knowledge, which were found to be insignificant (Table 4). However, being a woman has the highest impact and substantially increases positive attitudes towards green finance (contrary to Bethlendi et al., 2022, and similarly to Lanciano et al., 2025). In addition, environmental sustainability values were also more strongly expressed among 15-year-old girls in EU and OECD countries (Borgonovi et al., 2022a).

Furthermore, the impact of green finance attitudes on the adoption of at least one green financial service in the future was initially tested with analysis of variance, but as Levene's test of homogeneity of variances was not satisfied, a non-parametric solution, namely the Kruskal-Wallis test, was used. According to the results presented in Table 5, young financial consumers who would adopt at least one green financial service have the highest mean rank, indicating that they have stronger attitudes towards green finance. The Chi-Square test was 17.489 and significant ($\alpha = 0.000$). Therefore, green finance attitudes are confirmed as antecedents of adopting green financial services.

Table 5. Kruskal-Wallis test for future adoption of green finance services

	Adoption of at least one green financial service in the future	N	Mean Rank
Green finance attitudes	No	21	29.98
	Yes	22	66.59
	I do not know / I am not sure	59	53.53

Source: Authors' calculation

Overall, having and practising green values is more important for shaping positive attitudes towards green finance than having specific green or financial knowledge. Accordingly, Heeren et al. (2016) confirmed among 580 US university students that the level of sustainability knowledge was not a significant factor in pro-environmental behaviour, and social psychological components were rather more influential. Specifically, sustainability knowledge explained no more than 2 percent of the variance in any pro-environmental behaviour.

Nevertheless, enhancing environmental literacy (or eco-literacy) is recommended for the long-term acceptance of green financial products, when literacy refers to a skill that encompasses not only knowledge but also attitudes, appropriate decision-making, and behaviour. Knowledge alone may not be sufficient to change behavioural patterns, despite strong evidence of the influence of environmental knowledge on green purchasing behaviour (Naz, Oláh, Vasile, & Magda, 2020) and the importance of education in reducing environmental degradation (Afzal et al., 2022).

CONCLUDING REMARKS

Green finance is a critical factor in the green transition, and public expenditure alone is insufficient to address climate change. Therefore, understanding stakeholders' expectations regarding green finance, especially those of young adults such as students – often seen as agents of change – could assist financial service providers and policymakers, particularly in the field of education, in adapting or developing new instruments that will increase demand for green finance.

In this study, we examined the importance of knowledge about financial matters and green finance, as well as the pro-environmental values and behaviour of Croatian students, in order to identify the most influential factors for positive attitudes towards green finance. We found that values and behav-

iour are more important than financial knowledge or green finance awareness when it comes to fostering positive attitudes towards green finance. Therefore, educational programmes (formal or informal) should focus more on practical learning (learning by doing) rather than solely imparting factual knowledge. However, student responses should be regarded as an indication of interest in green financial instruments, and not as final decisions. Gaining more knowledge about green financial instruments might also reverse this trend, as has been shown in some studies. Furthermore, examining only the impact of knowledge can lead to biased results and should always be complemented by social and psychological components. In summary, cognitive factors alone cannot fully explain sustainability-linked financial decisions. Finally, in addition to personal barriers, young consumers may face significant financial constraints when making sustainable finance choices and accepting sustainable finance investments, which requires the adoption of adequate inclusive policies both from the financial industry and public policymakers.

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E&S PRACTICES IN CROATIAN ENTERPRISES: LESSONS (TO BE) LEARNED

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The environmental and social responsibility of SMEs has been gaining increasing attention. Literature highlights ESG performance benefits, but also reveals fragmentation in SME sustainability research, often overlooking the resource constraints, short-term priorities, and contextual drivers in emerging EU contexts. Scholars advocate viewing sustainability as a dynamic interplay between practices and performance, rather than isolated outcomes. Croatian SMEs are showing rising awareness, surpassing EU averages in sustainable goals, yet are lagging in systematic integration amid financial, expertise, and regulatory hurdles.

This paper provides exploratory qualitative evidence from two Croatian SME case studies in order to examine how environmental and social objectives can be incorporated into different business models. It explores organizational dynamics, synergies between environmental and social pillars, and implications for business performance, thereby contributing context-specific insights relevant for SME sustainability development in Croatia.

Employing a case study approach, the study analyses two ESG-awarded Croatian SMEs: a social cooperative in circular textiles, and a family-owned durable goods manufacturer. Primary data from semi-structured interviews with managers were complemented by secondary sources

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(websites, ESG reports, media). The thematic analysis, organized around enterprise profiles, ESG application, and performance impacts, yielded holistic case narratives, triangulated for validity.

Findings have revealed feasible ESG synergies: integration of circularity with inclusive employment, viable scaling, EU-based production, craftsmanship, and community engagement for sustainable growth. Lessons emphasize dignity in inclusion, replicable models amid constraints, and policy needs (incentives, training). Although limited to two case studies, the findings provide exploratory insights that may inform SME strategies, policymaking, and future comparative research on ESG implementation in SMEs.

Keywords: *SMEs, ESG, entrepreneurship, social enterprise, sustainability*

JEL classification: *M14, Q56, L26*

INTRODUCTION

Small and medium-sized enterprises (SMEs) form the backbone of the European economy: around 32 million SMEs account for 99% of all businesses in the EU and employ approximately 80 million people, representing two out of every three jobs. Beyond their crucial role in employment and economic cohesion, SMEs are the key drivers of Europe's green and digital transitions and a cornerstone of long-term prosperity (European Council, 2025). SMEs in Croatia continue to make a strong contribution to the economy, recording an employment growth rate of 5.8% in 2024, whereby the highest growth is noted among micro-enterprises, with a 7.3% increase in employment (EC, 2025b).

Environmental, social and governance (ESG) efforts have gained significant prominence in recent years, particularly following the introduction of ESG reporting requirements for large companies. Although SMEs are not required to report on ESG aspects, they increasingly recognize the importance of ESG efforts for their business development. In parallel, the European Union has introduced the Voluntary Sustainability Reporting Standard for non-listed SMEs (EFRAG, 2024; EC, 2025a). The VSME Standard (EFRAG, 2024) is designed to support SMEs by helping them respond to sustainability information requests from larger companies subject to the Corporate Social Reporting Directive (CSRD), particularly when they operate within their value chains. It

also facilitates access to finance by enabling SMEs to provide relevant sustainability information to banks and investors. In addition, the Standard supports the improvement of internal sustainability management, addressing environmental and social matters such as pollution, occupational health and safety, and resource efficiency.

SMEs have increasingly introduced environmentally friendly and socially responsible practices into their day-to-day operations, mostly driven by their founders' intrinsic motivations and business model-related considerations. This paper provides exploratory qualitative evidence from two Croatian SME case studies to examine how environmental and social objectives can be incorporated into different business models within the Croatian context. The identified lessons may be relevant for similar enterprises in emerging European contexts.

The theoretical background section reviews the key findings from the most recent literature sources addressing the relevance of ESG aspects for SME business development and growth accompanied by the benchmarks for the Croatian SMEs. The section with empirical results presents two case studies, one on the small enterprise named Hrvatski kišobran (Eng. Croatian Umbrella), and one on the social enterprise Humana Nova. Humana Nova has received several national and international recognitions for its work in circular economy, social inclusion, and sustainable entrepreneurship, including the Council of Europe Development Bank (CEB) Award for community engagement and climate action, the EASPD Innovation Award, the Climate Champion of Southeast Europe recognition, and the Generali SME EnterPRIZE award, where it was recognized as the overall "Hero of Sustainability". In addition, its manager Ivan Božić was recognized among the leading European managers of work integration social enterprises (WISEs). Hrvatski kišobran has also gained recognition for its socially responsible and inclusive business practices, particularly through the employment of persons with disabilities, the promotion of local production, and the emphasis on durable and design-oriented products. Hrvatski kišobran also received the title "Hero of Sustainability" as part of the SME EnterPRIZE competition in Croatia. The company and its owner Marin Rogić have also received recognitions related to sustainability, community contribution, and responsible entrepreneurship, including a recognition within the Croatian Sustainability Index initiative and the "Manager of the Year 2024" award for leadership in sustainability and social responsibility. These recognitions position both enterprises as relevant examples of ESG-oriented SME practices in the Croatian context. The final section highlights the key takeaways from the case studies and concludes the discussion.

SETTING THE SME-ESG SCENE: GLOBAL FINDINGS AND CROATIAN TRENDS

A growing body of literature highlights the numerous advantages for SMEs adopting ESG practices. The adoption of ESG standards has increasingly been recognized as a strategic driver of performance across firms of varying sizes, with a growing body of empirical evidence demonstrating measurable benefits for SMEs. Zaman et al.'s (2025) synthesis of the extensive research over the past two and a half decades has revealed that the SME sustainability literature remains fragmented and offers no comprehensive approach to defining or measuring sustainability. They argued that sustainability should not be viewed merely in terms of performance outcomes, but as a dynamic relationship between sustainability practices and firm performance. Furthermore, they stress that small businesses typically operate under significant resource constraints and are driven primarily by short-term economic and financial considerations, often with limited integration of sustainability dimensions. Identifying where SMEs fall along the sustainability spectrum can enable more efficient and targeted approaches tailored to their specific needs.

Based on a systematic literature review on the use of technology by SMEs to achieve sustainable development goals, Kannan and Gambetta (2025) claimed that SME leaders should integrate sustainability into their core business strategy by aligning it with economic goals, demonstrating leadership commitment, and fostering a supportive organizational culture. Leveraging digital and clean technologies, innovation, collaboration, training, and practical assessment tools can improve environmental performance and deliver efficiency and reputational gains, despite ongoing cost, skills, and risk-related constraints. Furthermore, Kannan and Gambetta (2025) suggested that policymakers should introduce targeted support for SMEs adopting sustainable technologies, including grants, tax incentives, and low-interest loans to reduce financial barriers. Investment in digital infrastructure and a balanced regulatory framework are essential to promote sustainability without overburdening SMEs, while knowledge-sharing platforms can foster the exchange of best practices among SMEs, large firms, and research institutions. Finally, the role of educators remains vital for the integration of sustainability and digital technologies into entrepreneurship and business programs. Kannan and Gambetta's (2025) findings are in line with Lisi et al.'s (2024) review on the SMEs' non-financial reporting on sustainability that identified legitimacy-based motivations, competitive advantage, and stakeholder engagement among the key drivers, whereas enabling factors focus on relevant tools and guidelines.

Arsenopoulou et al. (2025) found that ESG practices significantly enhance operational efficiency, especially through the ESG-value creation chain, and contribute to stronger financial performance and managerial decision quality over time. The study conducted on the SMEs in the Western Balkans (Vučković & Čučković, 2024) demonstrated that both internal factors (such as firm innovation and strategic orientation) and external pressures (like regulatory requirements and competition) significantly increase the likelihood of SMEs implementing green practices, especially those that are more capital-intensive. In addition, manufacturing SMEs are more likely to adopt green transition measures compared to service sector SMEs, likely due to higher energy use and environmental impact. Access to foreign technology and product innovation increases the likelihood of adopting green measures, highlighting the role of technological capability and innovation funding in driving environmental sustainability among SMEs.

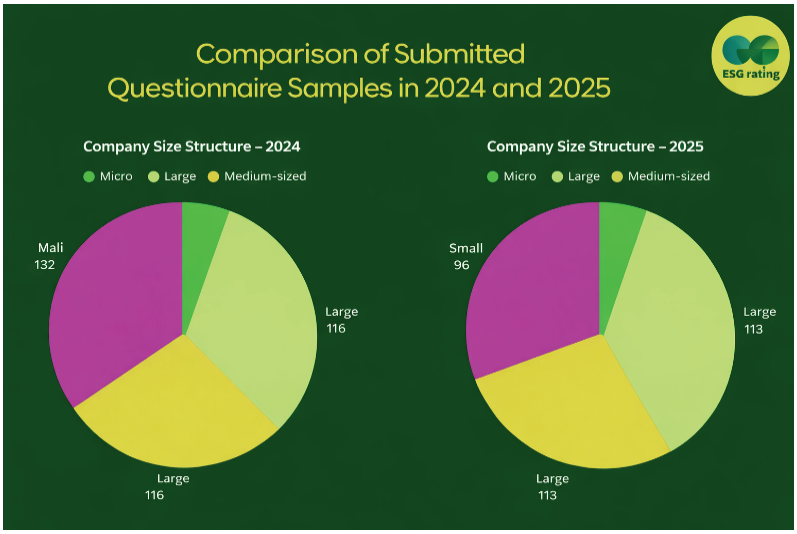
Although most ESG research focuses on broad performance outcomes, governance and ownership structures also play a critical role in shaping ESG outcomes. The study by D'Allura et al. (2025) highlighted how board diversity interacts with family ownership to influence ESG performance. More specifically, the authors showed that diverse boards embedded in family ownership structures can reinforce long-term orientation, ethical decision-making, and sustainability commitment. Moreover, family involvement appears to strengthen the positive effect of diversity on ESG outcomes, particularly through succession planning and intergenerational continuity, which embed prosocial values and ethical consistency into corporate governance. Thus, the study emphasized the S aspect in its implications, i.e. based on the positive correlation between board diversity and ESG performance, it is advised that companies, especially family-owned ones, should emphasize heterogeneity in board composition, and that includes gender, age, nationality, and qualifications.

The existing data indicate a growing awareness of sustainability among Croatian SMEs. According to the Global Entrepreneurship Monitor Croatia (Singer et al., 2024), sustainability is increasingly embedded in entrepreneurial decision-making, both among early-stage and established entrepreneurs. More than 70% of early-stage entrepreneurs and over 60% of experienced entrepreneurs familiar with sustainable development goals take concrete steps to enhance social impact and reduce environmental harm, placing Croatia above the EU average. A majority of entrepreneurs consider social and environmental impacts more important than short-term profit, with many of them defining the measurable sustainability goals and monitoring mechanisms (Alpeza et al., 2025).

Despite this growing engagement, the systematic integration of ESG principles among Croatian SMEs remains limited. In 2023, only 31% of SMEs had advanced in their sustainability transition, while a significant share had no plans to implement ESG. Nevertheless, SMEs that have adopted sustainable practices report positive outcomes, including higher employee and customer satisfaction, and improved risk management. To accelerate ESG uptake, Croatian SMEs highlight the need for policy support, particularly through tax incentives, access to EU funding, and investments in education and skills development, while ongoing financial constraints, limited expertise, and regulatory complexity remain the key barriers (Alpeza et al., 2025). This is in line with the previously presented policy implications by Kannan and Gambetta (2025).

When it comes to ESG measurement among Croatian companies, the ESG rating developed and implemented annually by the Croatian Chamber of Economy demonstrates sustained participation and interest from small, medium-sized, and large enterprises (Croatian Chamber of Economy, 2025). Each year, approximately two thirds of the submitted questionnaires are completed by SMEs, as displayed in Figure 1. These questionnaires serve not only as a rating instrument but also as a self-diagnostic tool, thereby increasing their practical business value.

Figure 1. ESG rating in Croatia – company size comparison among the submitted questionnaires



Source: Croatian Chamber of Economy (2025)

Overall, across all enterprises included in the sample, the most recent ESG rating results indicate clear progress: almost half of the participants are ranked in the high or very high category, confirming increased investment in sustainability and alignment with European standards. In addition, companies oriented toward the EU market achieve higher ESG ratings than those primarily focused on the Croatian or non-EU markets. Among the top ten companies, five operate in the manufacturing sector (Croatian Chamber of Economy, 2025).

In line with the above, Kearney's analysis (2024) of ESG practices in Croatia indicated a strong focus on ESG strategy, business planning, and monitoring, with around 80% of companies achieving mid-to-high scores in these areas (Figure 2). In contrast, environmental responsibility, employee well-being, diversity and inclusion, and governance remain underdeveloped, with more than half of the companies scoring below 2.5 and governance performing particularly weakly. While just over a half of the firms scored above 2.5 in ESG strategy and reporting, only a small minority approach the leading European standards. The social dimension shows relatively stronger performance, though top-tier scores remain rare. Importantly, micro-enterprises account for 22% of the sample and are subject to lighter ESG requirements, which depresses the aggregate results; when adjusted for firm size, overall ESG maturity, especially in strategy, employee well-being, and governance, appears notably higher.

Figure 2. The ESG picture for Croatian enterprises



Source: Kearney (2024: 3)

Kearney's (2024) findings highlight an increasing environmental awareness among Croatian SMEs, but also significant implementation gaps (Figure 3). While one third of SMEs have set emissions targets, only 24% achieve them, compared to much higher compliance among large firms, thus reflecting persistent resource and capacity constraints. Nearly two thirds of SMEs, particularly micro-enterprises, still lack formal emissions goals, and the vast majority do not assess their environmental footprint. Monitoring of waste and water use remains limited among SMEs, with fewer than one third tracking these indicators systematically. These disparities underscore substantial opportunities for SMEs to strengthen environmental management through targeted support and capacity building.

Figure 3. Croatian SMEs and emission targets



Source: Kearney (2024: 4)

In the social dimension, Kearney (2024) found that Croatian SMEs lag behind large companies in employee well-being and inclusion practices. While SMEs report a positive reputation among talent, often linked to organizational purpose, this rarely translates into long-term retention. Compared to large firms, SMEs are less likely to track employee well-being or implement support systems. Diversity and inclusion practices are particularly underdeveloped: most SMEs lack formal inclusion programs, and only a small minority ac-

tively monitor workforce diversity or apply diversity criteria in recruitment. In employee well-being, 55% of large companies have developed tracking and support systems, while only 36% of SMEs do the same. Diversity and inclusion remain a challenge: 44% of large companies and 59% of SMEs lack specific inclusion programs, though 33% of large firms actively monitor diversity, compared to just 12% of SMEs. These findings point to structural capacity constraints, but also highlight significant potential for targeted improvements in SME social practices.

In summary, the literature on SME sustainability often merges three distinct but related concepts. The first is sustainability as a set of business practices which reduce environmental damage, the second is local-production-based differentiation strategies that could correlate with lower environmental impact, and the third is the ESG phenomenon as a measurable set of environmental, social and governance practices subject to, for example, the ESG rating administered by the Croatian Chamber of Economy (2025). Without measurable indicators (e.g. product lifetime, recycled content, energy intensity), many attributes related to products risk functioning as marketing narratives (Bernini, 2024; Yang et al., 2024; UN; 2024). The EU Ecodesign for Sustainable Products Regulation, which entered into force in 2024, formalized this distinction by defining environmental performance through characteristics such as durability, repairability, hazardous substances, etc. (EC, 2024). We adopted this in the analysis included in the following sections through separating the environmental practices from differentiation strategies that may, but do not necessarily support them.

METHODS

This study employs a qualitative research design. In line with Creswell (2009), qualitative inquiry is characterized by a holistic perspective, aiming to construct a complex understanding of the focal problem by integrating multiple viewpoints, recognizing interacting factors, and situating them within a broader context. Among qualitative strategies, the case study is one of the most widely applied strategies in social research (Priya, 2021).

Methodologically, this paper follows Yin's (2018) case study approach, which conceptualizes the case study as a social science method suitable for an in-depth examination of a contemporary phenomenon within its real-life setting. Case studies are particularly useful in organization and management research because they enable researchers to grasp the dynamics within spe-

cific contexts (Eisenhardt, 1989). By integrating different perspectives, they reveal multiple dimensions of the phenomenon under investigation (De Massis & Kotlar, 2014).

The purpose of this paper is to investigate the implementation of ESG standards in two small Croatian enterprises. The firms were selected because they had been repeatedly recognized and awarded for their ESG performance. The aim of the case studies is to show how ESG-related activities are structured and enacted in these firms. Primary qualitative data were collected through semi-structured interviews with company managers. Interviews are especially effective for obtaining rich, practice-oriented insights, particularly when the phenomenon is relatively rare or sporadic (Eisenhardt & Graebner, 2007). This approach yields detailed and valuable empirical material. The interviews followed a semi-structured guide with open-ended questions organized around three themes: 1) basic information about the enterprises; 2) application of ESG standards; and 3) implications for company performance. Interviewees were encouraged to elaborate on their responses, and follow-up questions were used to clarify any ambiguities. With the interviewees' permission, the interviews were audio-recorded, and field notes were taken during the sessions. These materials subsequently formed the core empirical basis for the case studies.

In addition to the manager interviews, secondary data were collected and analyzed, including company websites, ESG reports, and media articles. These secondary sources complemented the primary data, and contributed to a more holistic picture of ESG implementation and its implications for firm performance in the two companies.

RESULTS

The data are structured in thematic fields and presented in two case studies.

CASE STUDY: HUMANA NOVA

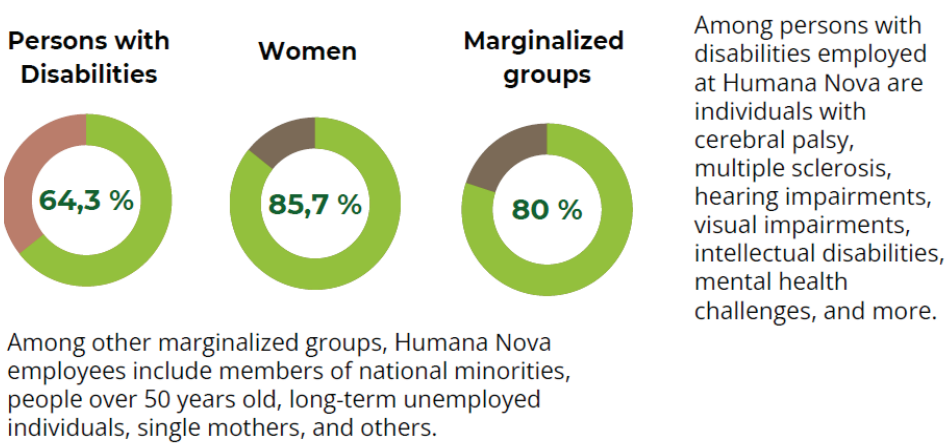
Background

Humana Nova is a Croatian social cooperative established in 2011, operating under a business model that integrates environmental sustainability, social inclusion, and economic viability. The cooperative was founded with the objective of addressing two interconnected societal challenges: textile

waste management and labor-market exclusion of vulnerable social groups. Its mission is to promote the employment of people with disabilities and other socially marginalized individuals through the collection, reuse, and transformation of textile waste into high-quality textile products made from recycled and ecological materials for domestic and international markets. Over time, the cooperative has developed from a small local initiative into one of the most visible examples of circular-economy-oriented social entrepreneurship in Croatia, receiving national and international recognition for its environmental and social impact.

In 2025, the cooperative employed 56 workers, including 33 persons with disabilities and 20 individuals from other marginalized social groups (Figure 4). The employment structure illustrates the central role of inclusive employment within Humana Nova's organizational model, where social integration and economic participation are treated as equally important dimensions of business sustainability. Humana Nova thus represents an example of a Croatian social enterprise attempting to simultaneously address environmental degradation (through textile waste management), social exclusion and unemployment (through inclusive hiring), and local economic development (through production, sales, and reinvestment).

Figure 4. Employee structure in Humana Nova



Source: Company website https://humananova.org/

This socially and environmentally oriented business model has also been accompanied by organizational and financial growth, suggesting that inclusive

and circular-economy-based practices can coexist with market sustainability and business expansion. Humana Nova demonstrated steady financial growth from 2022 to 2024, with total revenues increasing from EUR 1.5 million in 2022 to EUR 2.4 million in 2024, while the surplus of income over expenditures increased by 240% during the same period, reflecting enhanced operational efficiency and market expansion.

Environment: Textile Waste Management and Circular Economy

One of the cornerstones of Humana Nova's impact lies in its environmental practices. The cooperative systematically collects surplus and discarded textiles such as clothing, fabrics, and other textile items, which otherwise might end up in landfills or incinerated, posing environmental hazards. Once collected, the textiles are sorted: wearable items may be resold, reusable materials are redesigned or up-cycled, thereby offering sustainable alternatives to fast-fashion products, and unusable textiles are processed further. This approach aligns with the principles of the circular economy; resources are kept in use as long as possible, and waste is minimized by extending the useful life of materials and transforming waste into value. Humana Nova reports that it has to date collected over 5,000 tonnes of textiles. In 2024 only, the cooperative collected 723 tonnes, demonstrating both growth and increasing capacity.

Society: Inclusion, Employment, and Community Empowerment

The social dimension of Humana Nova is equally fundamental as its environmental commitment. The cooperative aims to integrate socially marginalized individuals into the workforce, in turn confronting structural barriers, as many of these individuals would otherwise face persistent unemployment, social exclusion, poverty, or marginalization. As the company manager states: "*We have removed distractors and burdensome elements so that each person can give what they know and can do best. The structure of employees ranges from highly educated people to people with severe forms of intellectual disabilities. We don't all understand and look at everything the same. But of course, we strive and work to ensure that during work hours we all have the same vision and share the same values.*" By offering stable and dignified employment opportunities to individuals who often struggle to find work, Humana Nova seeks to enhance the employees' quality of life, self-esteem, social inclusion, and economic security.

Furthermore, as a non-profit social enterprise, Humana Nova reinvests all profits back into the business, which enables continuous expansion of produc-

tion capacities, purchasing new machines, creating new jobs, and improving working conditions. Beyond employment, Humana Nova also undertakes educational and community-oriented activities. The cooperative organizes trainings and awareness-raising about circular economy, sustainable consumption, recycling, and social entrepreneurship, often collaborating with schools, associations, and local authorities to engage the broader public.

CASE STUDY: HRVATSKI KIŠOBRAN

Background

Hrvatski kišobran (Eng. Croatian Umbrella) is a manufacturing company based in Zaprešić, Croatia. The company dates back more than 30 years, when it operated as a small kiosk on the Zaprešić market, selling imported umbrellas and various other consumer goods. Over time, the company evolved, shifting to wholesale distribution by 2001. By 2002, it began importing and distributing umbrellas domestically and abroad. The pivotal transformation for the business came in the early 2010s, when production under the brand Hrvatski kišobran began. By 2013, the first umbrellas were exported outside the EU. Since then, the company has steadily grown in size, production capacity, and market presence, and today represents the only mass producer of umbrellas in the European Union.

The company currently employs more than 60 workers and has recorded continuous organizational and financial growth in recent years. According to financial reports, total revenues increased from approximately EUR 3 million in 2022 to EUR 4.5 million in 2024, while net profit exceeded EUR 1 million in 2024. In parallel, the company reported growth in employment, production, and export activities. Hrvatski kišobran currently produces approximately 300,000 umbrellas annually, with more than 50% of total production exported to international markets.

Environmental Practices: Product Durability, Repairability, Local Production and Sustainable Business Practices

Unlike enterprises primarily focused on environmental technologies or recycling systems, Hrvatski kišobran approaches sustainability through product durability, repairability, local production, and long-term resource efficiency. Although the company's external communication places stronger emphasis on social inclusion and business development than on formal environmental man-

agement systems, several elements of its production model reflect identifiable environmental sustainability practices. The company maintains production in Croatia, ensuring that manufacturing, quality control, and supply-chain activities remain under European regulatory and production standards. Localized production and shorter supply chains potentially reduce transport-related environmental impacts compared to globally dispersed manufacturing models while also enabling greater traceability and production oversight. A central element of the company's sustainability approach is the emphasis on product longevity and durability. The company increasingly develops umbrella repair services as part of its business model. This service-oriented component contributes to extending product life cycles, reducing product waste, and promoting repairability instead of disposal.

Social Practices: Inclusion, Employment, Community Engagement and Social Responsibility

The social dimension of Hrvatski kišobran represents one of the strongest aspects of its ESG orientation. The company emphasizes equal opportunity, inclusion, and supportive employment practices as integral components of its business model. In 2023, Hrvatski kišobran formally established an "integrative workshop" with the explicit goal of employing people with disabilities and individuals from vulnerable social groups.

At the time of the research, the company employed 12 persons with disabilities. The company applies an individualized and supportive approach, adapting work tasks to employees' functional abilities, while simultaneously providing continuous professional support and opportunities for developing work, social, and communication skills. According to the company owner and manager, whose commitment to ESG values is a key driver of the company's orientation toward sustainable behavior and operations, "*…inclusion requires more than just hiring: it demands systemic support, sensitivity, adaptation, and long-term commitment*". The company hired a psychologist in 2022, offering professional support both to the employees with disability status and to the broader workforce. The objective of the company is not merely to provide employment, but to create "*… a stable and secure work environment in which employees can develop a sense of competence, professional identity, and belonging to the work community*." Importantly, the social inclusion practices are embedded within a commercially viable and growing enterprise rather than functioning solely as externally funded social programs. The company reports a growth of approximately 15% in employment, alongside increasing produc-

tion and export capacity, indicating that inclusive employment practices coexist with business expansion and market competitiveness.

Beyond employment practices, Hrvatski kišobran actively engages in community-oriented and educational activities. The company organizes factory visits for kindergartens, schoolchildren, and students, thereby promoting awareness about manufacturing, entrepreneurship, design, craftsmanship, and production processes. It also participates in humanitarian activities, volunteering initiatives, and entrepreneurship-promotion programs such as "*(P)ostani poduzetnik*" (Eng. "Become an entrepreneur"), aimed at encouraging entrepreneurial activity and knowledge sharing within the broader community.

To further strengthen the analytical contribution of the study, Table 1 provides a comparative overview of the two case studies by summarizing their key organizational characteristics, ESG-related practices, business-development indicators, and approaches to environmental and social sustainability. The comparison highlights both the common elements and the distinct pathways through which the two SMEs integrate ESG principles into their business models.

Table 1. Comparative overview of ESG-oriented practices in Humana Nova and Hrvatski kišobran

Dimension	Humana Nova	Hrvatski kišobran
Type of enterprise	Social cooperative / social enterprise	Family-owned manufacturing SME
Core business activity	Textile reuse and recycling	Umbrella manufacturing
Year established	2011	1990; Hrvatski kišobran as a brand established in 2010
Main sustainability logic	Circular economy and textile waste reduction	Product durability, repairability, and local production
Environmental practices	Textile collection, reuse, upcycling, waste reduction	Durable products, repair services, shorter supply chains, local production
Measurable environmental indicators	More than 5,000 tonnes of textiles collected; 723 tonnes collected in 2024	Approx. 300,000 umbrellas produced annually; development of repair services
Social practices	Employment of persons with disabilities and marginalized groups	Inclusive employment and integrative workshop

Dimension	Humana Nova	Hrvatski kišobran
Inclusion indicators	56 employees; 33 persons with disabilities; 20 additional marginalized workers	More than 60 employees; 12 persons with disabilities
Organizational approach	Non-profit reinvestment model	Commercially viable inclusive business model
Market orientation	Domestic and international markets	More than 50% of production exported internationally
Business growth indicators	Revenue growth from EUR 1.5 million (2022) to EUR 2.4 million (2024); income surplus increased by more than 240%	Revenue growth from EUR 3 million (2022) to EUR 4.5 million (2024); profit above EUR 1 million
Community engagement	Education on circular economy and sustainable consumption	Factory visits, entrepreneurship promotion, volunteering
Key ESG recognitions	SME EnterPRIZE "Hero of Sustainability" 2023, CEB Award, Climate Champion of Southeast Europe	SME EnterPRIZE Croatia "Hero of Sustainability" 2024
Dominant ESG emphasis	Integration of environmental and social goals	Social inclusion combined with sustainable production practices

Source: Authors

The comparison of the two cases demonstrates that ESG-oriented practices in SMEs can emerge through different organizational logics and industry contexts. Humana Nova integrates environmental and social objectives directly through its circular business model, where textile waste reduction and inclusive employment are mutually reinforcing components of the enterprise's mission. In contrast, Hrvatski kišobran approaches sustainability through durable local production, product repairability, and structured support for vulnerable workers within a commercially competitive manufacturing business. While Humana Nova reflects a social-enterprise model grounded in circular economy principles, Hrvatski kišobran illustrates how more traditional manufacturing SMEs can gradually incorporate identifiable environmental and social practices into a market-oriented business model. Despite these differences, both enterprises demonstrate that ESG-related practices can coexist with organizational growth, international market presence, and business viability.

DISCUSSION AND CONCLUSION

This paper explored how two Croatian SMEs integrate environmental and social objectives into their business models through different organizational and strategic approaches. The findings suggest that ESG-oriented practices are more convincing and sustainable when embedded within the core business model rather than treated as isolated or externally imposed activities. In both cases, environmental and social objectives are integrated into everyday operations, production processes, and organizational values, although through different pathways and business logics.

The case of Humana Nova demonstrates a social-enterprise model in which environmental and social goals are directly interconnected. Through textile collection, reuse, and upcycling, the cooperative simultaneously addresses waste reduction and inclusive employment of marginalized groups. The findings suggest that circular economy principles and social inclusion can operate as mutually reinforcing dimensions of a sustainable business model. Humana Nova further illustrates that inclusive employment becomes more sustainable when combined with long-term organizational commitment, reinvestment of profits, supportive working conditions, and community engagement.

In contrast, Hrvatski kišobran represents a commercially oriented manufacturing SME that incorporates ESG-related practices through product durability, repairability, local production, and structured support for vulnerable workers. Unlike Humana Nova's explicitly circular model, Hrvatski kišobran approaches sustainability through longer product life cycles, repair services, shorter supply chains, and durable production. At the same time, the company integrates inclusive employment into a growing and export-oriented business model, demonstrating that social inclusion can coexist with competitiveness, production growth, and international market expansion.

Taken together, the two cases illustrate that environmental and social objectives in SMEs may be complementary, but achieved through different strategies depending on the organizational mission, ownership structure, industry characteristics, and market positioning. While Humana Nova integrates environmental and social objectives through circular economy and social-enterprise logic, Hrvatski kišobran demonstrates how traditional manufacturing SMEs can gradually embed identifiable environmental and social practices into commercially viable business models.

At the same time, the findings also point to the costs, constraints, and trade-offs associated with ESG implementation in SMEs, which are often underrepresented in the literature. The practices observed in both enterprises require

organizational adaptation, managerial commitment, investment in production processes, employee support systems, and continuous balancing between social objectives and market competitiveness. The existing research similarly highlights complexity, operational costs, regulatory requirements, and limited human resources as important barriers to sustainability adoption in SMEs (Kannan & Gambetta, 2025; Naseer et al., 2025). In addition, investment costs related to sustainable production, administrative reporting burdens, and the diversion of scarce managerial resources may represent substantial challenges for smaller firms (EFRAG, 2024; UNESCAP, 2025; Naseer et al., 2025). The findings of this study further suggest that socially inclusive employment models also require structured organizational support and long-term investment in workplace adaptation, professional support, and employee integration. Without external support mechanisms, such practices may become difficult to sustain over time (Bonaccio et al., 2020; Lindsay et al., 2018; Bredgaard, 2018).

Consequently, the replicability of ESG-oriented SME business models will likely depend not only on entrepreneurial commitment and niche-market positioning, but also on the availability of targeted institutional support through EU funding programs, social-economy frameworks, inclusive-employment subsidies, advisory services, and public procurement mechanisms. The findings, therefore, point to the importance of policy measures that can reduce implementation barriers and enable SMEs to integrate sustainability principles into long-term business development strategies.

This qualitative case study is limited to two Croatian SMEs, constraining generalizability to broader populations or contexts. Reliance on manager interviews risks response bias, while secondary data may overlook unobservable dynamics. Future research could employ larger, multi-country samples with mixed methods, including quantitative metrics and longitudinal tracking, to test the generalizability and causality. Comparative analyses across sectors or firm sizes would further elucidate the contextual factors shaping ESG adoption in SMEs.

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ESG FOR SMES IN CROATIA - THE WAY TO GO

Ružica ŠIMIĆ BANOVIĆ*

Small and medium-sized enterprises (SMEs) in the European Union are not yet required to submit Environmental, Social and Governance (ESG) reports. Nevertheless, their market position, access to (green) finance, and relationships with major business partners increasingly depend on their commitment to ESG requirements. Moreover, embedding sustainability into their business models is essential for long-term resilience, and creating shared value should not serve merely as a PR instrument. The existing literature predominantly focuses on large companies subject to mandatory ESG reporting and on the postponement of ESG obligations for SMEs in the EU. However, survey findings indicate that one third of SMEs in Croatia are already implementing sustainability strategies, while expressing a growing need for clearer support mechanisms and financing for the transition.

In response to the identified needs of SMEs, this paper aims to map the key supporting events and trainings that target ESG alignment of SMEs in Croatia, outlining their advantages, limitations, and potential overlaps and synergies. In addition, it provides their perceived effectiveness by the participants and key actors. The research relies on primary and secondary sources, including desk research and conversations with convenors and participants of relevant programmes and initiatives held in 2025. It concludes with recommendations for more efficient capacity building support activities targeting SMEs in Croatia, yet applicable in the EU as well. Thus, the paper contributes by mapping the ESG capacity-building ecosystem in Croatia and providing suggestions for its improvement.

This paper reinforces the notion that SMEs must both prepare for and align with the ESG requirements while recognising and leveraging ESG-

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compliant practices they may already have in place, in order to strengthen their market position. It also highlights the core content provided, as well as the notable gaps, in conference and training programmes, which serve as important online and in-person platforms for ESG education and awareness-raising among SMEs. The findings confirm that meaningful progress in advancing ESG integration among Croatian SMEs requires a strengthened and well-structured training landscape, better-aligned support initiatives, and strategic use of emerging opportunities.

Keywords: *SMEs, entrepreneurship, ESG, sustainability, governance*

JEL classification: *M14, Q56, L26*

1. INTRODUCTION

Environmental and social responsibility, together with sound governance practices, have gained increasing attention in recent years, particularly within the context of EU-led ESG regulatory developments. Nevertheless, perceptions among small and medium-sized enterprise (SME) owners remain divided. While a significant share of SMEs continues to view sustainability requirements primarily as an administrative or financial burden, others had already embedded environmentally and socially responsible practices, as well as governance awareness, into their business models well before the introduction of formal ESG regulatory pressures. Importantly, growing evidence suggests that ESG integration extends beyond compliance, offering tangible operational and strategic value, including enhanced risk management, improved stakeholder relations, and long-term competitiveness. In any case, most SME owners, despite not being subject to formal reporting obligations, require enhanced support in incorporating ESG principles into their business models. Accordingly, this paper examines the trainings and initiatives offered in Croatia, as well as the feedback received from convenors and participants. Finally, it provides recommendations for further ESG-related programmes and initiatives designed for SMEs in Croatia, which are consequently intended to contribute to the quality of the entrepreneurial ecosystem as well.

This article seeks to map the key supporting events and trainings that target ESG alignment of SMEs in Croatia, outlining their advantages, limitations, and potential overlaps and synergies. In addition, it provides an overview of their perceived effectiveness by the participants and key actors. It adopts an exploratory qualitative design that draws on informal conversational interviews

with ESG conference participants and organisers, as well as members of the ESG initiatives, embedded within participant observation and documented through detailed field notes. Such informal, naturally occurring conversational encounters are recognised as a legitimate qualitative method that can produce context-rich and less performative accounts of participants' motivations, experiences and perceptions (Swain & King, 2022; Davis & Brown, 2024). Patton (2015: Ch 7 and Ch 8) defined the informal conversational interview as a flexible, context-dependent approach to qualitative data generation that adapts to natural conversational flow rather than following a fixed set of questions. Consequently, it may be different for each person interviewed, and the same interviewee may be interviewed on different issues and at different events, if needed. Accordingly, informal conversations conducted at live events have been shown to be particularly suitable for capturing attendees' expectations, reflections and suggestions in situ, when interactions are brief and sampling is necessarily opportunistic (Davis & Brown, 2024; Davis, Hayes & Brown, 2025). Moreover, informal conversations are defined as 'casual and free-flowing with no formal structure and without the disclosing of a specific agenda' (Davis et al., 2025: 115). They are claimed to be more effective than using surveys or interviews in such events, as the data collected are more authentic and the 'lived' experience is captured that cannot be usually grasped by the more rigid data collection methods (Davis et al., 2025). In this research, short dialogues with conference attendees (presented in Table 1) were treated as informal interviews, with data captured immediately afterwards through expanded and reflexive field notes that recorded both descriptive content and the researcher's interpretive reflections, following best-practice guidance for rigorous qualitative field note use (Patton, 2015; Phillippi & Lauderdale, 2018). The qualitative data were analysed using a reflexive thematic approach based on iterative engagement with field notes from informal conversational interviews and participant observation. Reflexivity was maintained throughout, acknowledging the researcher's influence on the research process. Finally, this research contributes to the future research recommendations provided by Davis et al. (2025) addressing the utilisation of informal conversations in event spaces other than the ones presented in their work, i.e. mainly sport and music festival events.

Table 1. List of interviewees

ID	Role / profession	Specific role at event	Event	Profile or affiliation
1	University graduate student	First-time participant	HRIO Conference	Early-career student preparing for labour market
2	ESG consultant	Long-time participant	HRIO Conference	ESG advisor or consultant
3	ESG manager	Presenter	HRIO Conference	Large regional company
4	Conference organisers	Organisers	HRIO Conference	Event organising team
5	Entrepreneur	Participant	ChangeMakers Conference	SME owner from Istria
6	Entrepreneur	Participant	ChangeMakers Conference	SME owner from Zagreb
7	ESG manager	Participant	Roundtable: Can Croatia Achieve Sustainable Tourism?	Medium-sized hospitality enterprise
8	University professor	Participant	Roundtable: Can Croatia Achieve Sustainable Tourism?	Academic
9	Entrepreneur	Participant	ReStart! Let's Support Sustainability Conference	SME owner from Dalmatia
10	International speaker	Presenter	ReStart! Let's Support Sustainability Conference	External expert
11	Legal counsel	Participant	ReStart! Let's Support Sustainability Conference	Large Croatian company
12	Entrepreneur	Participant	ReStart! Let's Support Sustainability Conference	SME owner from Zagreb
13	Entrepreneur	Panellist	Erste Bank Croatia: A focus on ESG lecture series	Entrepreneur from Zagreb
14	Entrepreneur	Training programme participant	ESG Academy / Transformator Programme	Entrepreneur from the Northern Adriatic coast

This article is structured as follows. Section 2 presents the most relevant and recent literature findings and international benchmarking results, with emphasis on Croatia and the EU. Section 3 analyses the empirical data collected through primary and secondary sources. Section 4 concludes the discussion and highlights the main takeaways and recommendations.

2. ESG ADOPTION BY SMES IN CROATIA AND THE EU: LITERATURE REVIEW AND BENCHMARKS

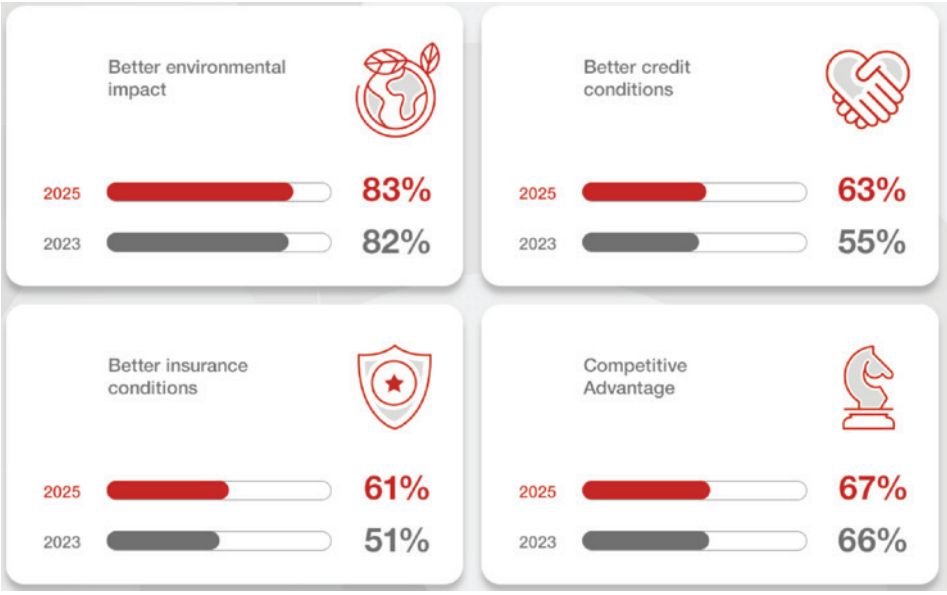
The SMEs' responsibilities, roles and contributions in the environmental, social, and governance domains are becoming a growing focus of debate across business, policy, and academic arenas (Caputo et al., 2024; European Commission, 2025; European Council, 2025; Galli et al., 2024; Gionfriddo & Piccaluga, 2024; Kannan & Gambetta, 2025; Lisi, Mignaca & Grimaldi, 2024; Martin et al., 2022; Santini & Caputo, 2024; Zaman, Tanewski & Ekanayake, 2025). Environmental, social, and governance practices in SMEs build on the longer CSR tradition, but are increasingly framed through measurable indicators, technology-enabled practices, and formalised non-financial reporting. Systematic literature reviews show that sustainability and ESG in SMEs are multidimensional constructs that span environmental efficiency, social and employee-related practices, governance and transparency, and innovation-oriented business models, while also stressing that owners' values, institutional pressures, and stakeholder expectations are critical drivers of adoption. Kannan and Gambetta (2025) demonstrated how digital technologies, data analytics, and smart production systems can act as enablers of technology-driven sustainability in SMEs, although significant capability and resource gaps remain. Lisi et al. (2024) synthesised the emerging evidence on non-financial (including ESG-related) reporting by SMEs, and highlighted both the legitimacy and competitive benefits of such reporting, as well as the challenges related to the standardisation, skills, and proportionality of the existing frameworks. Zaman et al. (2025) further mapped how sustainability is conceptualised in SME research, showing that it combines triple-bottom-line considerations, circular-economy practices, supply-chain pressures, and managerial capabilities, and arguing that tailored ESG models for SMEs are needed in order to reflect their resource constraints and embeddedness in local ecosystems.

The key finding observed by Stubbs et al. (2023) is the vital role of soft skills in implementing sustainable business models, particularly during periods of crisis and disruption. Skills such as persistence, adaptability, flexibility, and a willingness to learn underpin SME resilience, enabling firms to navigate uncertainty, respond to rapid environmental change, and adapt their business models, thus representing potentially transformative capabilities for other SMEs. In line with that, Damiano and Valenza (2024) reviewed the literature on the relationship between SME sustainability orientation and resilience, and argued that an entrepreneurial trajectory toward sustainable solutions can strengthen SME resilience and, in turn, enhance the resilience

and well-being of the wider economic environment. Furthermore, Caputo et al. (2024) stressed the concerns regarding the ways in which SME organisational structures shape sustainability-related practices, which differ markedly across firms and are strongly influenced by the psychological profiles of the owner-managers, and are subject to specific resource constraints. As a result, SMEs tend to rely on informal organisational arrangements and unplanned activities, making sustainability frameworks developed for large, bureaucratic corporations only partially applicable to the SME context. While exploring the potentially ESG-enabling environment, Iqbal et al. (2025) further highlighted the stakeholders' influence on SMEs' sustainability adoption through regulatory pressures, stakeholder expectations, strategic intent, and personal values, reflecting coercive, mimetic, and normative isomorphism. Among these, the actions driven by strategic intent and imitation of successful peers emerged as the dominant mechanism, while regulatory and stakeholder pressures played a more supportive role. This is mostly in line with the study conducted by Vučković and Čučković (2024), revealing that internal factors like innovation and strategic orientation, as well as external factors such as competitive and regulatory pressures, have a great impact on sustainability adoption. According to Kinderman (2020), business associations are the key actors in these debates in the business environment, as they play a decisive intermediary role between firms and regulators, and can significantly shape, delay or redirect ESG-related regulatory and other outcomes, regardless of the actual sustainability practices of their member firms.

As in most countries worldwide, small and medium-sized enterprises in Croatia account for the largest share of the total number of firms, representing 99.7% of all enterprises in the last five years. In 2023, the SME sector employed 72% of the total workforce and generated 54% of the total revenues, as well as 46% of Croatia's total exports (Alpeza et al., 2025). Still, Croatian SMEs continuously operate in a rather complex environment (Alpeza et al., 2022, 2025; Šimić Banović, 2015, 2016).

Figure 1. Sustainability pays: ESG and business benefits

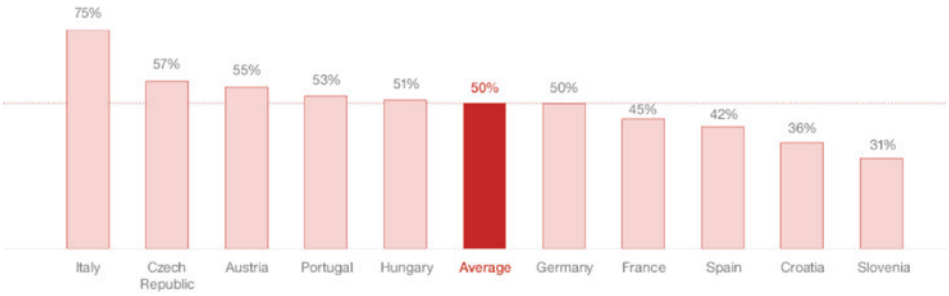


Source: Generali & Bocconi, 2025

The study by Generali & Bocconi (2025) on SMEs in ten EU countries indicates that there is a consolidation of sustainability adoption among SMEs, with "Heroes" and potential "Heroes" firms jointly accounting for 44%, which is up from 34% in 2020, despite increasing challenges. As mostly shown in Figure 1, sustainability remains very relevant and is perceived advantageous in terms of business outcomes, with 83% of SMEs reporting improved environmental impacts, around 75% noting higher employee and customer satisfaction, 67% reporting enhanced competitiveness, and 63% experiencing better credit conditions - an 8% increase compared to 2023. However, SMEs are facing growing implementation barriers, including limited public incentives (54%), institutional support gaps (53%), and restricted access to sustainable finance (53%), while climate resilience awareness varies significantly, with 69% of sustainability leaders recognising climate risks compared to a 50% average, and price volatility identified as the main concern (47%). Croatian (36%) and Slovenian (31%) enterprises seem to be among the least aware of the climate risk, as demonstrated in Figure 2. The gap between leading and lagging countries in terms of climate risk awareness is perceived as 'concerning' (Generali & Bocconi, 2025: 48). The results of the Croatian ESG rating (CCC, 2025a) predominantly complement the

previously presented findings. Namely, each year, around two thirds of submitted questionnaires are completed by SMEs. These questionnaires function both as rating tools and as self-diagnostic questionnaires, which enhances their practical business relevance. Recent ESG ratings for all the participating enterprises show clear improvement: nearly half are now classified in the high or very high category, signalling stronger sustainability investment and closer alignment with European standards. Firms oriented toward EU markets obtain higher ESG ratings than those primarily serving Croatian or non-EU markets, and five of the top ten companies operate in the manufacturing sector (CCC, 2025a).

Figure 2. SMEs and Climate Risk: % of SMEs declaring being subject to climate change risk



Source: Generali & Bocconi, 2025

Similar to most of the other nine EU countries included in the study sample (Generali & Bocconi, 2025: Ch 5), the main areas where SMEs in Croatia seek support are EU-subsidised funds to finance the green transition (75%), national subsidised funds for the green transition (72%), a clear and simplified regulatory framework for SMEs (74%), tax incentives to promote sustainable products and services (69%), and education, capacity building, and the transfer of competencies (70%).

Despite the perceived lack of institutional support, ESG adoption remains among the top three advantages in terms of customer satisfaction, i.e. 74% SMEs in selected EU countries declare it as a benefit, whereas in Croatia this percentage rises to 85% (Generali & Bocconi, 2025: Ch 5). As presented in Figure 3, Kearney's (2024) survey indicates that nearly 60% of Croatian SMEs believe that their customers perceive their products or services as purpose-driven, with 29% reporting that customers are willing to pay a premium. However, one quarter of SMEs feel that their products and services are not viewed as purpose-driven at all. Compared to large firms, SMEs show lower confidence in value alignment

across the supply chain: 29% believe that the suppliers do not recognize their purpose, and more than half are uncertain or feel unrecognized. Supplier selection remains largely price-driven, as only 6% of both SMEs and large companies apply the predefined ESG standards in procurement.

Figure 3. Perception of Croatian customers regarding the ESG integration in products and services



Source: Kearney (2024: 7)

Governance practices further reveal structural gaps among SMEs. While all large companies have formal codes of ethics, 29% of SMEs lack them, and only 41% report strong employee adherence to ethical standards. Succession planning is also less developed, with just over a half of SMEs having formal plans, compared to 83% of large firms. Women hold 39% of managerial positions in SMEs, broadly reflecting overall gender balance, yet governance di-

versity remains limited: independent board members account for only 11% of SME boards, compared to 31% in large companies, indicating significant room for strengthening governance quality and oversight (Kearney, 2024).

Hence, the recommendations for policy makers presented below, produced by Generali and Bocconi (2025: 15), appear to be fully in line with the literature review findings and all the afore-elaborated empirical data for Croatia and the selected EU countries. They mainly address regulatory simplification matching the business capabilities of SMEs, comprehensive capacity-building programmes, and a targeted and enhanced public support system aimed at faster sustainability transition.

3. ENGAGEMENT AND CAPACITY BUILDING SUPPORT FOR SMES IN CROATIA – EMPIRICAL INSIGHTS

This section provides an overview of the key events held in Croatia in 2025 that aimed at educating enterprises, providing information, raising awareness of ESG topics among Croatian businesses, and recognising the best performers.

1. Conference on Sustainable Development and Croatian Sustainability Index Award Ceremony (HRIO)

The 17th Conference on Sustainable Development and the 18th Croatian Sustainability Index (HRIO) Awards, held on 11–12 November 2025, aimed to advance responsible and sustainable business practices in Croatia. The event targeted corporate leaders, sustainability professionals, policymakers, and academics. Its programme combined keynote lectures, thematic panels, case-study presentations, hands-on workshops and the formal HRIO award ceremony recognizing companies with outstanding ESG performance. The key programme topics included ESG integration, corporate governance, sustainability reporting, and alignment with the EU regulatory frameworks. The conference also served as a networking platform for exchanging best practices and strengthening collaboration between business and public-sector stakeholders (HR PSOR, 2025). This Conference and its accompanying award have the longest tradition among ESG-related conferences in Croatia. It can be attended both in-person and online, and access to the recordings of both Conference days is also possible. The Conference organisers are very proud of that tradition, as well as of the wide audience that the Conference keeps attracting every year. The participants unanimously confirmed that impression, as noted below.

University graduate student – first-time conference participant: "I was so happy to see that, as a student, I didn't have to pay a conference fee. It was very interesting and very useful for the topics I expect to deal with in the job market very soon. I met some inspiring businesspeople, and the food was amazing as well. It's a pity that I have to run to a mandatory lecture now!"
ESG consultant, long-time conference participant: "We can't have enough of this kind of conference. It is very motivating for our ESG community and quite promising for reaching future clients. It runs for two full days, yet both the sessions and the breaks are highly productive. I keep getting new ideas for future conference speakers."
ESG manager in a large regional company, Conference presenter: "Sharing our experiences with sustainability initiatives over the years was highly rewarding, both personally and professionally."
Conference organisers: "A huge amount of work, but all worth it. We are happy that we have recordings of all the sessions. People actually do watch them."

2. ChangeMakers Conference

The ChangeMakers Conference, held at end of September 2025, was a full-day programme focused on leadership, innovation, and systemic change in the context of sustainability and digital transformation. Designed for entrepreneurs, executives, policymakers, and change agents, the event emphasized forward-looking perspectives on economic and social transformation. The programme featured keynote speeches, inspirational talks, and panel discussions addressing innovation ecosystems, sustainable growth, and leadership competencies. Particular attention was given to the role of individuals and organizations as drivers of change in uncertain and disruptive environments. The event aimed to inspire action-oriented leadership and cross-sector collaboration for long-term societal impact. Two interactive ESG workshops were offered in parallel to the plenary programme (ChangeMakers, 2025). Yet, from the first panel, the programme began to run late, which disrupted the flow and made it difficult to participate in the interactive workshops, apparently reducing the number of workshop attendees. This organisational issue likely contributed to lower content absorption among the participants, as suggested in the testimonials below. Nevertheless, the networking opportunities are always welcome among the participants.

Entrepreneur from Istria, conference participant: "We paid the fee and travelled here this morning because we are interested in the topics presented. Poor time management was a major issue. The first panel was introductory,

had too many panellists, and went on for too long. I would have preferred more practical content."

Entrepreneur from Zagreb, conference participant: "The workshops were very informative and at the same time gave us a chance to meet other entrepreneurs facing similar problems. We lack more opportunities to network, exchange experiences, and meet new people. Not to mention that public administration most of the time forgets that there are so many SMEs in Croatia. Sometimes, it just makes my day to hear that other entrepreneurs have the same troubles."

3. Roundtable: "Can Croatia Achieve Sustainable Tourism?"

The roundtable "Can Croatia Achieve Sustainable Tourism?", held on 7 October 2025, addressed sustainability challenges in the tourism sector. The event targeted policymakers, academics, tourism professionals, and corporate managers. Its programme consisted of an introductory expert presentation, a keynote speech delivered by the Minister of Tourism, and moderated panel discussions. The key topics included sustainable tourism governance, destination management, ESG integration in tourism, and balancing economic growth with environmental and social responsibility. The roundtables aimed to foster dialogue between academia, public institutions, and industry stakeholders to support evidence-based policymaking (HDKUM, 2025). The convenors and participants expressed high levels of satisfaction with the Minister's speech, noting that it demonstrated a strong understanding of ESG specificities in tourism, as well as the long-term trends and implications for the sector. Such mutual understanding is often one of the most deficient elements in discussions between the business community and political incumbents.

ESG manager from a medium-sized hospitality enterprise, Event participant: "Many of us were genuinely encouraged to hear a well-informed minister with a business-oriented mindset who is not afraid to confront major challenges. I gained more insight than expected, which was refreshing. Learning by doing, as we are often forced to do, can be exhausting."

University professor, Event participant: "I did not expect to see so many new faces. The topic and the choice of speakers were clearly timely organized and well targeted. Opportunities for multi-stakeholder discussions like this are still too rare."

4. 'ReStart! Let's Support Sustainability' Conference

The 'ReStart!' event, organized at the beginning of September 2025, was designed to support entrepreneurship and innovation, with a strong focus on sus-

tainability. The target audience included startups, SMEs, investors, accelerators, and business-support organizations. The programme combined pitch competitions, expert panels, workshops, and networking sessions. Key content areas included sustainable business models, access to finance, innovation scaling, and ESG-driven entrepreneurship. The main objective of the event was to accelerate sustainable ventures and connect entrepreneurs with investors and institutional partners (CCC, 2025b). This Conference was the largest one, with more than 700 participants attending the programme lasting two and a half days, and attendance has been increasing every year. In addition to high-quality international and domestic speakers and excellent production, the event can best be described as "walking the talk." All conference goodies were sustainability-driven products, catering was focused on locally grown and produced food, as well as local comfort food, and the menu was designed to prevent food waste. Moreover, all leftovers were packed and offered to the participants on their way out, and no single-use plastic was used. In the visitors' area, public health campaigns were promoted, offering a clear value for the participants, such as screening for eye hypertension, a condition that is often underrated without good reason.

> Entrepreneur from Dalmatia, conference participant: "I love every aspect of this conference. It finally feels good to be a member of the Chamber and to receive training and conference participation through the ESG centre. I feel motivated when I hear about the best performers and their stories."
> International speaker, conference presenter: "Fantastic audience. It is my first time here, and I did not expect them to be so responsive and interested in international best practices. I am impressed by the organisation, content, and dynamics."
> Legal counsel from a large Croatian company, conference participant: "I had much lower expectations and did not expect to stay this long and really listen to the roundtables and presentations."
> Entrepreneur from Zagreb, conference participant: "Connecting profitability and sustainability – that is what we need. Developing or reshaping that kind of mindset in our businesses is key."

5. Erste Bank Croatia: Public Lecture Series: "*A focus on ESG"*, ESG Academy and Transformator Programme

The "A focus on ESG" lecture series, organised by Erste Bank Croatia throughout 2025, consisted of regular public lectures aimed at raising ESG awareness among a broader audience, including SMEs, professionals, students,

and the general public. The programme was designed as an open educational platform, combining expert lectures, panel discussions, and interactive Q&A sessions. Key topics included ESG fundamentals, sustainable finance, climate risk, social responsibility, and the regulatory landscape affecting businesses. The lectures featured contributions from academics, industry experts, financial professionals, and policymakers, fostering cross-sector dialogue. The primary objective of the series was to build ESG literacy, support informed decision-making, and encourage wider societal engagement with sustainability and responsible business practices (Erste Bank Croatia, 2025).

In addition to those lecture series, Erste Bank is a partner and/or supporter of several ESG-related initiatives and programmes such as the ESG Academy and the Transformator Programme, both delivered in 2025, focused on education and capacity building for sustainable business transformation. Targeted primarily at SMEs, managers, and professionals, the programme offered structured training modules, practical tools, and expert mentoring. Core programme topics included ESG fundamentals, sustainability strategy, regulatory requirements, and implementation practices. The initiative aimed to strengthen managerial competencies and enable companies to integrate ESG principles into their business models. By combining education with practical application, the programme supported long-term organizational transformation (Erste Bank Croatia, 2025). Entrepreneurs, social entrepreneurs and representatives of social cooperatives place a high value on the support they receive from Erste Bank. At the same time, Erste is widely perceived as a front-runner in the financial sector in all aspects of ESG support, and has received the most ESG-related awards among the financial institutions.

> Entrepreneur from Zagreb, panellist: "I would never have expected our story to be featured in this lecture series. I am very honoured and grateful for the opportunity to meet like-minded businesspeople, NGO representatives, public servants and academics who show genuine interest in what we are doing and the practices we have developed. Wow!"
> Entrepreneur from the Northern Adriatic coast, participant in the training programmes: "I am a strong ESG advocate and practitioner. The programmes provided by Erste helped me enormously in my early-stage efforts. Now, there is an inflation of ESG initiatives and programmes; I can't attend them all, and it is not always easy to choose which ones justify spending a day or two away from work and home."

A systematic comparison of the key features of the analysed events, accompanied by the key findings from those events, is presented in Table 2.

Table 2. Overview of the analysed ESG events that took place in Croatia in 2025

Event	Target group	ESG depth	Capacity-building intensity	Stake-holder integration	Perceived usefulness (from testimonials)
HRIO Conference and Croatian Sustainability Index Awards	Corporate leaders, ESG professionals, policymakers, academics, students	High; ESG integration, governance, reporting, EU alignment	High; knowledge exchange and inspiration with some practical elements	Very high; business, public sector, academia, students, networking	Very positive; motivating, productive sessions, strong networking, valuable for students and practitioners
ChangeMakers Conference	Entrepreneurs, executives, policymakers, change agents	Medium; broad sustainability and innovation focus	Mixed; intended to be interactive, but organisational delays reduced effectiveness	Medium; networking valued, but less structured	Mixed; networking appreciated, but poor time management reduced workshop participation and content absorption
Roundtable: Can Croatia Achieve Sustainable Tourism?	Policymakers, tourism professionals, academics, corporate managers	High; sector-specific ESG, governance, destination management	Low to medium; discussion-oriented rather than training-based	High; academia, public institutions, and industry brought together	Positive; strong relevance, informed ministerial contribution, rare multi-stakeholder dialogue
ReStart! Let's Support Sustainability Conference	Startups, SMEs, investors, accelerators, business-support organisations	High; sustainable business models, access to finance, ESG-driven entrepreneurship	High; practical and action-oriented	Very high; entrepreneurs, managers, public administration representatives, CCC employees	Very positive; strong motivation, high-quality organisation, practical relevance, visible sustainability in event delivery
Erste Bank Croatia: A focus on ESG lecture series, ESG Academy and Transformator Programme	SMEs, managers, professionals, students, wider public	Very high; fundamentals, strategy, regulation, implementation	Very high; continuous, structured, practice-oriented	High; finance, business, academia, public sector, NGOs	Very positive overall; practical value and early-stage support highly appreciated.

Source: Author's compilation based on the informal conversations conducted

4. CONCLUSION

In large firms, ESG practices are typically characterized by highly formalized strategies, dedicated organizational units, structured reporting systems and certifications, a predominantly global orientation, and strong reputational and regulatory pressures. In contrast, ESG practices in SMEs are largely embedded in informal, day-to-day business activities shaped primarily by the owner-manager, communicated mainly through verbal interactions rather than standardized reporting mechanisms, and oriented toward local stakeholders and communities. Hence, SMEs tend to engage in ESG-related practices primarily on the basis of (founder's) values and competitive pressures, reflecting the close social embeddedness of owner-managers within their local business ecosystems.

The evidence presented in this paper largely confirms the existing research that portrays SMEs as simultaneously being central for the economy and being structurally disadvantaged actors in the sustainability transition: they carry substantial aggregate environmental and social impacts, yet face resource constraints, (indirect) regulatory ambiguity and fragmented support landscapes (Lisi et al., 2024; Zaman et al., 2025; Kannan & Gambetta, 2025; Caputo et al., 2024). At the same time, the Croatian cases illustrate how soft skills, entrepreneurial values and local embeddedness – emphasised in the literature as key drivers of SME resilience and sustainability orientation (Stubbs et al., 2023; Damiano & Valenza, 2024; Vučković & Čučković, 2024) – can be activated and amplified through well-designed conferences, lectures, one-off workshops and training programmes. In line with Kinderman's (2020) argument about the pivotal role of business associations as intermediaries, the Croatian Chamber of Economy, Croatian Employers' Association and Business Council for Sustainable Development effectively operate as 'ESG hubs' that translate evolving external pressures into practice-relevant knowledge, foster peer learning and offer visibility to frontrunners in the micro, small, medium and large segments of business.

Hence, this exploratory analysis of ESG-related events in Croatia offers several conceptual insights for SME-oriented ESG capacity building. First, the partially overlapping initiatives suggest a saturation effect, indicating that coordination and differentiation of ESG support may be as important as their wide availability. Second, the findings show how local embeddedness and soft skills can be activated and strengthened through events that enable peer learning, recognition and cross-sector networking. Third, the central role of business associations and financial institutions as convenors positions them as meso-level intermediaries that translate abstract regulatory pressures into practice-relevant guidance for SMEs, with potential relevance beyond the Croatian context.

Thus, from a policy perspective, the findings suggest that expanding the quantity of ESG-related initiatives is insufficient without improved coordination and differentiation. SMEs perceive a saturation of ESG topics and consequently face increasing opportunity costs when selecting among overlapping events and programmes, highlighting the need for clearer pathways, modular training structures, and better alignment between public institutions, business associations, and financial actors. Targeted capacity-building initiatives should, therefore, prioritise practical relevance, sector-specific applications, and learning trajectories that reflect SMEs' heterogeneous starting points.

Nevertheless, some limitations of this exploratory research design study shall be acknowledged: the opportunistic sampling limits generalisability beyond ESG-related events, the lack of standardised questions reduces comparability, brief interactions constrain data depth, reflexive field notes influence the researcher's subjectivity, and limited follow-up opportunities prevent deeper exploration. However, the findings offer context-rich insights for the generation of hypotheses rather than generalisable claims. Finally, further research could provide an in-depth comparison of similar ESG trainings and initiatives across EU Member States, explore online and blended formats for reaching SMEs, and examine more systematically how participation in such initiatives translates into measurable changes in SME practices and outcomes over time.

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CIRCURAL ECONOMY
and WATER ECONOMICS

CIRCULAR ECONOMY STRATEGIES AND THEIR IMPACT ON CONSUMER TRUST AND LOYALTY

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This paper examines the role of selected circular economy (CE) strategies in shaping consumer trust and brand loyalty within contemporary marketing practice. Although CE principles such as recycling, material reuse, and environmental responsibility are being increasingly incorporated into business operations, their influence on consumer-related marketing outcomes remains insufficiently examined in the academic literature. The study focuses on two CE-related brand cues, namely the perceived use of recycled materials and perceived brand authenticity, and investigates their predictive relationship with consumer trust. Consumer trust is further examined as a predictor of brand loyalty, in line with the proposition that trust plays a central role in the development of enduring consumer–brand relationships. The research is based on a quantitative design and draws on data collected through a structured online survey administered to 675 consumers in Croatia. All constructs were measured using validated scales on a five-point Likert scale. The empirical analysis included descriptive statistics, reliability testing, correlation analysis, and regression analysis. The findings indicate that the perceived use of recycled materials has a statistically significant, although modest, positive relationship with consumer trust. Consumer trust, in turn, shows a statistically significant and stronger positive relationship with brand loyalty. By contrast, perceived brand authenticity does not demonstrate a significant direct relationship with consumer trust within this sample. These findings suggest that concrete and visible sustainability practices are more effec-

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tive in strengthening consumer trust than symbolic or declarative brand signals alone. The observed correlation patterns further reinforce the importance of credible and demonstrable CE-related practices in the formation of trust and loyalty. From a managerial standpoint, the study offers practical implications for firms seeking to strengthen consumer relationships through sustainability-oriented marketing. Brands that incorporate observable circular practices, particularly the use of recycled materials, may be better positioned to build trust and encourage longer-term consumer loyalty. From an academic perspective, the study contributes to the growing literature on circular economy marketing by offering empirical evidence on the relationships among CE-oriented practices, consumer trust, and brand loyalty. The findings support the view that sustainability can function not only as an environmental or regulatory imperative, but also as a meaningful strategic basis for stronger and more durable consumer–brand relationships.

Keywords: *Circular economy, brand authenticity, recycled materials, consumer trust, brand loyalty*

JEL classification: *M31, Q56, D12, L21*

1. INTRODUCTION

The circular economy (CE), emphasizing sustainable practices such as waste reduction, recycling, and material reuse, has gained significant momentum in the business sector in the recent years (Chamberlin and Boks, 2018; Ranta et al., 2018; Geissdoerfer et al., 2017; Korhonen et al., 2016). This shift is largely driven by rising consumer awareness of environmental issues and an increasing demand for sustainable products and services, a trend widely documented in recent sustainability and consumer behaviour research (White et al., 2019; Testa et al., 2020). As a result, companies are increasingly integrating CE principles into their core strategies not only in operations and production, but also within the marketing approaches, in order to meet the evolving expectations of environmentally conscious consumers (García-Rosell and Moisander, 2007; Bartolacci et al., 2019; Camacho-Otero et al., 2018). While numerous businesses have embraced initiatives such as eliminating single use plastics or launching eco-certified product lines, the specific role of CE-oriented marketing strategies in building consumer trust and sustaining long term brand loyalty remains insufficiently addressed in academic literature. Although previous

research has explored sustainability communication more broadly, there is still limited understanding of how concrete CE practices, such as the incorporation of recycled materials or the articulation of authentic brand narratives, contribute to trusted brand relationships and repeat purchasing behaviours (Kusa and Piatrov, 2020; Magnier and Schoormans, 2015; Steenis et al., 2017). This study addresses that gap by focusing on two CE-based marketing strategies: the use of recycled materials and brand authenticity. It examines their influence on the formation of consumer trust and investigates the role of trust in the development of brand loyalty. The research applies a quantitative approach supported by a comprehensive literature review and empirical analysis derived from a structured consumer survey conducted in Croatia. Unlike earlier studies that focused primarily on brand reputation or perceived sustainability, this study narrows its focus to trust-based brand dynamics. It aims to understand how tangible and value-driven sustainability practices shape consumer–brand relationships within the framework of circular economy marketing. As companies seek to align themselves with sustainability goals and differentiate their brand offerings in competitive markets, the strategic value of CE-aligned marketing becomes increasingly evident (Henninger et al., 2022). However, meaningful consumer engagement requires not only the adoption of circular practices, but also a deeper understanding of which sustainability signals are most effective in fostering trust and loyalty. This study contributes to that understanding by identifying the concrete strategies and values that influence consumer trust and brand loyalty, offering practical guidance for marketing professionals and laying the groundwork for future academic inquiry into sustainable branding within the CE paradigm.

2. THEORETICAL BACKGROUND

The prevailing economic paradigm, traditionally rooted in the linear "take-use-dispose" model, has come under increasing scrutiny due to its inherently unsustainable approach to resource management. This critical perspective has paved the way for the emergence and adoption of the circular economy (CE), which advocates for restorative and regenerative systems aimed at extending the lifecycle of products and materials. The conceptual foundations of CE can be traced to pioneering works such as Boulding's (1966) vision of "Spaceship Earth", which framed the planet as a closed system with finite resources, necessitating an economic model grounded in long term sustainability. Pearce and Turner (1990) further developed this line of reasoning by critiquing the

limitations of the linear model and promoting a shift toward closed loop systems. At the core of the CE lies the General Systems Theory (Bertalanffy, 1968), which provides a theoretical framework for analysing the interdependencies among economic, environmental, and social systems. This systems thinking approach enables a comprehensive re-evaluation of production and consumption patterns, challenging traditional business models that overlook the cumulative effects of resource depletion and waste accumulation. The Ellen MacArthur Foundation (2013) defines the CE as "an industrial system that is restorative or regenerative by intention and design", emphasizing principles such as eliminating the end-of-life concept, promoting renewable energy, and eliminating toxic substances that inhibit reuse. More recent academic contributions reinforce these foundations by highlighting CE as a transformative paradigm that integrates environmental stewardship with long term economic competitiveness (Geissdoerfer et al., 2017; Korhonen et al., 2016; Ghisellini et al., 2016). The CE thus aims to eliminate waste through superior design of materials, products, systems, and business models. The operationalization of CE is most commonly articulated through the "R" strategies. Initially conceptualized as the 3Rs (reduce, reuse, recycle), the framework has evolved to include additional strategies such as remanufacture, repair, refurbish, repurpose and recover (Kirchherr et al., 2017). These approaches collectively aim to maximize resource utility, extend product lifespans, and minimize waste, effectively challenging planned obsolescence and shifting business priorities toward sustainability. Further empirical research shows that the expansion of "R" strategies contributes to both environmental performance and market differentiation (Bocken et al., 2016; van Loon et al., 2020). Antikainen et al. (2015) highlighted that such strategies yield not only ecological benefits, but also measurable economic gains, such as cost reductions, improved operational efficiency, and enhanced resilience in the face of market fluctuations. CE implementation occurs on multiple levels: macro (national regulations and policy instruments), meso (inter-firm collaborations and supply chains), and micro (firm-level practices and consumer interactions). Bourguignon (2016) and Kumar and Carolin (2019) noted that CE not only enhances compliance with policy frameworks like the European Green Deal and the Corporate Sustainability Reporting Directive, but also contributes to business continuity and resilience. Complementary studies have emphasized the importance of system-level transitions supported by policy incentives, digital innovation, and cross sectoral partnerships (De Angelis et al., 2018). This systemic integration often requires firms to shift from product-centric to service-oriented business models, enabling long-term product stewardship and end-of-life recoverability.

In the marketing domain, the CE opens new avenues for value co-creation. Consumers play a vital role as active participants in circular models through recycling, product sharing, and contributing to the extension of product lifecycles. Studies by Jaakkola and Hakanen (2013) and Ghisellini et al. (2016) have demonstrated that consumer involvement in coproduction processes significantly enhances the success of circular strategies. Research on consumer acceptance of circular products further highlights that willingness to engage depends heavily on perceived value, environmental consciousness, and trust in the brand's sustainability claims (Testa et al., 2020; Kulli et al., 2023). Moreover, embedding CE principles into marketing, especially through the use of recycled materials, transparent and authentic messaging, and a focus on sustainability driven narratives has proven to be effective in fostering consumer trust and loyalty (Chamberlin and Boks, 2018; Magnier and Schoormans, 2015; Steenis et al., 2017; Henninger et al., 2022). Taken together, theoretical and empirical evidence suggests that the shift from a linear to a circular economy constitutes more than an environmental necessity; it represents a structural transformation of economic logic with profound implications for sustainable growth. By embedding CE into both strategic vision and everyday operations, firms are better positioned to manage resource constraints, meet regulatory demands, and respond to the values of environmentally aware consumers. The following sections of this paper build on this theoretical foundation to empirically assess the extent to which CE-aligned marketing practices, particularly the use of recycled materials and brand authenticity, contribute to consumer trust and brand loyalty.

2.1. CONSUMER TRUST IN CIRCULAR ECONOMY BRANDING

Consumer trust represents a central relational construct in marketing because it reduces perceived uncertainty and supports the development of stable and enduring relationships between consumers and brands. Within relationship marketing theory, trust is regarded as one of the key conditions of successful long-term exchange (Morgan and Hunt, 1994). In branding research, it is more specifically understood as the consumer's willingness to rely on a brand on the basis of its perceived credibility, reliability and integrity (Delgado-Ballester and Munuera-Alemán, 2001; Delgado-Ballester et al., 2003). Its relevance becomes even more pronounced in sustainability-related markets, where consumers are frequently exposed to information asymmetry and are often unable to directly verify whether environmental claims genuinely reflect organisa-

tional practices. Under such conditions, trust depends not only on what brands communicate, but also on whether sustainability-related claims are perceived as credible, consistent and supported by concrete evidence (Pivato et al., 2008). Trust becomes particularly important in circular economy branding. As firms increasingly communicate recycling, material reuse, product longevity, and responsible resource management as part of their market positioning, consumers are required to assess whether such signals reflect substantive organisational practices or merely symbolic sustainability communication. Prior research suggests that the effectiveness of circular economy-related communication depends strongly on the perceived credibility and intelligibility of the message conveyed to consumers. Chamberlin and Boks (2018) argued that circular economy marketing requires communication approaches capable of translating circular principles into meaningful consumer value propositions. More recently, Mostaghel et al. (2023) emphasized that the transition towards circular economy business models requires a reconsideration of traditional marketing theory, particularly in relation to the communication of value, credibility and sustainability-related signals. Similarly, Paiva (2025) highlighted transparency, traceability, and protection against greenwashing as essential conditions for the effectiveness of circular economy marketing. Testa et al. (2020) further showed that consumer engagement with circular practices depends substantially on how relevant and trustworthy such practices are perceived to be. In addition, visible and tangible sustainability cues embedded in products or packaging may strengthen favourable consumer evaluations because they make environmental responsibility easier to infer and assess (Magnier and Schoormans, 2015; Steenis et al., 2017). Consumer trust in circular economy branding may, therefore, be understood as a consumer judgement based on the perceived alignment between a brand's circularity claims and the visible, credible, and consistent implementation of its sustainable practices.

2.2. BRAND LOYALTY IN CIRCULAR ECONOMY BRANDING

Brand loyalty is widely regarded as one of the most important outcomes of successful consumer–brand relationships because it reflects not only repeated purchase intentions, but also a more enduring attitudinal commitment to the brand. In branding literature, loyalty is commonly associated with a consumer's willingness to continue choosing the same brand over time, to resist competitive alternatives and to maintain a stable preference based on positive prior experience and relational confidence. In sustainability-oriented markets,

loyalty acquires additional significance because consumers increasingly evaluate brands not only in terms of product quality and functional performance, but also in relation to environmental and ethical expectations. Recent research has, likewise, shown that customer loyalty remains a central driver of broader brand outcomes, especially when sustainability-oriented practices strengthen positive consumer evaluations and long-term brand attachment. The relationship between trust and loyalty has been consistently supported in prior research. Delgado-Ballester and Munuera-Alemán (2001) showed that brand trust plays a decisive role in the development of consumer loyalty, while Sirdeshmukh et al. (2002) demonstrated that trust contributes to relational value and long-term commitment. More recent studies have reinforced this view by confirming the close interdependence of trust and loyalty in the development of long-term brand relationships. Cardoso et al. (2022) showed that trust and loyalty remain central to the maintenance of durable brand relationships, while Mostaghel et al. (2023) argued that circular economy-oriented marketing requires firms to rethink how value is created and communicated in ways that sustain stronger consumer relationships. Sah et al. (2025) further indicated that circular economy-related quality can strengthen customer loyalty and broader brand outcomes. Applied to the circular economy, this suggests that loyalty is unlikely to emerge solely from declarative sustainability positioning or symbolic environmental claims. Rather, it is more likely to develop when consumers perceive circular practices as credible, relevant, and consistent with actual brand behaviour. In this sense, circular economy strategies may strengthen brand loyalty not only through favourable evaluations of sustainability, but also through the development of trust as a key psychological mechanism linking perceived circular practices with enduring consumer commitment.

3. RESEARCH MODEL AND HYPOTHESES

The research model of this study is grounded in relational marketing theory, which identifies trust as a central mechanism in the development of long-term consumer–brand relationships (Morgan and Hunt, 1994; Sirdeshmukh et al., 2002). Prior research suggests that sustainability-related cues, such as the use of recycled materials and the communication of authentic brand values, can shape how consumers evaluate a brand's credibility, responsibility and integrity. In circular economy (CE) marketing, such cues may strengthen consumer trust by signalling a genuine and transparent commitment to sustainable practices (Chamberlin and Boks, 2018; Testa et al., 2020; Mostaghel et

al., 2023). On this basis, the proposed research model identifies the perceived use of recycled materials and perceived brand authenticity as antecedents of consumer trust. Recycled materials are understood not only as functional inputs, but also as visible indicators of environmental responsibility, while brand authenticity refers to the alignment between brand communication and actual brand behaviour (Morhart et al., 2015; Fritz et al., 2017). Consumer trust is further positioned as a predictor of brand loyalty, in line with prior research showing that trust plays an important role in shaping consumer commitment and longer-term behavioural intentions (Delgado-Ballester and Munuera-Alemán, 2001; Chaudhuri and Holbrook, 2001). Accordingly, the model proposes three direct relationships: the effect of perceived use of recycled materials on consumer trust, the effect of perceived brand authenticity on consumer trust, and the effect of consumer trust on brand loyalty. The hypothesized relationships among the examined variables are presented in *Table 1.*

Table 1. Hypothesized relationships among the examined variables

Hypothesis	Description
H1	Perceived use of recycled materials is a positive and statistically significant predictor of consumer trust.
H2	Perceived brand authenticity is a positive and statistically significant predictor of consumer trust.
H3	Consumer trust is a positive and statistically significant predictor of brand loyalty.

Source: Author

4. METHODOLOGY

This study employs a quantitative research design aimed at empirically examining the relationships between selected circular economy (CE) strategies, consumer trust, and brand loyalty. In line with the proposed research model, perceived use of recycled materials and perceived brand authenticity are treated as antecedents of consumer trust, while consumer trust is positioned as a predictor of brand loyalty. The study, therefore, focuses on the extent to which these CE-related marketing cues are associated with the formation of consumer trust and whether trust, in turn, contributes to stronger brand loyalty. In order to ensure construct validity and comparability, the measurement instrument was developed using previously validated scales. Items measuring the perceived use of recycled materials were adapted from Bovea et al. (2018)

and Ostermann et al. (2021), whereas brand authenticity was operationalized based on Morhart et al. (2015). The consumer trust scale drew on the contributions by Delgado-Ballester et al. (2003) and Pivato et al. (2008), while brand loyalty was assessed following the approaches of Chaudhuri and Holbrook (2001) and Gommans et al. (2001). The scale development process also followed established methodological guidelines in marketing research (Churchill, 1979; DeVellis, 2017), with the aim of ensuring conceptual consistency across constructs and preserving comparability with previous studies in the fields of branding, consumer behaviour, and sustainability-oriented marketing. All items were measured on a five-point Likert scale ranging from "strongly disagree" to "strongly agree". The data were collected during February and March 2025, using a structured online questionnaire distributed through social media platforms and direct digital outreach. Convenience sampling was applied, consistent with common practice in consumer behaviour research (Bryman, 2016), yielding a total of 675 valid responses from adult consumers in Croatia. The use of an online questionnaire enabled efficient access to respondents and facilitated the collection of data relevant to contemporary consumer perceptions of circular economy-related brand practices. Data analysis was conducted using SPSS v23 software. In order to evaluate the proposed relationships, a multi-step analytical procedure was applied. First, descriptive statistics were calculated to provide an overview of the central tendencies and distributions of all study variables. Internal consistency reliability of the constructs was assessed using Cronbach's alpha, following the recommended thresholds in marketing and social science research (Nunnally and Bernstein, 1994). Given that the study relies on multi-item scales adapted from prior research, this step was necessary in order to confirm the reliability of the measurement instrument within the present sample. Normality tests, specifically the Kolmogorov–Smirnov and Shapiro–Wilk tests, indicated significant deviations from normal distribution across the examined variables. This finding justified the use of non-parametric statistical techniques in the subsequent stages of analysis. Kendall's tau-b correlation coefficients were, therefore, calculated to examine the bivariate associations among the perceived use of recycled materials, brand authenticity, consumer trust, and brand loyalty, consistent with the methodological recommendations for ordinal and non-normally distributed data (Field, 2018). This procedure enabled an initial assessment of the direction and strength of the relationships among the key constructs included in the research model. Regression analysis was then performed to test the hypothesized relationships and assess the predictive role of the examined variables. More specifically, the analysis examined the effect of perceived use of recycled

materials on consumer trust, the effect of perceived brand authenticity on consumer trust, and the effect of consumer trust on brand loyalty. In this way, the study evaluated whether the proposed antecedents significantly contribute to trust formation and whether trust significantly predicts loyalty. The regression procedure also made it possible to assess the strength and statistical significance of each hypothesized relationship, thereby providing an empirical basis for the evaluation of the proposed research model. The applied methodological approach offers a statistically grounded basis for examining the role of CE-oriented marketing strategies in shaping consumer trust and brand loyalty. At the same time, it ensures consistency between the theoretical framework, the proposed hypotheses, and the empirical procedures used to test them.

5. RESULTS

Empirical analysis was conducted on a final sample of 675 fully completed responses to an online survey focusing on sustainable brand practices within the framework of the circular economy. Respondents evaluated a series of statements related to four constructs: perceived use of recycled materials, brand authenticity, consumer trust, and brand loyalty. All statements were measured on a five-point Likert scale ranging from "strongly disagree" to "strongly agree". In order to provide an overview of general response patterns and the distribution of values, descriptive statistics were calculated. The results indicate that all examined constructs recorded moderately high average values, suggesting that the respondents expressed relatively favourable attitudes towards sustainability-oriented brand practices. Trust was observed to have the highest mean value (M = 4.24), followed by brand loyalty (M = 4.08), perceived use of recycled materials (M = 2.99), and brand authenticity (M = 2.29). In addition, the internal consistency of each construct was evaluated using Cronbach's alpha coefficient. All constructs exceeded the recommended threshold of 0.8, indicating high reliability of the applied measurement scales. Specifically, trust recorded $\alpha = 0.805$, recycled materials $\alpha = 0.919$, authenticity $\alpha = 0.824$, and loyalty $\alpha = 0.901$ *(Table 2)*.

Table 2. Descriptive statistics and reliability

Construct	Mean	SD	Min	Max	Cronbach's α
RECYCLED MATERIALS	2.99	0.55	1.00	5.00	0.919
BRAND AUTHENTICITY	2.29	0.59	1.00	4.80	0.824
TRUST	4.24	0.60	1.20	5.00	0.805
LOYALTY	4.08	0.65	1.60	5.00	0.901

Source: Author's calculation

Normality tests, specifically the Kolmogorov–Smirnov and Shapiro–Wilk tests, revealed that the distributions of recycled materials, brand authenticity, trust, and loyalty significantly deviated from normality ($p < 0.01$ for all variables) *(Table 3)*. Consequently, non-parametric statistical methods were employed in the subsequent stages of analysis.

Table 3. Tests of distribution normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Stat.	df	p	Stat.	df	p
RECYCLED MATERIALS	.114	688	.000	.978	688	.000
BRAND AUTHENTICITY	.092	688	.000	.978	688	.000
TRUST	.161	688	.000	.897	688	.000
LOYALTY	.096	688	.000	.951	688	.000
a. Lilliefors Significance Correction						

Source: Author's calculation

Kendall's tau-b correlation analysis was conducted to assess the relationships among the examined constructs *(Table 4)*. The results indicate partial associations among the variables. Perceived use of recycled materials was positively related to consumer trust ($\tau b = 0.18$, $p < 0.01$). By contrast, brand authenticity did not show a significant relationship with trust ($\tau b = 0.05$). The relationship between trust and brand loyalty was positive and statistically significant ($\tau b = 0.39$, $p < 0.01$). Additional analyses revealed significant positive associations between perceived use of recycled materials and brand loyalty ($\tau b = 0.18$, $p < 0.01$), as well as between brand authenticity and brand loyalty ($\tau b = 0.13$, $p < 0.01$). These findings suggest that perceptions of recycled materials are associated with higher levels of consumer trust and loyalty, whereas perceived brand authenticity is linked to loyalty, but not directly to trust within this sample.

Table 4. Kendall's tau-b Correlation Matrix

	RECYCLED MATERIALS	BRAND AUTHENTICITY	TRUST	LOYALTY
RECYCLED MATERIALS	1.00	-.05	.18**	0.18**
BRAND AUTHENTICITY	-.05	1.00	.05	.13**
TRUST	.18**	.05	1.00	.39**
LOYALTY	.18**	.13**	.39**	1.00
*Note: **$p <$	*0.01*			

Source: Author's calculation

The *hypothesis H1* was tested using regression analysis. The model summary revealed a statistically significant but weak positive relationship between the perception of recycled materials and consumer trust ($R = 0.229$, $R^2 = 0.053$, $p < 0.01$). This indicates that 5.3% of the variance in consumer trust can be explained by the perceived use of recycled materials. The analysis yielded a standard error of the estimate of 0.537, suggesting moderate variability around the regression line. The change statistics, with an F value of 37.417 and a significance level of $p < 0.01$, confirm the statistical significance of the model, indicating that perceptions of recycled materials significantly contribute to the level of consumer trust *(Table 5)*.

Table 5. Model summary

Mod	R	R^2	A R^2	SE	Change Statistics				
					EC	FC	df1	df2	P FC
1	.229[a]	.053	.051	.53678	.053	37.4	1	673	.000
a. Predictors: (Constant), Recycled materials									

Source: Author's calculation

The ANOVA table assesses the overall significance of the regression model examining the effect of perceived use of recycled materials on consumer trust. The analysis indicates that the model is statistically significant, with an F value of 37.417 ($p < 0.01$). Specifically, the regression explains a significant portion of the variance in consumer trust, as evidenced by the sum of squares for regression (10.781) compared to residuals (193.915). The significance level confirms that perceptions of recycled materials are a significant predictor of consumer

trust, supporting the hypothesis that perceived use of recycled materials has a positive effect on consumer trust *(Table 6)*.

Table 6. ANOVA table

Model		SS	df	MS	F	p
1	Regression	10.781	1	10.781	37.417	.000[a]
	Residual	193.915	673	.288		
	Total	204.696	674			
a. Predictors: (Constant), Recycled materials						

Source: Author's calculation

The table of coefficients provides further support for the hypothesis. The unstandardized coefficient ($B = 0.210$, $p < 0.01$) indicates that for each one unit increase in perceived use of recycled materials, consumer trust increases by approximately 0.21 units, holding other variables constant. The standardized coefficient ($\beta = 0.229$) suggests a small but significant positive effect of recycled materials on consumer trust. The t-value of 6.117 and the corresponding p-value (< 0.01) confirm that this effect is statistically significant. Collinearity diagnostics show tolerance and VIF values of 1.000, indicating no multicollinearity issues *(Table 7)*. Overall, these results provide robust evidence that perceived use of recycled materials positively influences consumer trust, supporting the hypothesis.

Table 7. Regression coefficients

Model		UC		SC	t	p	Collinearity Stat.	
		B	SE	Beta			Tol.	VIF
1	(Constant)	0.210	.147		14.28	.000		
	Recycled materials	.21	.03	.23	6.12	.00	1.0	1.0
Dependent Variable: Trust								

Source: Author's calculation

The collinearity diagnostics table indicates that multicollinearity is not a concern in this regression model. The eigenvalues show a high value (1.990) for the first dimension and a very low value (0.010) for the second. The condition index is 14.181, which is below the commonly accepted threshold of 30, suggesting no severe multicollinearity issues *(Table 8)*. The variance proportions show that the constant and the predictor variable load on separate dimensions, with no double loading that would indicate multicollinearity. Specifical-

ly, the constant contributes only to the first dimension, while perceived use of recycled materials contributes only to the second. These diagnostics confirm that multicollinearity does not affect the validity of the regression coefficients, supporting the robustness of the findings that perceived use of recycled materials has a significant positive effect on consumer trust.

Table 8. Collinearity Diagnostics

Model	Dim.	Eig.	CI	VP	
				(Constant)	RM
1	1	1.990	1.000	.00	.00
	2	.010	14.181	1.00	1.00
Dependent Variable: Trust					

Source: Author's calculation

The hypothesis H2 was tested using regression analysis. The model summary indicates that the relationship between perceived brand authenticity and consumer trust is not statistically significant ($R = 0.037$, $R^2 = 0.001$, adjusted $R^2 = 0.000$, $F(1, 673) = 0.916$, $p > 0.05$). This suggests that perceived brand authenticity explains only a negligible proportion of the variance in consumer trust. The model, therefore, does not provide evidence that brand authenticity significantly contributes to trust formation in this sample. Accordingly, these findings do not support H2 *(Table 9)*.

Table 9. Model summary

Mod	R	R^2	A R^2	SE	Change Statistics				
					EC	FC	df1	df2	P FC
1	.037[a]	.001	.000	.59710	.001	.916	1	673	.339
Predictors: (Constant), Brand authenticity									

Source: Author's calculation

The ANOVA results confirm that the regression model examining the effect of perceived brand authenticity on consumer trust is not statistically significant ($F(1, 673) = 0.916$, $p > 0.05$). The sum of squares for regression (0.327) is very small relative to the residual sum of squares (239.940), indicating minimal explained variance. This confirms that the model does not provide a statistically significant basis for predicting consumer trust from perceived brand authenticity (Table 10).

Table 10. ANOVA table

Model		SS	df	MS	F	p
1	Regression	.327	1	.327	.916	.339[a]
	Residual	239.940	673	.357		
	Total	240.267	674			
Dependent Variable: Trust Predictors: (Constant), Brand authenticity						

Source: Author's calculation

The hypothesis H3 was tested using regression analysis. The model summary indicates a moderate positive predictive relationship between consumer trust and brand loyalty. The R-squared value of 0.246 suggests that approximately 24.6% of the variance in brand loyalty is explained by consumer trust. The adjusted R-squared value of 0.245 confirms the stability of this estimate after accounting for the number of predictors. The model is statistically significant ($F(1, 673) = 220.026$, $p < 0.01$), indicating that consumer trust is a significant predictor of brand loyalty. Accordingly, these findings support H3 *(Table 11).*

Table 11. Model summary

Mod	R	R^2	A R^2	SE	Change Statistics				
					EC	FC	df1	df2	P FC
1	.496[a]	.246	.245	.52208	.246	220.026	1	673	.000
Dependent Variable: Brand loyalty Predictors: (Constant), Trust									

Source: Author's calculation

The ANOVA table evaluates the overall significance of the regression model examining the effect of consumer trust on brand loyalty. The analysis shows that the model is statistically significant, with an F-value of 220.026 ($p < 0.01$). Specifically, the regression explains a meaningful portion of the variance in brand loyalty, as indicated by the sum of squares for regression (59.972) compared to the residual sum of squares (183.437). The significance level confirms that consumer trust is a significant predictor of brand loyalty *(Table 12).*

Table 12. ANOVA table

Model		SS	df	MS	F	p
1	Regression	59.972	1	59.972	220.026	.000[a]
	Residual	183.437	673	.273		
	Total	243.409	674			
Dependent Variable: Brand loyalty Predictors: (Constant), Trust						

Source: Author's calculation

Table 13 presents the regression coefficients for the model examining the effect of consumer trust on brand loyalty. The analysis reveals a significant positive relationship between consumer trust and brand loyalty (B = 0.457, SE = 0.031, $p < 0.01$). This indicates that higher levels of consumer trust are associated with higher levels of brand loyalty. The standardized coefficient (β = 0.496) reflects the strength of this effect and allows for comparison with other potential predictors in future models. The collinearity diagnostics show a tolerance value of 1.000 and a VIF of 1.000, indicating that multicollinearity is not present for this predictor.

Table 13. Regression coefficients

Model		UC		SC	t	p	Collinearity Stat.	
		B	SE	Beta			Tol.	VIF
1	(Constant)	2.375	.127		18.690	.000		
	Trust	.457	.031	.496	14.833	.000	1.000	1.000
Dependent Variable: Brand loyalty								

Source: Author's calculation

Table 14 presents the collinearity diagnostics for the model examining the effect of consumer trust on brand loyalty. The analysis reveals two dimensions. Dimension 1 shows a high eigenvalue (1.987) and a low condition index (1.000), with minimal variance proportions for both the constant and trust (0.01 for each). Dimension 2 displays a low eigenvalue (0.013) and a condition index of 12.569. This second dimension accounts for a substantial proportion of the variance in both the constant and trust (0.99 for both). Although these values indicate some concentration of variance within the second dimension, the condition index of 12.569 remains well below commonly accepted thresholds, suggesting that multicollinearity is not a significant concern in this model.

Table 14. Collinearity Diagnostics

Model	Dim.	Eig.	CI	VP	
				(Constant)	Trust
1	1.987	1.000	.01	.01	1.987
	.013	12.569	.99	.99	.013
Dependent Variable: Brand loyalty					

Source: Author's calculation

Empirical results provide partial support for the proposition that circular economy-based marketing practices serve as meaningful predictors of consumer trust and brand loyalty. The analysis confirms that the perceived use of recycled materials is a statistically significant, although relatively weak, positive predictor of consumer trust (H1 supported). However, contrary to theoretical expectations, perceived brand authenticity does not emerge as a significant predictor of consumer trust within this sample (H2 not supported). Consumer trust, in turn, is found to be a strong and statistically significant predictor of brand loyalty (H3 supported), underscoring its central role in translating sustainability-related brand perceptions into loyal consumer behaviour. Taken together, these findings highlight the importance of tangible CE-related practices, particularly the visible use of recycled materials, as an effective driver of trust formation and, consequently, of long-term brand loyalty.

6. DISCUSSION

The findings of this study provide partial support for the proposition that circular economy-based marketing practices contribute to the development of consumer trust and brand loyalty. More specifically, the results show that the perceived use of recycled materials has a statistically significant, although relatively weak, positive effect on consumer trust. This finding is consistent with prior research suggesting that visible and tangible sustainability cues can positively influence consumer evaluations because they make environmental responsibility easier to identify and assess (Magnier and Schoormans, 2015; Steenis et al., 2017). It is also in line with Chamberlin and Boks (2018), who argued that circular economy marketing becomes more effective when circular principles are translated into recognisable consumer value propositions. In the present study, recycled materials appear to function as such a cue, offering consumers a concrete and observable signal of environmental responsibility.

However, the relatively modest strength of this relationship suggests that the use of recycled materials alone is not sufficient to generate high levels of consumer trust. This result may indicate that consumers do respond positively to visible CE-related practices, but that trust formation still depends on a broader set of factors, including previous brand experience, perceived consistency of communication, and the general credibility of sustainability claims. The findings, therefore, support the view that circular economy-oriented actions can contribute to trust formation, but that their effect should not be overstated when considered in isolation. Perceived brand authenticity, by contrast, did not emerge as a significant predictor of consumer trust. This finding runs counter to the initial theoretical expectation, and therefore calls for closer interpretation. One possible explanation is that, within sustainability-oriented markets, authenticity may be perceived as a more abstract and communication-dependent construct than the use of recycled materials. While recycled materials represent a visible and concrete manifestation of circularity, authenticity is more difficult to verify directly and may therefore have weaker immediate effects on trust. In markets where consumers are increasingly exposed to sustainability messaging, authenticity claims may also be met with greater scepticism unless they are supported by clear and observable practices. This interpretation is consistent with recent literature emphasizing transparency, traceability, and protection against greenwashing as important conditions for the credibility of circular economy marketing (Paiva, 2025). It also aligns with Testa et al. (2020), who showed that consumer engagement with circular practices depends strongly on whether such practices are perceived as relevant and trustworthy. Another possible explanation is that authenticity may be more closely related to broader attitudinal evaluations of the brand than to trust in a narrow, predictive sense. This interpretation is indirectly supported by the correlation analysis, where brand authenticity was positively associated with brand loyalty, although not with trust. Authenticity may, therefore, still matter for consumer–brand relationships, but its influence may not operate through the same mechanism as the visible use of recycled materials. Rather than directly generating trust, authenticity may contribute to more general favourable brand evaluations, emotional alignment, or longer-term brand attachment.

The findings regarding H3 provide the strongest support for the proposed model. Consumer trust was found to be a statistically significant and comparatively strong predictor of brand loyalty, confirming its central role in the development of enduring consumer–brand relationships. This result is consistent with the relationship marketing theory (Morgan and Hunt, 1994) and with prior branding research showing that trust plays a decisive role in fostering

consumer commitment and loyalty (Delgado-Ballester and Munuera-Alemán, 2001; Chaudhuri and Holbrook, 2001; Sirdeshmukh et al., 2002). It also corresponds with more recent research emphasizing the continued importance of trust and loyalty in long-term brand relationships (Cardoso et al., 2022). In the context of circular economy marketing, this result suggests that trust remains a key mechanism through which sustainability-related perceptions can be translated into more durable behavioural intentions and relational outcomes.

Taken together, the results suggest that not all CE-related brand cues are equally effective in shaping consumer trust. Consumers appear to respond more strongly to tangible and visible sustainability practices than to abstract claims related to authenticity. This finding has both theoretical and managerial implications. Theoretically, it suggests that research on CE-based branding should distinguish more carefully between different types of sustainability signals and their respective psychological effects. From a managerial perspective, it indicates that firms seeking to strengthen trust and loyalty through circular economy strategies should prioritise concrete, observable, and verifiable actions, particularly those that can be directly connected to the product or service offering. In other words, circularity appears to be most persuasive when it is made visible. The study should, nevertheless, be interpreted in light of certain limitations. The data were collected from a convenience sample of consumers in Croatia, which may limit the broader generalisability of the findings. In addition, the study relies on self-reported perceptions and cross-sectional data, which do not allow stronger causal inferences. Future research could, therefore, build on these findings by employing comparative, longitudinal, or experimental designs in order to examine more precisely how different circular economy cues influence trust and loyalty across industries and national settings. Future studies may also explore whether authenticity exerts an indirect effect on loyalty through variables other than trust, such as brand image, perceived value, or emotional attachment.

7. CONCLUSION

This study confirms the relevance of circular economy-based marketing strategies in shaping consumer trust and strengthening brand loyalty. The findings show that the perceived use of recycled materials contributes to higher levels of consumer trust, although the effect is relatively modest. By contrast, perceived brand authenticity did not demonstrate a direct influence on trust within this sample, suggesting that consumers may respond more strongly to

tangible sustainability actions than to value-driven or symbolic brand cues. Consumer trust emerged as a key factor in the development of brand loyalty, underscoring its importance in translating sustainability-related perceptions into behavioural commitment. These results highlight the need for brands to prioritise credible and visible circular practices, particularly those related to the use of recycled materials, as a means of enhancing trust and fostering long-term consumer relationships. From a managerial perspective, the study offers practical guidance for companies seeking to strengthen their market position through sustainability-oriented strategies. Transparent communication, consistent behaviour, and clear evidence of circular practices appear essential for building trust and securing loyalty. From an academic perspective, the study contributes to the growing literature on circular economy marketing by offering a conceptual and empirical framework that links CE-related practices with consumer responses. Although the research was conducted within a single national setting, the findings offer useful insights into the relationship between circular economy practices, trust, and loyalty. Future studies could extend this line of inquiry through comparative, longitudinal, or experimental designs in order to examine how these relationships evolve across different cultural and industry settings. Overall, the results suggest that sustainability should be understood not only as an ethical or regulatory requirement, but also as a strategic basis for strengthening consumer trust and long-term brand loyalty.

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ENVIRONMENTAL INNOVATION AND WATER SUSTAINABILITY: THE ROLE OF CLEAN TECHNOLOGIES AND POLICIES IN OECD COUNTRIES

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Environmental innovation and effective policy design are increasingly recognized as essential to addressing water sustainability challenges, particularly in OECD countries where economic growth, demographic pressures, and environmental limits intersect. While Sustainable Development Goal 6 (Clean Water and Sanitation) calls for innovative solutions to balance water demand and supply, the academic literature has paid limited attention to how environmental innovation, measured through clean technology patents, shapes water sustainability. This study addresses that gap by analyzing the impact of clean environmental patents and environmental policy stringency on public water supply (PWS) withdrawals across 28 OECD economies in the period between 2000 and 2022. Using panel quantile regression, this study captures heterogeneous effects across the distribution of water usage intensity, thereby moving beyond mean-based estimates. The results reveal that clean technology patents significantly reduce public water withdrawals in both the lower (10th) and upper (75th and 90th) quantiles, indicating that environmental innovation contributes to lowering water withdrawals under both low and high water-stress conditions. However, the effects are statistically insignificant at the middle quantiles, suggesting that the influence of technological innovation is not uniform across the distribution of water usage intensity. Environmental policy stringency shows a negative association with water use in the baseline model and in low-stress contexts. However, the quantile

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results suggest that its effectiveness weakens and can even turn positive at upper quantiles, possibly reflecting transitional costs or enforcement gaps. Population growth emerges as a robust driver of water withdrawals across all quantiles, though its marginal effect diminishes under extreme stress, suggesting that demographic pressures condition the space for policy and innovation. Precipitation has a positive influence, indicating that greater water availability tends to increase withdrawals, while GDP shows no significant impact, underscoring that economic scale alone does not determine water outcomes in OECD countries. Taken together, these findings demonstrate that fostering innovation ecosystems, when aligned with stringent and well-enforced policy frameworks, is essential for managing water resources sustainably. The study contributes to the emerging water–innovation nexus literature by showing that the benefits of clean technology patents are contingent on the level of water stress, and it provides policy-relevant insights for integrating technological and governance solutions into national water strategies under the SDG framework.

Keywords: *Public water supply, clean technology patents, environmental innovation, water sustainability, panel quantile regression*

JEL classification: *Q25; O33; Q55; Q58; C23*

INTRODUCTION

In recent decades, concerns over water stress, climate change, and resource sustainability have driven policymakers and researchers to examine the interplay between environmental innovation and water management systems. OECD countries, in particular, have seen a rise in clean technology patenting activity aimed at improving environmental efficiency and meeting Sustainable Development Goals (SDGs). Public water supply (PWS), as a critical component of water security and sustainable infrastructure, has garnered attention for its sensitivity to both ecological and institutional pressures.

Environmental innovation, especially in the form of clean technology patents, has been proposed as a key driver for resource efficiency and pollution control (Popp et al., 2010). In the water sector, innovations targeting leakage reduction, wastewater recycling, energy-efficient pumping, and smart monitoring systems are increasingly prevalent (OECD, 2023). Yet, the question remains whether the proliferation of such patents translates into tangible improvements in public water provision.

Parallel to this technological shift, the role of environmental policies and regulatory frameworks has grown in importance. The Environmental Policy Stringency Index (EPSI), developed by the OECD, provides a proxy for the strength of regulatory frameworks aimed at reducing environmental degradation (Botta and Kozluk, 2014). Stronger policy signals may catalyze innovation diffusion and influence operational decisions in water utilities. However, these effects are likely to differ across institutional and economic contexts.

Water-related outcomes are also shaped by macro-structural factors such as income, demographic change, and climate. For instance, GDP influences investment capacity in infrastructure; population growth affects water demand and system strain; and precipitation patterns determine natural supply constraints. Previous studies have linked these factors to the availability, affordability, and quality of water services (World Bank, 2022; UN-Water, 2023).

Despite growing attention to sustainability transitions, limited empirical work has investigated the impact of clean innovation on water systems using a distributional econometric lens. Most studies employ average-effect models that mask variability across countries with differing water stress levels, institutional capacities, and innovation readiness. This study addresses this gap by applying the Panel Quantile Regression (PQR) approach to evaluate how clean technology patents affect public water supply across the conditional distribution.

Focusing on 28 OECD countries in the period between 2000 and 2022, this study combines patent data on clean technologies with macroeconomic and institutional indicators, such as economic growth, precipitation, population, and EPSI. The study makes the following three key contributions: (i) this study quantifies the heterogeneous impact of environmental innovation across water supply regimes; (ii) this study also integrates multiple structural and policy drivers into a unified analytical framework; and (iii) it informs policy targeting by identifying conditions under which innovation delivers the greatest benefits.

The remainder of the paper is structured as follows. Part 2 reviews the literature on environmental innovation and water management. Part 3 outlines the data set and econometric methodology, including the PQR model. Part 4 presents and interprets the empirical findings. Part 5 concludes with a summary of key insights and policy implications for advancing water sustainability in OECD countries.

LITERATURE REVIEW

Environmental innovation has increasingly been recognized as a key driver of resource efficiency and environmental sustainability. Technological progress can improve environmental performance by reducing resource intensity, enhancing efficiency, and supporting cleaner production systems (Popp et al., 2010). In this context, environmental policy instruments and regulatory frameworks may also stimulate technological innovation by creating incentives for the development and diffusion of clean technologies (Johnstone et al., 2010).

A growing body of empirical research has investigated whether environmental innovation, particularly clean technology patents, translates into improved water-related outcomes. For instance, Tan and Zou (2023) find that water-related technological innovation has significantly improved water use efficiency across a global sample of 75 countries. Using a panel fixed-effects model, they report that increases in water-related patents are associated with higher efficiency in water use, and this positive effect persists for several years. Interestingly, their study finds the beneficial impact to be heterogeneous: the gains from innovation are the strongest in low-income, democratic, and left-leaning countries. This suggests that political and institutional contexts, such as governance quality and policy priorities, can mediate how effectively innovation translates to water savings.

Recent studies have further emphasized the role of sustainability-oriented practices and governance innovations in improving environmental performance. For example, Veloaras et al. (2025) showed that environmental certification and sustainability practices can reduce both energy and water consumption while improving overall environmental performance in service industries. Similarly, Dai et al. (2025) highlighted the importance of technological integration and governance innovation in advancing sustainable water management and achieving both ecological and economic sustainability outcomes.

Despite this generally positive perspective, the literature also presents contrasting evidence. Nyiwul et al. (2025) identified a "productivity paradox" in the water sector using a global panel dataset covering 81 countries. Analyzing a global panel of 81 countries over 20 years with instrumental variable and system-GMM estimations, they expected technological innovation to enhance water productivity (e.g. economic output per unit of water). Instead, their results showed a negative and statistically significant relationship between water-related patent counts and water productivity. Moreover, more clean-water patents coincided with lower water productivity, contrary to theoretical expectations. This paradox mirrors the well-known productivity paradox in the IT sector and suggests that simply generating innovations is not automatically

yielding efficiency gains in water use. These contrasting findings indicate that the effectiveness of environmental innovation is highly context-dependent and may vary across countries with different institutional capacities, infrastructure conditions, and levels of water stress.

Other studies have explored the relationship between innovation and water stress across economic sectors. Esen et al. (2024) examined 30 OECD countries using a Method of Moments Quantile Regression approach. This advanced technique allowed them to see how the effect of water-related patents varies across countries with low vs. high water stress. They found a nuanced, sector-dependent pattern: in agriculture, increased innovation activity worsens water stress at lower-to-median stress levels.

Most recent OECD-focused studies have emphasized water quantity (use, efficiency, stress) rather than water quality. Nevertheless, it is notable that, historically, about three-quarters of water-related patents have targeted water pollution abatement technologies (OECD, 2020). Patented innovations in treatment and pollution control play a role in public water supply sustainability by improving water quality and safety. While specific empirical analyses of patents vs. water quality outcomes in OECD countries were not prominent in 2020–2025 literature, the emphasis on pollution abatement patents suggests an ongoing innovation effort to address water quality challenges. For instance, Lee and Jepson (2025) applied a patent analysis of desalination technologies and highlighted how technological innovation is addressing the energy and environmental challenges of desalination, thereby improving the sustainability of water supply systems.

Beyond the water sector, a broader literature has examined how environmental innovation contributes to overall environmental sustainability. For instance, Ercan et al. (2024) investigated CO_2 emissions in the EU-27 with an EKC model that included patent-based innovation indicators. They employed panel VAR techniques to analyze dynamic relationships among income, inequality, trade, and innovation. A notable finding was that green technological innovation helps mitigate environmental pollution in the long run in Europe. Similarly, Agan Celik (2026) showed that environmental policy frameworks and green openness play a crucial role in advancing sustainable development by influencing environmental and macroeconomic dynamics, highlighting the importance of integrating innovation and policy mechanisms in sustainability strategies.

Furthermore, Sohag et al. (2015) demonstrated that technological innovation and energy dynamics play an important role in shaping environmental and economic performance, highlighting the broader relevance of innovation-driven sustainability transitions. One recent study by Sohag et al. (2024) focused

on OECD countries and found that tighter environmental policies significantly reduce the ecological footprint (a broad measure of natural resource use and pollution) through innovation and renewable energy channels. Using a panel CS-ARDL approach (1990–2018), they showed that strict regulations drive investments in clean innovation, which in turn lead to lower overall environmental impacts. This underscores a policy leverage point: stringent environmental policies can both stimulate green innovation and ensure those innovations are applied, yielding tangible sustainability benefits.

Despite this expanding body of literature, relatively limited empirical work has examined how environmental innovation influences public water supply outcomes across different performance regimes within OECD economies. Most existing studies rely on mean-based estimation techniques, which may obscure heterogeneous relationships across countries with varying levels of institutional capacity, infrastructure development, and water provision. Addressing this limitation, the present study applies a panel quantile regression (PQR) framework to examine how clean technology patents and environmental policy stringency affect public water supply across the conditional distribution.

Based on the theoretical and empirical literature on environmental innovation, policy frameworks, and water sustainability, several testable hypotheses can be formulated, as follows:

H1: Environmental innovation, proxied by clean technology patents, significantly influences public water supply outcomes.

H2: Environmental policy stringency significantly affects public water supply through regulatory and institutional mechanisms.

H3: Climatic conditions, represented by precipitation levels, positively influence public water supply availability.

H4: Population size significantly affects public water supply due to scale effects in water infrastructure and demand dynamics.

These hypotheses were empirically tested using a panel quantile regression framework to capture potential heterogeneity across different levels of water provision among OECD countries.

DATA AND METHODOLOGY

This study employs a balanced dataset covering 28 OECD countries in the period from 2000 to 2022, in order to investigate the relationship between environmental innovation and water sustainability. The primary objective is to assess whether clean technology development, along with macroeconomic and

environmental policy variables, contributes to improvements in national water provision systems.

The dependent variable is Public Water Supply (PWS) per capita, representing a core aspect of water resource sustainability. The analysis incorporates a range of explanatory factors, including clean technology patents (CE), environmental policy stringency (EPSI), economic output (GDP), annual precipitation (RAIN), and population (POP), capturing both innovation dynamics and contextual controls. The EPSI ranges from 0 to 6, where higher values indicate more stringent environmental policy frameworks (0 = lowest policy stringency; 6 = highest policy stringency). The variables used in the empirical analysis are described in Table 1.

Table 1. Data information

Variable	**Description**	**Measurement unit**	**Data source**
PWS	Public Water Supply per capita	Cubic meters per person (m^3/person)	OECD Water Statistics
CE	Clean Technology Patents	Number of clean tech patents (solar, wind, hydrogen, etc.)	OECD ENVTECH / Patent Databases
EPSI	Environmental Policy Stringency Index	Index value (0–6 scale)	OECD statistics
GDP	Gross Domestic Product (constant)	Constant 2015 USD	World Bank (WDI)
RAIN	Annual Precipitation	Millimeters (mm/year)	FAO Climate Data
POP	Total Population	Number of people	World Bank (WDI)

Source: Compiled by the author using data from the OECD Water Statistics (2024), OECD ENVTECH Patent Database (2024), World Bank World Development Indicators (WDI) (2024), and FAOSTAT (2024).

The empirical analysis was conducted using the Panel Quantile Regression (PQR) framework, which enables the estimation of the conditional distribution of public water supply (PWS) across multiple quantiles. This method is particularly effective in heterogeneous settings such as OECD countries, where variations in environmental policy stringency, innovation capacity, and climate conditions result in differentiated impacts on water sustainability. Quantile regression techniques have been widely used to examine distributional heterogeneity in panel data settings, allowing researchers to capture heterogeneous relationships across different points of the outcome distribution (Koenker, 2004; Šarić et al., 2018).

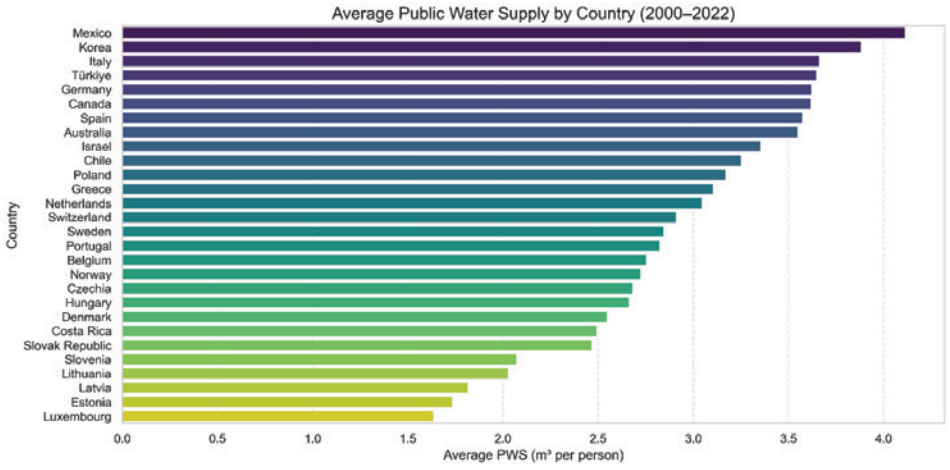
Unlike traditional panel estimators such as Fixed Effects (FE) or pooled OLS, the quantile regression approach captures distributional heterogeneity, allowing for the identification of asymmetric effects across low- and high-performing countries in terms of public water provision. This is crucial in environmental studies where average effects may mask important dynamics occurring in the upper or lower tails of the outcome distribution. The general form of the quantile regression model is provided as follows:

$$Q_{\tau}(PWS_{it} \mid X_{it}) = \alpha_i + \beta_{\tau} X_{it}$$

where $Q_{\tau}(PWS_{it} \mid X_{it})$ denotes the τ-*th* conditional quantile of public water supply for country i at year t, α_i represents a time-invariant country-specific effect capturing unobserved heterogeneity across countries, X_{it} denotes the vector of explanatory variables including clean technology patents, environmental policy stringency, economic output, precipitation, and population, and β_{τ} represents the quantile-specific coefficients.

In order to ensure the robustness of the results, a traditional FE model was also estimated. While the FE model provides insights into average within-country effects, the PQR model reveals how the impact of environmental innovation shifts across the distribution of water supply performance, offering a more granular understanding of policy and innovation dynamics in shaping water sustainability across advanced economies.

Figure 1. Trends in public water supply by country (2000–2022)



Source: www.oecd.org

Figure 1 displays the average PWS per capita for 28 OECD countries over the period 2000–2022. The results reveal considerable variation across countries, reflecting diverse geographic, climatic, economic, and institutional conditions that shape national water management systems.

At the top of the distribution, countries such as Mexico, Korea, Italy, and Türkiye exhibit the highest levels of public water supply, with annual per capita values approaching or exceeding four cubic meters per person annually. These elevated levels may stem from a combination of climatic water demand, population-driven consumption, infrastructure scale, and national policies regarding water pricing and access.

In contrast, Luxembourg, Estonia, and other Baltic and Central European countries demonstrate substantially lower levels of water provision, with averages closer to or below two cubic meters per person. These patterns may indicate either more efficient water use, stricter conservation measures, or limitations in public supply coverage.

The figure underscores the structural heterogeneity among OECD countries in terms of water resource provisioning. This variation justifies the application of econometric techniques such as PQR, as average-effect models may mask important distributional differences. Understanding how innovation and policy influence water outcomes across varying performance regimes is essential for designing targeted and equitable sustainability strategies.

EMPIRICAL FINDINGS

Before proceeding with formal regression analysis, we provide a graphical overview of the core variables to detect any preliminary patterns or distributional irregularities. Figure 2 presents the pairwise relationships and marginal distributions of the main variables included in the empirical analysis. The diagonal panels display the kernel density estimates (KDEs) of each variable, offering insights into their distributional shapes, while the off-diagonal panels show scatter plots that capture the bivariate associations between variables.

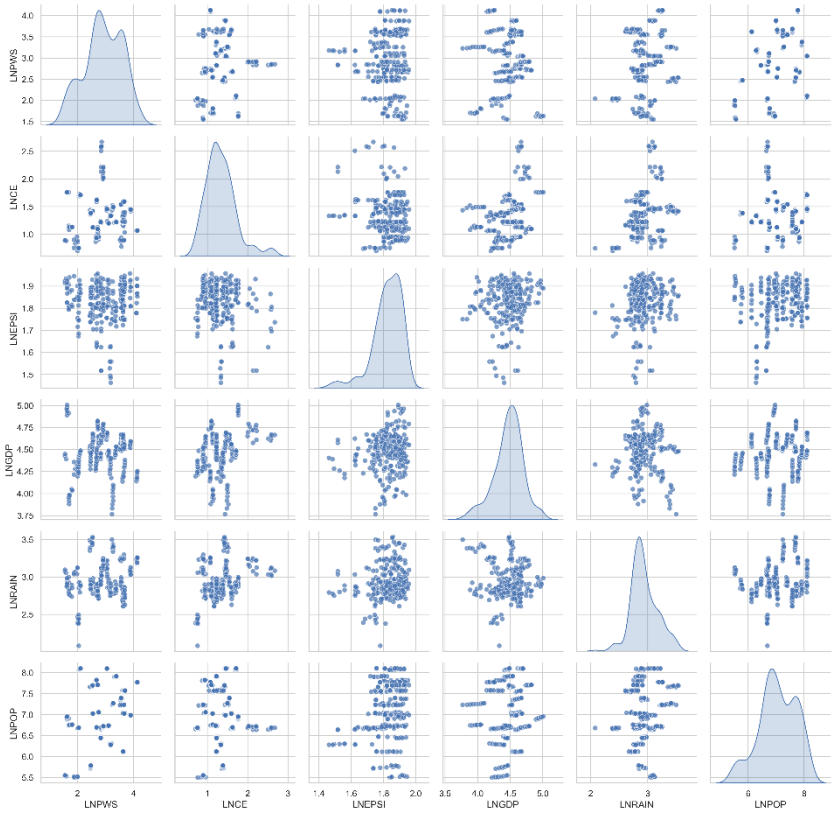
The dependent variable, LNPWS, appears to follow a moderately left-skewed distribution, indicating a concentration of countries with relatively high levels of water provision. In contrast, LNCE is highly right-skewed, suggesting a long tail of high-innovation countries, with the majority exhibiting lower levels of patent activity.

In terms of bivariate relationships, the scatter plots show no strong linear patterns among the explanatory variables, which is consistent with the modest

pairwise correlations observed earlier. However, a slightly positive visual association can be observed between LNPWS and LNGDP, implying that higher-income countries tend to provide more public water supply per capita. The relationship between LNPWS and LNEPSI appears more diffuse, potentially indicating nonlinear or conditional effects that justify the use of quantile-based methods.

Particularly, the absence of multicollinearity patterns supports the robustness of the subsequent regression specifications. The diversity in distributions and relationships observed here reinforces the need for econometric techniques like Panel Quantile Regression, which can account for heterogeneity across the distribution of the dependent variable rather than assuming a single uniform effect.

Figure 2. Pairwise relationships and distributions of variables (Scatter and KDE)



Source: Author's estimation

Table 2 summarizes the log-transformed descriptive statistics of the main variables used in the analysis. The dependent variable, LNPWS, averages 2.92, reflecting substantial variation in public water supply across OECD countries. Among the explanatory variables, LNCE shows wide dispersion, indicating differences in clean technology innovation, while LNEPSI has the least variation due to the stable nature of policy stringency scores. LNGDP and LNRAIN exhibit moderate variability, whereas LNPOP highlights the inclusion of both small and large countries. These distributional differences justify the use of quantile regression, which captures heterogeneous effects across the outcome distribution.

Table 2. Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
LNPWS	252	2.922	0.661	1.554	4.130
LNCE	252	1.337	0.375	0.701	2.671
LNEPSI	252	1.824	0.091	1.463	1.957
LNGDP	252	4.472	0.221	3.766	5.005
LNRAIN	252	2.940	0.230	2.080	3.538
LNPOP	252	7.053	0.653	5.503	8.106

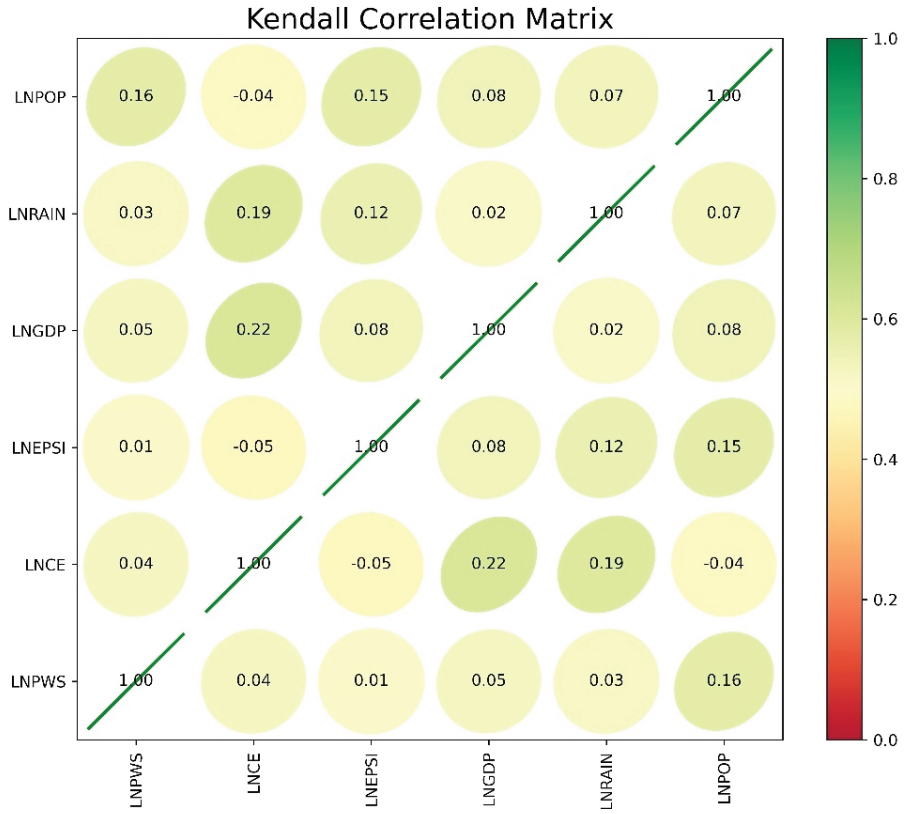
Source: Author's calculations

Figure 3 presents the Kendall rank correlation matrix among the main variables in the dataset. Unlike Pearson correlation, which captures linear relationships, Kendall's τ measures the ordinal association between variables, and is particularly suited for non-parametric settings and datasets that may violate normality assumptions.

The results reveal generally weak to moderate pairwise associations across variables, with all correlation coefficients falling below 0.25 in absolute value. This suggests the absence of strong linear or monotonic dependencies, which is desirable in multivariate regression analysis to avoid multicollinearity. The dependent variable LNPWS shows very low correlations with the explanatory variables. The highest correlation observed is with LNPOP ($\tau = 0.16$), followed by LNGDP ($\tau = 0.05$) and LNCE ($\tau = 0.04$). These weak associations indicate that none of the covariates have a dominant linear effect on public water supply, supporting the use of quantile regression to explore conditional effects across the distribution. Among the independent variables, the highest correlation is between LNCE and LNGDP, reflecting the intuitive link between eco-

nomic scale and clean innovation intensity. However, this level of correlation is still within acceptable limits and does not suggest a risk of multicollinearity.

Figure 3. Kendall rank correlation matrix



Source: Author's calculations

Table 3 presents the results of cross-sectional dependence (CD) tests for the baseline model, where LNPWS is regressed on key explanatory variables. All three tests – Pesaran, Friedman, and Frees – strongly reject the null hypothesis of independence, indicating significant cross-sectional dependence among OECD countries. This outcome aligns with the expectations, given the interlinked nature of environmental, economic, and policy factors across nations. This also underscores the need for robust estimation techniques, such as quantile regression, which better handle distributional heterogeneity and interdependencies in panel data.

Table 3. Cross-sectional dependence test results

Model*	Pesaran Test	Friedman Test	Frees Test
Test statis.	12.540	51.848	3.418
Prob-value	0.000	0.000	0.000

Note: * shows the model of LNPWS =f (LNCE, LNEPSI, LNGDP, LNRAIN, LNPOP).

Source: Author's calculations

Table 4 reports the panel unit root test results for all variables under both the constant and constant-plus-trend specifications. Given the presence of cross-sectional dependence identified in Table 3, the Cross-sectionally Augmented Im–Pesaran–Shin (CIPS) panel unit root test proposed by Pesaran (2007) was employed to examine the stationarity properties of the variables. The results indicate that most variables, including LNPWS, LNEPSI, LNGDP, and LNPOP, are non-stationary at levels, but become stationary after first differencing, suggesting that they are integrated of order one, I(1). In contrast, LNCE and LNRAIN appear to be stationary at a level, indicating that they are integrated of order zero, I(0). The use of the CIPS test is appropriate in this context as it explicitly accounts for cross-sectional dependence across panel units. These findings confirm the mixed integration order typical of macro panel datasets and support the use of quantile-based estimation techniques, which do not require a uniform integration order across variables.

Table 4. Unit root test results

Variables	Constant		Constant and trend	
	Level	First difference	Level	First difference
LNPWS	-1.802	-3.483***	-1.456	-3.241***
LNCE	-3.935***	-3.817***	-3.539***	-3.653***
LNEPSI	-0.799	-2.674***	-0.876	-2.688***
LNGDP	-1.605	-2.345***	-1.938	-2.337***
LNRAIN	-3.485***	-3.333***	-3.360***	-3.275***
LNPOP	-1.466	-2.536***	-1.787	-2.460***

*Note: Stationarity at a significance level of *10%, **5%, and ***1%.*

Source: Author's calculations

Table 5 presents the results of several panel cointegration tests. The Kao and Pedroni tests, which are first-generation panel cointegration tests, produced

statistically significant test statistics suggesting the presence of a long-run relationship among the variables. However, these tests assume cross-sectional independence. Since Table 3 confirms the presence of cross-sectional dependence across OECD countries, the results of these first-generation tests should be interpreted with caution.

The Westerlund test, which accounts for cross-sectional dependence, failed to reject the null hypothesis of no cointegration ($p = 0.2962$), indicating that the evidence for a robust long-run equilibrium relationship is not conclusive. Given these mixed findings, the subsequent empirical analysis did not rely on a strict cointegration assumption. Instead, the study employed a panel quantile regression framework, which focused on conditional distributional relationships and allowed the effects of explanatory variables to vary across different quantiles of the dependent variable. Accordingly, the results were interpreted as conditional associations rather than long-run equilibrium relationships.

Table 5. Panel cointegration test results

Statistic	**Value**	**p-value**
Dickey-Fuller t (Kao test)	-14.1284	0.0000
Augmented Dickey-Fuller t (Kao test)	-3.4996	0.0000
Modified Dickey-Fuller t (Kao test)	-3.3233	0.0004
Variance ratio (Westerlund test)	-0.5355	0.2962
Phillips-Perron t (Pedroni test)	-20.5028	0.0000

Source: Author's calculations

Table 6 presents the results of PQR estimates across five quantiles (10th, 25th, 50th, 75th, and 90th) alongside a benchmark FE model. The comparison revealed meaningful heterogeneity in the effects of the key variables on public water supply (LNPWS) across its conditional distribution. Clean technology patents (LNCE) have a statistically significant negative effect at upper quantiles (75th and 90th), suggesting that in countries with already high levels of water provision, increases in clean innovation may be associated with efficiency-driven reductions in water usage. Interestingly, this effect is strongly negative at the 10th quantile as well, potentially indicating that innovation might substitute for infrastructure in low-performing cases. This pattern is broadly consistent with previous studies such as the one conducted by Tan and Zou (2023), which suggest that environmental innovation can enhance resource efficiency and reduce resource intensity through technological improvements and cleaner production processes.

Environmental policy stringency (LNEPSI) showed a positive and significant effect at the 90th quantile, suggesting that stricter environmental regulation may strengthen public water provision primarily in top-performing countries. However, the effect is negative and significant at the 10th quantile, which could indicate short-term adjustment costs or institutional lag in low-capacity settings. This result also resonates with recent research on water governance and sustainability transitions (Dai et al., 2025), highlighting that the effectiveness of environmental policies often depends on governance capacity and the integration of technological and institutional innovations.

Precipitation (LNRAIN) exhibited a positive and statistically significant effect at all quantiles except the 75th (10th, 25th, 50th, and 90th), confirming the importance of climatic water availability in supporting public water supply systems. This finding aligns with Vörösmarty et al. (2010), who emphasized that climatic and environmental conditions remain fundamental determinants of water resource availability and management outcomes across countries. Population (LNPOP) maintained a positive and statistically significant effect across most quantiles, especially in the lower and middle quantiles. This likely reflects the economies of scale in water infrastructure and access.

The pseudo R^2 values varied across quantiles, with the highest explanatory power observed at the 90th quantile (0.4157), reinforcing the appropriateness of quantile regression in capturing distributional dynamics that traditional mean-based models may miss. Overall, the results demonstrated that the relationship between environmental innovation, policy stringency, and public water provision is highly heterogeneous across the distribution of water supply performance. This contributes to the existing literature by showing that innovation and environmental policy impacts differ substantially across countries with varying levels of water provision, highlighting the value of distribution-sensitive approaches such as panel quantile regression for analyzing sustainability outcomes.

Table 6. Panel quantile regression results

Variable	FE	Quantile regression				
		10th	25th	50th	75th	90th
C	4.281*** (1.84)	-2.29 (1.12)	-0.719 (1.21)	0.387 (1.63)	1.917 (1.24)	0.938 (0.74)
LNCE	0.010 (0.00)	-0.912*** (0.12)	0.184 (0.12)	0.039 (0.17)-	-0.299** (0.12)	-0.237*** (0.10)
LNEPSI	0.056** (0.00)	-0.770* (0.04)	-0.653 (0.20)	-0.031 (0.02)	0.269 (0.03)	0.851** (0.37)
LNGDP	-0.022 (0.19)	0.388 (0.31)	0.242 (0.335)	-0.191 (0.28)	-0.066 (0.64)	-0.091 (0.14)
LNRAIN	0.027** (0.22)	0.561** (0.22)	0.325** (0.35)	0.443*** (0.20)	-0.128 (0.21)	0.538*** (0.87)
LNPOP	0.290*** (0.07)	0.498*** (0.06)	0.308*** (0.02)	0.307*** (0.03)	0.293*** (0.06)	0.057* (0.03)
Pseudo R^2	0.725	0.3723	0.3538	0.2146	0.1727	0.4157
Observations	252	252	252	252	252	252

*Note: *, ** and *** indicate at 10%, 5% and 1% level, respectively. The z statistics-values are represented in parentheses.*

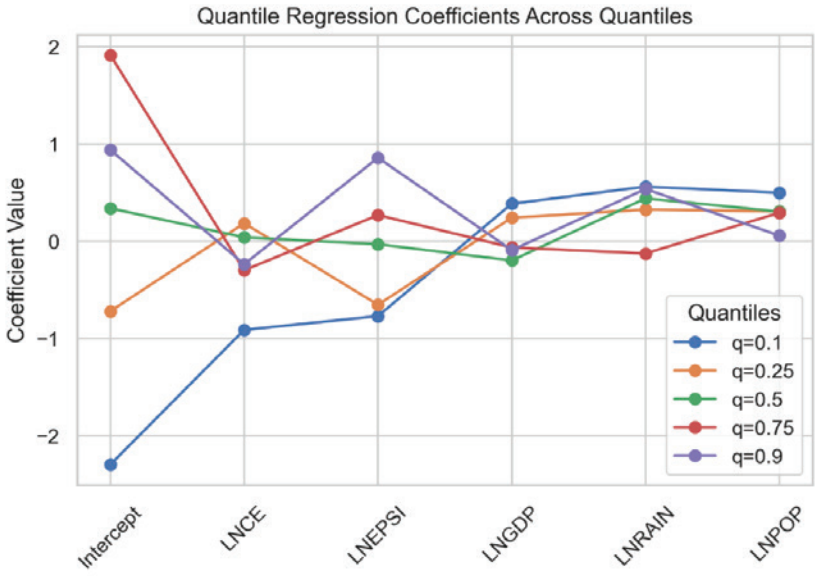
Source: Author's calculations

Figure 4 illustrates how the effects of explanatory variables on public water supply vary across the different points of its conditional distribution, highlighting the heterogeneity captured by the PQR framework. The coefficient of LNCE was strongly negative at the 10th quantile, became statistically insignificant at the middle quantiles, and turned negative again at the upper quantiles (75th and 90th). This pattern suggests that the effect of clean innovation is most pronounced at the lower and upper tails of the distribution, while it weakens in middle-performing countries. In contrast, the coefficient of LNEPSI rose steadily from negative at the lower quantiles to positive and statistically significant values at the 90th quantile. This suggests that environmental policies are more strongly associated with public water provision in high-performing countries, while their relationship appears weaker or even negative in lower-performing contexts.

LNRAIN exhibited a positive and statistically significant association at most quantiles, particularly at the 10th, 25th, 50th, and 90th quantiles, although the effect was not significant at the 75th quantile. This pattern highlights the importance of climatic water availability in supporting public water supply across countries. LNPOP maintained a consistently positive effect across all quantiles, reflecting potential economies of scale in water infrastructure pro-

vision. Meanwhile, LNGDP did not exhibit a strong or systematic effect on public water supply across the distribution. Therefore, the figure confirms the quantile-dependent nature of the key relationships, highlighting the limitations of average-effect models and reinforcing the value of the PQR approach in assessing sustainability outcomes.

Figure 4. Quantile-specific effects of explanatory variables on public water supply



Source: Author's estimation

CONCLUSION AND POLICY IMPLICATIONS

This study explored the impact of environmental innovation on water sustainability in 28 OECD countries in the period from 2000 to 2022, focusing specifically on the role of clean technology patents in shaping public water supply outcomes. Using a PQR framework, the analysis accounted for heterogeneous effects across the distribution of water provision levels, thereby uncovering distribution-sensitive insights often obscured by average-based estimators. Control variables such as GDP, precipitation, population, and environmental policy stringency were used to provide a comprehensive assessment of the determinants of public water supply.

The empirical findings provide important insights regarding the hypotheses formulated in the study. First, the results provide partial support for Hypothesis 1, which proposed that environmental innovation significantly influences public water supply outcomes. Clean technology patents exhibit statistically significant negative effects at both the lower and upper quantiles. This suggests a dual mechanism: in countries with lower levels of water provision, technological innovation may substitute for insufficient infrastructure, whereas in high-performing countries innovation tends to improve efficiency and reduce water use intensity. Second, the findings support Hypothesis 2, indicating that environmental policy stringency influences public water supply outcomes, although the effects are heterogeneous across the distribution. Specifically, environmental policy stringency shows a strong positive impact at the upper quantiles, suggesting that regulatory frameworks are more effective in countries with higher institutional capacity and technological readiness. Conversely, negative effects observed at the lower quantiles may reflect adjustment costs or institutional constraints that limit policy effectiveness in lower-performing contexts.

Third, the results support Hypothesis 3, confirming that climatic conditions represented by precipitation significantly influence water availability and public water supply systems. Precipitation shows positive and statistically significant effects across most quantiles, highlighting the critical role of natural water availability in shaping water supply dynamics. Finally, the results provide strong support for Hypothesis 4, as population size consistently exerts a positive and statistically significant effect on public water supply across most quantiles. This finding likely reflects scale effects in water infrastructure development and service provision, as larger populations typically require more extensive water distribution systems.

These results have focused on several important policy implications. First, the distributional nature of the findings calls for tailored water sustainability strategies. Countries with low water provision levels may benefit more from direct investment in water infrastructure, supported by targeted innovation strategies that replace or augment basic systems. Conversely, high-performing countries should focus on efficiency-enhancing innovations, regulatory refinement, and integration of digital monitoring systems.

Second, the asymmetry in the effectiveness of environmental policy stringency across quantiles suggests that such policies require complementary institutional capacities to succeed. In lower-performing countries, merely enacting stringent regulations may prove ineffective without parallel efforts to enhance governance, monitoring, and technological readiness. Capacity-building

initiatives, regulatory training programs, and technology transfer mechanisms should be prioritized.

Third, the consistent influence of population highlights the need for infrastructure scaling policies. Policymakers should ensure that growing urban populations are met with proportional expansions in sustainable water systems. Integrated urban water management, smart water metering, and decentralized supply models can support this objective.

Fourth, clean technology development should remain a central focus of environmental innovation policy. Given its nonlinear but significant effects, innovation policy must go beyond R&D support and address deployment, upscaling, and real-world application. Financial mechanisms such as green bonds, innovation subsidies, and public-private partnerships can facilitate this transition. Fifth, the study underscores the utility of quantile-based econometric approaches in environmental policy research. By revealing how explanatory variables influence different segments of the water supply distribution, such methods help refine policy targeting and evaluation.

Despite its contributions, this study has several limitations that should be acknowledged. First, the analysis focuses exclusively on OECD countries, which limits the generalizability of the findings to developing economies where institutional structures and water infrastructure conditions may differ substantially. Second, environmental innovation is proxied by clean technology patents, which may not fully capture the actual adoption or implementation of innovative technologies in water management systems. Third, although the panel quantile regression framework allows for distributional heterogeneity, it does not explicitly capture potential spatial spillovers or dynamic interactions among countries. These limitations suggest avenues for future research to further refine the understanding of the innovation–water sustainability nexus.

Finally, future research could expand the model by incorporating spillover effects, digital monitoring adoption, or climate vulnerability indicators. Moreover, linking patent data with actual implementation and performance results could strengthen the causal narrative. In sum, this study advocates for a differentiated, innovation-driven, and context-sensitive approach to water sustainability in developed economies. OECD countries should not rely on universal solutions, but instead craft tailored policy packages that align technological, institutional, and demographic factors to achieve long-term water resilience and sustainability.

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CIRCULAR CONSUMPTION AND PRODUCT LONGEVITY IN BOSNIA AND HERZEGOVINA: WILLINGNESS AND BARRIERS TO REPAIR, REUSE AND UPCYCLING

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The global environmental crisis has intensified the need to reconsider how products are designed, used, and disposed of, as accelerating resource extraction and rising waste generation place increasing pressure on ecosystems. In this context, the circular economy has emerged as an alternative to the traditional "take–make–dispose" model, emphasizing product longevity through repair, reuse, upcycling, and more efficient resource use. Extending product lifespans can significantly reduce material and energy consumption while generating both environmental and economic benefits. However, despite growing awareness and policy support, the adoption of circular practices remains limited, constrained by technical, economic, and behavioural barriers.

This paper examines consumer behaviour in Bosnia and Herzegovina (B&H), focusing on willingness and barriers related to product repair, reuse, and upcycling. An online survey was conducted between July and August 2024 with 450 respondents, using a questionnaire developed on the basis of recent literature on sustainable consumption and circular economy practices. The findings reveal strong pro-environmental orientations and a general readiness to engage in circular behaviours, alongside persistent obstacles such as perceived repair costs, lack of skills, limited

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repair infrastructure, and institutional constraints. By providing empirical evidence from an underexplored context, the study contributes to a better understanding of consumer-driven pathways toward circular economy transitions, and offers a foundation for future research and evidence-based policy development in B&H.

Keywords: *Circular economy, sustainability, reuse, repair, Bosnia and Herzegovina*

JEL classification: *Q53, Q56*

INTRODUCTION

Growing global environmental pressures – including unsustainable resource use, increasing waste generation, and climate change – have highlighted the limitations of the dominant linear model of production and consumption based on the principle of "take–make–dispose" (Ellen MacArthur Foundation, 2025). Beyond its environmental impacts, this model has also contributed to economic vulnerabilities linked to rising resource dependency and fragile global supply chains. In response, the circular economy has emerged as a systemic alternative aimed at reconciling environmental sustainability with economic resilience.

A central objective of the circular economy is to extend product lifetimes through strategies such as repair, reuse, and more efficient resource use, thereby reducing waste and environmental pressures (Cooper, 2010; Sonego et al., 2022; Wieser & Tröger, 2016). While product design, technology, and business models are critical enablers of these strategies, their effectiveness ultimately depends on consumer behaviour (Cox et al., 2013; Laitala et al., 2021). Existing studies consistently document an attitude–behaviour gap: although consumers often express pro-environmental values, these do not always translate into everyday practices such as repairing, reusing, or upcycling products. This gap is shaped by multiple barriers, including perceived repair costs, limited skills and information, insufficient repair services, time constraints, and perceptions of technological obsolescence.

In B&H, empirical research on consumer engagement in repair, reuse, and upcycling is extremely limited. Historically, practices of product repair and extended use have been widespread, often driven by economic necessity. However, the growing availability of low-cost replacement products may be weakening these practices and reinforcing more linear consumption patterns.

Understanding how consumers navigate these dynamics is, therefore, essential for designing effective policies and initiatives that support circular economy transitions.

Against this background, this study examines consumers' willingness to repair, reuse, and upcycle products in B&H, as well as the key barriers that discourage these practices. By providing empirical evidence from an under-explored national context, this study contributes to a better understanding of consumer-driven pathways toward circular and sustainable consumption.

THEORETICAL FRAMEWORK

PRODUCT LONGEVITY AND CONSUMER ENGAGEMENT IN CIRCULAR PRACTICES

The circular economy is widely conceptualized as a systemic alternative to the linear "take–make–dispose" model, which has proven environmentally unsustainable due to rising waste generation, resource depletion, and ecosystem degradation (Cooper, 2010; Ellen MacArthur Foundation, 2025). Its core objective is to retain the value of products, materials, and resources within the economy for as long as possible by slowing, closing, and narrowing resource loops (Bocken et al., 2016). Among these strategies, those aimed at slowing loops – through product durability, repairability, maintenance, reuse, and upcycling – are considered particularly effective because they preserve both material and functional value (Cooper, 2010; Wieser & Tröger, 2016).

Extending product longevity has, therefore, emerged as a central pillar of circular economy strategies. Declining product lifespans in industrialized economies have contributed to increased material throughput and waste streams (Huisman et al., 2012), prompting growing attention to design approaches that support durability, repairability, and upgradeability (Bocken et al., 2016; Løvbak Berg & Hebrok, 2024). These efforts are increasingly reinforced by policy initiatives, particularly within the European Union, through ecodesign requirements and right-to-repair regulations that mandate access to spare parts, repair information, and software updates (Dalhammar et al., 2025).

Product longevity, however, cannot be understood solely as a technical attribute. Research highlights that replacement decisions are often driven by social, emotional, and cultural factors rather than functional failure alone (Hebrok, 2016; Madon, 2023). Concepts such as emotional durability (Chapman,

2009; Fletcher, 2012), psychological durability (Haug, 2018, 2019; Hebrok, 2014), and user attachment (Mugge et al., 2005; Mugge et al., 2010) emphasize that products remain in use when they acquire personal meaning and align with user identity. Product longevity thus emerges from interactions between design, consumer practices, emotional relationships, technological change, and socio-cultural context.

Within this framework, repair, reuse, and upcycling represent key consumer-level mechanisms for extending product lifespans. Repair prevents premature disposal and delivers greater environmental benefits than recycling or remanufacturing (McLaren et al., 2020; Wieser & Tröger, 2016). Reuse prolongs product life by transferring products to new users without significant material input, while upcycling adds new value by creatively transforming discarded products into items with renewed functionality (Fletcher & Grose, 2011; Paras & Curteza, 2018). Engagement in these practices ultimately depends on consumer willingness to act, as consumers remain the final decision-makers in whether products are maintained, repaired, or replaced (Ackermann et al., 2018). Consistent with the existing research, willingness to engage in circular behaviours is shaped by environmental concern, perceived value, emotional attachment, skills, and everyday consumption routines (Bocken et al., 2016; Cox et al., 2013; Laitala et al., 2021).

In line with this perspective, RQ1 examines consumers' willingness to repair, reuse, and upcycle products as a key behavioural dimension of circular economy transitions.

STRUCTURAL, INFORMATIONAL AND CULTURAL BARRIERS TO CIRCULAR CONSUMER PRACTICES

Despite increasing policy attention to circular economy principles, consumer engagement in repair, reuse, and upcycling remains constrained by a set of interrelated barriers. While circular design strategies and right-to-repair policies aim to enable product longevity, their effectiveness depends on whether consumers perceive repair and reuse as accessible, reliable, and worthwhile options in everyday consumption contexts (Ackermann et al., 2018; Ellen MacArthur Foundation, 2021).

A central group of barriers relates to product design and market structures. Many contemporary products are designed with limited reparability, relying on complex assemblies, proprietary components, and restricted access to spare parts, manuals, and tools (Bakker et al., 2014; Cooper, 2010; Masi et al., 2018).

Planned obsolescence – technical, aesthetic, or psychological – further accelerates replacement cycles by normalizing novelty and discouraging long-term use (Guiltinan, 2009; Sierra-Fontalvo et al., 2023).

Economic and practical barriers further influence consumer decisions. Repair services are often perceived as costly, time-consuming, or unreliable, particularly when low-cost replacement products are readily available (Sabbaghi et al., 2017; Sonego et al., 2022). Effective repair also depends on the long-term availability of spare parts throughout the product lifecycle, which is frequently neglected by manufacturers (Sabbaghi et al., 2017). Time constraints and limited access to skilled technicians add additional friction, especially in contexts with underdeveloped repair infrastructure (Sonego et al., 2022).

Informational and institutional barriers play a similarly important role. Consumers often lack clear knowledge of repair options, guarantees, and legal rights, increasing uncertainty and perceived risk associated with repair and reuse (Pérez-Belis et al., 2017; Suryantini et al., 2021). Limited transparency in producer communication and weak consumer protection mechanisms further undermine trust in repair as a viable alternative to replacement (Singh & Giacosa, 2019).

Social and cultural factors additionally shape consumer engagement. Prevailing norms frequently associate newness with quality and status, while repaired or reused products may carry negative symbolic meanings (Ger, 1997; Bajaj et al., 2021; Pérez-Belis et al., 2017). In sectors characterized by rapid aesthetic turnover, such as fashion and consumer electronics, these norms reinforce frequent replacement and discourage repair and reuse (Fletcher & Grose, 2011). Skill-related barriers are particularly relevant for upcycling, as creative reuse requires competencies and confidence that many consumers do not possess (Cova & Cova, 2012; Watson & Shove, 2008). Although community-based initiatives such as repair cafés and maker spaces can mitigate these limitations, their availability remains uneven (Cox et al., 2013; Spekkink et al., 2022).

Collectively, these findings, in line with RQ2, indicate that limited engagement in circular practices cannot be attributed solely to individual attitudes, but is also shaped by broader structural and institutional conditions that influence consumer choices.

RESEARCH FRAMEWORK AND METHODOLOGY

This study builds on circular economy literature that emphasizes product longevity through repair, reuse, and upcycling as key strategies for reducing

environmental impacts and extending the useful life of products. While international research identifies environmental awareness, perceived value, emotional attachment, and structural barriers as central determinants of these behaviours, empirical evidence from B&H remains largely absent. This lack of context-specific research represents a significant gap, particularly given the country's socio-economic characteristics and historically embedded repair practices.

In order to address this gap, the study focuses on two research questions. The first examines consumers' willingness to engage in repair, reuse, and upcycling as behavioural expressions of product longevity within a circular economy (RQ1). The second explores the barriers – structural, informational, economic, and cultural – that discourage these practices and contribute to the persistent gap between pro-environmental attitudes and everyday consumption behaviour (RQ2). Together, these questions reflect the dual emphasis of the theoretical framework on both motivational drivers and systemic constraints shaping circular consumer practices.

The conceptual framework directly informed the empirical design of the study. A quantitative online survey was conducted between July and August 2024 within the Interreg Euro-MED REPper project, which aims to strengthen repair ecosystems, support small and medium-sized enterprises, develop repair-related skills and infrastructure, and promote a culture of product longevity across participating countries. The pronounced shortage of empirical research on repair, reuse, and upcycling behaviours in B&H served as the primary motivation for undertaking this study within the project context.

The questionnaire was developed by the authors based on a review of recent international literature on sustainable consumption and circular economy practices. As no validated measurement instruments exist for this specific national context, survey items were adapted to capture consumers' attitudes, past behaviours, perceived motivators, experienced barriers, and socio-demographic characteristics. Given the exploratory nature of the research and the absence of prior empirical studies in B&H, the analysis relies primarily on descriptive statistics to establish baseline patterns of consumer engagement in repair, reuse, and upcycling. In order to examine whether socio-demographic characteristics are associated with engagement in repair and upcycling, binary logistic regression models were estimated. Repair and upcycling behaviour were specified as dichotomous dependent variables (yes/no), while age, gender, education, employment status, income, marital status, number of children, and place of residence were included as predictors. Given the exploratory and cross-sectional design of the study, the regression analyses were intended to identify potential associations rather than establish causal relationships.

By combining a theoretically grounded framework with an exploratory empirical approach, the study provides an initial evidence base for understanding consumer-driven pathways toward circular consumption in B&H. The findings offer a foundation for future research employing more advanced analytical techniques, and support the development of targeted policy and practice interventions aimed at strengthening repair-oriented circular economy strategies.

SAMPLE CHARACTERISTICS

A total of 450 respondents participated in the online survey conducted between July and August 2024. The sample consists of consumers from across B&H who voluntarily completed the questionnaire. The age structure is broad, with most respondents aged 36–45 (36.4%), followed by 46–55 (29.8%) and 26–35 (22.2%) age groups. Younger adults (18–25) make up 6.2%, and those over 56 account for 5.3%. The sample is predominantly female (80.9%), with 19.1% male respondents. Most participants hold a university degree (80.9%), while 18.7% completed secondary school.

Regarding employment, 82.2% are employed, while 8.4% are unemployed, 4.4% are students, 3.1% are self-employed, and 1.3% are retirees. Income levels are mostly average (57.3%), with 28.9% being above average and 13.8% below average. In terms of household structure, 69.3% live with a spouse or partner, 26.2% live alone, and 4.4% live with parents. Almost half (45.3%) the participants have no children, while 23.1% have one and 26.2% two.

A large majority reside in urban areas (84.9%), compared to 15.1% living in rural settings. Collectively, the sample is predominantly urban, well-educated and economically active, providing a solid basis for analysing repair, reuse, and upcycling behaviours in B&H, while acknowledging the inherent limitations of non-probability sampling.

RESULTS AND DISCUSSION

The results are presented and interpreted below, in line with the two research questions and providing a coherent analytical framework for understanding consumer repair, reuse and upcycling practices.

FINDINGS RELATED TO RQ1: CONSUMER WILLINGNESS TO REPAIR, REUSE, AND UPCYCLE PRODUCTS

Addressing the RQ1, the findings reveal strong pro-environmental orientations and clear patterns in consumers' willingness to repair, reuse and upcycle products. The survey results show that respondents in B&H consistently express environmental values that form a robust foundation for circular behaviours. Environmental protection is described as a personal life priority with an average of M=4.12 (Median=4, Mode=4, SD=0.897), and the narrow spread around the mean suggests that agreement with this statement is not only widespread, but deeply anchored in the participants' value systems. The willingness to modify everyday habits for environmental reasons is rated even higher, reaching M=4.37 (Median=5, Mode=5, SD=0.778). The maximum median and mode indicate a strong readiness to act.

These strong personal commitments contrast sharply with the perceptions of institutional engagement. Respondents overwhelmingly disagree that local authorities pay sufficient attention to environmental issues (M=1.63, Median=1, Mode=1, SD=0.765), and they similarly rate media attention as inadequate (M=1.92, Median=2, Mode=2). Assessments of environmental education in schools are only marginally higher (M=2.25, Median=2, Mode=2, SD=0.951). Overall, these results reflect a consistent belief that institutions are not providing adequate support, forming an important contextual backdrop: consumers hold strong environmental values, but do not feel institutionally empowered or encouraged to act on them.

Perceptions of personal consumption are more nuanced. Respondents are divided on whether their households generate "a lot of waste," reflected in moderate agreement (M=3.33, Median=3, Mode=4, SD=1.047). A similar pattern emerges for the perception of buying "more products than needed" (M=3.17, Median=3, Mode=4, SD=1.211). The higher standard deviations in both indicators suggest heterogeneous views – some participants recognize overconsumption, while others do not perceive their habits as problematic. This variation hints at segmentation potential for future circular economy interventions. Collectively, these attitudinal findings confirm that environmental values are strong, but do not automatically translate into consistent circular practices.

These attitudinal trends become more concrete when linked to preferences for product longevity. Many respondents prefer using products longer rather than replacing them prematurely (M=3.87, Median=4, Mode=4, SD=0.992), and similarly express preference for repairing broken items rather than buying

new ones (M=3.62, Median=4, Mode=4, SD=1.109). The alignment of median and mode at 4 in both cases reflects a pronounced normative orientation toward extending product lifetimes. Near-one standard deviations indicate meaningful differences among consumers: while the general tendency favours longevity and repair, the intensity of this preference varies across groups.

Compared to these strong orientations toward repair and longevity, attitudes toward upcycling remain considerably more neutral. The statement "I prefer to turn old products into new items instead of throwing them away" yields M=3.14 (Median=3, Mode=3, SD=1.212), a combination that points to limited consensus and broad variability. Upcycling is not yet a culturally normalized practice, likely requiring more skills, creativity or time than many consumers currently possess.

This attitudinal landscape is mirrored in actual consumer behaviour. Repair is already relatively common – 57.3% of respondents report having repaired a product themselves, while 42.7% have not. Upcycling, however, is far less widespread – only 28.4% have engaged in it independently, 18.7% have experienced it through someone else, and 52.9% have never upcycled any item. This reinforces the assumption that repair is familiar and feasible, whereas upcycling remains peripheral and skill dependent.

Intended behaviour in end-of-life and breakdown scenarios provides further insight. When considering the end of a product's useful life, donation clearly dominates socially shareable goods – 74.3% would donate clothing and 53.0% would donate sports or recreational equipment. Upcycling remains marginal (generally between 6.7% and 14.1%), while disposal is prevalent for technically complex categories, such as small household appliances (64.3%) and miscellaneous electronics (42.9%). These differences point to a strong product-dependent logic – respondents readily circulate items perceived as still useful or emotionally neutral, but tend to discard goods requiring specific expertise or technical handling.

A different pattern emerges when products break. Repair becomes the dominant intended action for high-value or technical items – a clear majority would seek repair for mobile phones (63.2%), computers (65.5%), audio/TV equipment (62.9%), and large household appliances (55.0%). These behavioural intentions align closely with attitudinal indicators (median and mode=4 for repair preference), underscoring the cultural embeddedness of repair – particularly when replacement is costly or technically demanding. For categories such as clothing or furniture, respondents more often choose donation, disposal, or replacement, consistent with lower product value and lower emotional or functional attachment.

Additional attitudes deepen this understanding. Regular waste sorting is not widely practiced, with a mean of M=2.77 (Median=3, Mode=1, SD=1.453), indicating significant variability – while some respondents engage in sorting, many do not. Conversely, interest in learning more about reuse, upcycling, and repair is high (M=4.06, Median=4, Mode=5, SD=1.008), revealing a strong educational appetite, especially among those lacking confidence or experience in circular practices. Motivational structures add further clarity. The most commonly selected reasons for engaging in repair or reuse include extending product lifetime (17.2%), acting out of environmental awareness (16.2%), and achieving financial savings (13.6%). Creativity and enjoyment motivate 9.1%, while emotional attachment contributes 8.9%. High product prices (7.8%) and availability of repair services (6.0%) play smaller roles, and formal legal requirements (3.2%) remain the least influential. This distribution confirms that circular behaviours are primarily driven by functional, ecological, and economic motivations rather than regulatory or institutional pressures.

In order to examine whether socio-demographic characteristics influence the likelihood of having repaired products, a logistic regression analysis was conducted. The overall model was statistically significant, $\chi^2(17)=31.0$, $p=0.02$, indicating that the predictors as a set distinguished between respondents who had engaged in repair and those who had not. However, the explanatory power was modest (McFadden $R^2=5.01\%$), and the model correctly classified 64.1% of the cases, suggesting that socio-demographic variables explain only a limited portion of variance within this sample. None of the individual socio-demographic variables emerged as statistically significant predictors of repair behaviour, indicating that repair engagement in this sample does not appear to be strongly differentiated across socio-demographic groups. Consistent with these results, non-parametric statistical tests showed no statistically significant differences between respondent groups across socio-demographic characteristics, confirming that repair-, reuse- and upcycling-related behaviours are broadly shared regardless of age, gender, education, income, or household structure.

With the aim of further examining the determinants of upcycling behaviour, a logistic regression analysis was conducted using socio-demographic variables as predictors. The model was statistically significant, $\chi^2(14)=31.3$, $p=0.005$, indicating that the predictors as a set distinguished between respondents who had upcycled a product and those who had not. However, the explained variance was modest (McFadden $R^2=5.08\%$), and the model correctly classified 61.0% of the cases, suggesting that socio-demographic variables explain only a limited portion of variance within this sample. One socio-demographic factor emerged as significant – gender. Female respondents were

approximately twice as likely to engage in upcycling than male respondents (OR=2.006, 95% CI [1.196, 3.364]). No statistically significant effects were found for age, education, employment status, income, marital status, number of children, or place of residence.

These findings indicate that, within this sample, repair behaviours do not appear to be strongly differentiated across socio-demographic groups, whereas upcycling is more gender-differentiated, with women more likely to engage in creative reuse. Overall, respondents demonstrate readiness for circular practices that are familiar, practical, and economically meaningful, with repair emerging as the most culturally embedded form of circularity, reuse through donation as well-established, and upcycling remaining limited and unevenly understood. These patterns confirm the key determinants identified in RQ1 and highlight a context-specific strength – the comparatively high prevalence of hands-on repair experience in B&H, which offers potential for scaling repair-oriented initiatives.

Together, these findings provide a layered picture of willingness across attitudes, past behaviour, and intended action. The relatively high prevalence of repair engagement in this sample is broadly consistent with findings from other European contexts, where repair behaviour remains more common for higher-value and technically complex products (Wieser & Tröger, 2016; Laitala et al., 2021). However, the comparatively strong stated willingness observed here may reflect contextual or cultural factors specific to B&H.

While the above findings illustrate the respondents' willingness to engage in circular practices (RQ1), the following section examines the structural and perceived barriers that may limit the realization of these intentions (RQ2).

FINDINGS RELATED TO RQ2: BARRIERS TO REPAIR, REUSE AND UPCYCLING

In contrast to the relatively strong pro-environmental orientations identified under RQ1, the respondents reported multiple barriers that constrain behavioural realization.

Consistent with RQ2, the findings reveal a complex and layered structure of barriers that collectively limit consumers' ability to translate positive environmental attitudes into consistent circular behaviours. These barriers include perceived high repair costs, limited repair infrastructure, lack of knowledge and skills, insufficient time, availability of cheaper replacement products, and low institutional support, each playing a distinct role in shaping behaviour.

A striking insight concerns the perceived availability and reliability of professional repair services. Respondents generally disagree that there are enough skilled repairers available in their communities, with a mean of M=2.37 (Median=2, Mode=2, SD=1.079). This perception reflects both geographic disparities and systemic underdevelopment of repair infrastructure. Combined with parallel results showing that respondents lack detailed knowledge of repair rights and guarantees (M=2.95, SD=1.102), it becomes clear that informational gaps and infrastructural deficiencies jointly constrain consumers' ability to choose repair as a default behaviour.

The survey also captures specific barriers that discourage repair and upcycling. The most frequently selected obstacles include the high price of repair services (10.5%), lack of information or necessary skills (10.3%), limited time (9.6%), perceptions of inferior quality of repaired products (8.0%), and insufficient availability of professional repairers (11.9%). These obstacles span economic, technical, informational and practical domains, indicating multiple overlapping challenges. Interestingly, the presence of cheaper new replacement products (6.4%) also discourages repair – a reflection of market dynamics in which low-quality, low-cost imported goods make replacement economically attractive, a trend noted in international circular economy literature.

Collectively, these findings show that repair intentions are concentrated in technically complex and higher-value products (such as mobile phones, computers, audio/TV equipment and large household appliances), whereas clothing, furniture and other lower-value items are more often candidates for donation, replacement or disposal rather than repair.

The perception that "new products are more advanced" represents another important psychological barrier, chosen by 10.2% of the respondents. This reflects a form of technological bias – the belief that newer technology inherently offers superior performance – an attitude that has been documented as a strong driver of replacement behaviour in consumer electronics markets. Relatedly, respondents emphasized product obsolescence (14.8%), indicating that many items are replaced not solely due to malfunction, but due to perceived or actual outdatedness.

One of the most significant systemic barriers concerns the shortage of spare parts for older models, noted by participants in the open-ended categories as a frequent limitation. Although this response appears in a small numeric category in the dataset, its presence signals structural constraints at the market level – manufacturers may restrict access to repair-relevant components, thereby limiting repairability and nudging consumers toward replacement. This aligns with the EU "right to repair" efforts to reduce producer-driven barriers.

Time-related barriers also play a non-negligible role. With 9.6% of the respondents selecting lack of time, repair and upcycling are perceived as activities requiring more effort than consumers can realistically invest. This mental and practical cost becomes particularly salient when repair competes with easily accessible low-priced replacement options.

Importantly, lack of knowledge and skills represents one of the most prominent barriers, chosen by 10.3% of the respondents. This aligns with attitudinal variability observed in upcycling-related measures (M=3.14, SD=1.212), which indicates uneven familiarity with creative reuse practices. The combination of interest in learning more (M=4.06, SD=1.008) and low actual confidence suggests a large potential for capacity-building interventions such as community workshops, repair cafés, maker spaces, or educational programs – activities that directly align with the objectives of the Interreg REPper project.

Institutional barriers extend beyond repair infrastructure to include perceptions of inadequate consumer protection. Respondents express low confidence that consumers in B&H are effectively protected (M=2.08, Median=2, Mode=1, SD=0.951) and strongly believe that consumers abroad enjoy better protections (M=4.13; Median=4, Mode=5). These sentiments discourage engagement in repair because consumers may feel uncertain about their rights, guarantees, or the recourse they have when repair services fail to meet expectations. Similarly, a low mean score of M=1.96 (Median=2, Mode=1, SD=0.998) for the belief that producers adequately inform consumers about their repair-related rights reveals a significant information asymmetry.

The perceived low reliability of repaired products (8.0%) further compounds these barriers. Many respondents believe that repaired items do not perform as well as new ones. This perception is reinforced by everyday consumer experience in markets where service quality is inconsistent and standardized procedures for repair, certification, and guarantees are limited. Such perceptions discourage experimentation with repair and shift consumer preferences toward purchasing new goods.

Financial considerations manifest both as direct repair costs and broader economic trade-offs. Although repair cost is the most frequently selected barrier (10.5%), the perceived high price of new products (7.8%) also appears among motivators for engaging in repair. This duality underscores the context-specific economic logic within the B&H market: repair becomes attractive only when new products are sufficiently expensive, while replacement is preferred when affordable alternatives exist. This cost-based calculus plays a central role in shaping circular behaviours.

Finally, the extremely high variability in waste sorting practices (M=2.77, SD=1.453, Mode=1) and uneven familiarity with consumer rights reflect broader systemic limitations: environmental practices require infrastructure, information, and public trust. Without these, even highly motivated consumers may struggle to consistently choose circular options. Collectively, the findings reveal that circular behaviours in B&H are constrained by a multi-dimensional barrier ecosystem, where structural, informational, economic, and practical obstacles intersect. While consumers hold strong pro-environmental values and express clear interest in circular practices, they frequently encounter conditions that undermine follow-through. Addressing these barriers may require integrated interventions – improving repair infrastructure, expanding consumer education, enhancing transparency from producers, strengthening regulatory frameworks, and aligning incentives in favour of repair and reuse. These barriers directly reinforce the strategic relevance of the Interreg REPper project, which seeks to strengthen local repair ecosystems and empower consumers to adopt more sustainable product-use behaviours. Non-parametric statistical tests showed no statistically significant differences in perceived barriers across socio-demographic groups, indicating that structural, informational and economic obstacles to repair, reuse and upcycling are experienced broadly and consistently within the population. These patterns collectively validate RQ2 by demonstrating that structural, informational and economic constraints substantially weaken consumers' capacity to act on their positive environmental intentions.

The findings also contribute to the broader theoretical discussion on product longevity and the attitude–behaviour gap in sustainable consumption. Although respondents express strong pro-environmental values and willingness to engage in repair and reuse, structural and economic barriers frequently limit behavioural realization. This pattern is consistent with prior research highlighting the persistence of the attitude–behaviour gap in circular consumption practices.

The identified barriers – particularly perceived repair costs, lack of spare parts, and limited repair infrastructure – closely mirror the challenges reported in prior research across EU and non-EU contexts. This suggests that the structural constraints observed in B&H are not unique, but rather reflect broader systemic tensions within contemporary consumption systems.

Furthermore, the product-specific nature of repair intentions – particularly for higher-value and technically complex goods – aligns with literature on product longevity, which emphasizes that replacement decisions are shaped not only by functional failure but also by perceived value, cost considerations,

and emotional attachment. The limited prevalence of upcycling suggests that circular practices requiring higher levels of creativity and competence remain less embedded, supporting theoretical perspectives that stress the importance of skills, user attachment, and everyday routines in extending product lifetimes.

CONCLUSIONS AND RECOMMENDATIONS

Based on the analysed non-probability online sample, the findings indicate that respondents in B&H express strong pro-environmental values and, consistent with RQ1, demonstrate a clear willingness to engage in repair, reuse, and – to a lesser extent – upcycling practices. Repair emerges as the most embedded circular practice, particularly for higher-value and technically complex items, while donation dominates for lower-value goods. Upcycling remains limited to specific consumer groups, underscoring the role of product characteristics and required competencies in shaping circular choices. These patterns align with the ongoing EU "right to repair" initiatives and point to the importance of harmonizing national policies with emerging European standards.

In line with RQ2, the respondents face multiple barriers that hinder the translation of positive intentions into action. High repair costs, limited availability of skilled repairers, lack of technical knowledge, time constraints, and the affordability of replacement products all discourage repair. Institutional and informational barriers – such as low trust in consumer protection mechanisms, limited awareness of repair-related rights, and scepticism toward producers' claims – further weaken the confidence in repair as a reliable option. Together, these factors constrain the enabling environment necessary for a wider adoption of circular practices.

These findings carry several policy and practice implications. These recommendations are derived from the perceptions reported by the respondents, and should be interpreted as indicative rather than as evidence of direct causal effects. Strengthening consumer protection enforcement, clarifying repair-related rights, and improving transparency in after-sales communication may support greater confidence in repair services. Specific instruments could include repair voucher schemes for households, certification programs for professional repair providers to enhance service quality and consumer trust, and public support for local repair hubs and training initiatives aimed at strengthening technical skills and access to spare parts. Expanding repair infrastructure through technician training, certification schemes, and incen-

tives for small repair businesses could help address critical supply-side gaps. Educational institutions, civil society, and community initiatives can promote repair literacy and practical skills through workshops, repair hubs, and public campaigns highlighting the economic and environmental value of product longevity. Producers and retailers should also improve the visibility and clarity of repair information to rebuild consumer trust.

The composition of the sample may also have influenced the observed levels of environmental orientation and engagement in circular practices. The predominance of female, urban, and highly educated respondents may be associated with higher environmental awareness and greater familiarity with sustainability-related issues, as suggested in previous research. Urban residence may also facilitate access to repair services and donation networks. Consequently, the reported levels of willingness and engagement may reflect the characteristics of this specific respondent profile rather than the broader population.

Several limitations should be acknowledged. The non-probability, self-selected online sample limits the generalizability of the findings, particularly given the predominantly female, highly educated, and urban composition of the respondents, while reliance on self-reported data may introduce social desirability bias. Given the composition of the sample, the findings should be interpreted as indicative rather than representative of the broader population of B&H. Future research would benefit from more representative sampling, longitudinal designs, and cross-regional comparisons, complemented by qualitative and more advanced analytical approaches.

Despite these limitations, the findings provide indicative evidence of substantial potential for strengthening the repair ecosystem in B&H, particularly among the environmentally oriented and urban consumers represented in this sample. With coordinated policy action, improved information flows, and targeted capacity-building, the existing consumer motivation may be translated into more consistent circular behaviour, potentially contributing to environmental sustainability and supporting the broader objectives of the REPper project.

Beyond the national context, the findings may also be relevant for other middle-income and transition economies where traditional repair practices coexist with the increasing availability of low-cost replacement products. The results suggest that circular transitions in such settings depend not only on consumer motivation but also on institutional capacity, repair infrastructure, and regulatory alignment with broader European frameworks.

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INNOVATION PATHWAYS FOR CIRCULAR ECONOMY ADOPTION IN SMALL FAMILY BUSINESSES: A CONCEPTUAL FRAMEWORK

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Background: The global shift from the traditional linear "take - make - dispose" model to a circular economy (CE) has become an imperative driven by environmental pressures, resource scarcity, and the growing need for sustainable and resilient economic systems. This transition highlights the importance of businesses, including small family businesses (SFBs), in implementing circular practices such as resource recovery, waste minimisation, and closed-loop operations. Although the existing academic and policy discussions tend to highlight the capacity of large multinational corporations to lead this transition, the potential contribution of small family businesses (SFBs) remains significantly underexplored. This is particularly relevant in emerging economies, where SFBs not only represent a major share of the business landscape, but also possess distinctive characteristics—such as long-term orientation, intergenerational continuity, and strong community embeddedness—that can enable them to act as effective agents of circular transformation. However, despite these advantages, SFBs face substantial constraints, including restricted access to finance, limited technological expertise, and inadequate institutional support. These challenges hinder their ability to innovate and adopt circular practices, creating a clear gap in the literature regarding

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the mechanisms through which SFBs can leverage innovation to overcome structural barriers and integrate circular economy principles into their operations. Emphasising circular economy principles within SFBs is essential for sustainable local development and for promoting more resilient economic systems in emerging economies.

Purpose: This paper aims to examine how innovation can serve as a strategic driver in facilitating the transition of SFBs to circular economy models, with a focus on the specific challenges and opportunities present in emerging economies. Specifically, the study investigates how the adoption of circular strategies in products, processes, and business models can enhance both environmental sustainability and the long-term competitiveness of SFBs. The objective is to develop a conceptual framework that links the organisational features of family firms with innovation pathways—product, process, and business model innovation—to explain how SFBs can simultaneously generate economic value and reduce environmental impact.

Method: The study follows a conceptual and qualitative research approach supported by a thorough review of the literature and a thematic analysis. A total of 68 peer-reviewed articles and specialist publications in the domains of circular economy, innovation studies, and family business research were analysed. This selection ensures a comprehensive understanding of how circular economy principles intersect with innovation and family business practices. The evidence was synthesised into an integrative conceptual framework categorising three forms of circular innovation: product innovation (enhanced durability and reparability), process innovation (resource efficiency and closed-loop systems), and business model innovation (product-as-a-service models and local industrial symbioses). Each form is explicitly evaluated for its contribution to advancing circular economy objectives. The analysis also considers internal enablers—such as long-term vision and intergenerational stewardship—and external drivers, including targeted policies, knowledge-sharing platforms, and financial incentives.

Conclusion: The findings indicate that SFBs can play a significant role in advancing the circular economy when innovation aligns with their inherent strengths. By adopting circular practices, SFBs can contribute not only to environmental sustainability, but also to building resilient, locally embedded economic systems. Innovation in business models is identified as the most transformative path, enabling sustained value retention and recurrent revenue generation. However, persistent barriers—financial constraints, linear mindsets, and weak institutional frameworks—limit progress. Tai-

lored policy measures supporting the unique nature of SFBs are, therefore, essential to accelerate the circular transition. Such measures would facilitate the integration of circular economy principles into everyday business operations, maximising both the social and ecological impact.

Keywords: *Innovation, family business, circular economy, green transition, sustainability*

JEL classification: *L26, O31, Q57*

INTRODUCTION

Transitioning from a linear economy to a circular economy (CE) requires a paradigm shift in how resources are consumed and how waste is generated to support sustainability and boost the economy's resilience. Within emerging economies of long-term nature and local embeddedness, small family businesses (SFBs) could prove to be important actors in adopting and implementing CE. Studies have shown that family-owned SMEs integrate circular innovations at a higher rate than their non-family counterparts, as a result of their linkage to the surrounding communities and ecosystems (Goyal et al., 2016; Lodh et al., 2013).

There is a steep transition to CE, but there are also many challenges. SFBs often face strong impediments, including limited accessibility of funding, inadequate understanding of CE practices, and hierarchical thinking that stifles technological innovation (Geissdoerfer et al., 2017). The exigency of deploying CE principles in developing economies is further exacerbated by fast-paced consumption behaviours and resource limitations, leading to a desperate demand for sustainable business models that fulfil the dual economic and ecological priorities (Rehman et al., 2022; Kuik et al., 2023). Research has further established that innovation in circular economy contributes to the competitive advantage and global performance of SMEs in terms of furthering the triple bottom line sustainability: environmental, social, and economic (Goyal et al., 2016; Gil-Lamata & Martínez, 2022).

Innovation is key to enabling this transition, particularly through new products, improved production processes, and the development of circular business models. Examples such as the "Product as a Service" (PaaS) and local industrial symbioses represent ways to re-conceptualise the SFBs' business model that is committed to a circular economy, where ownership and resource loops exist in the organisation's locality (Geissdoerfer et al., 2020;

Bocken et al., 2019). Business models should evolve to embrace circularity, transitioning from being an "optional" tactic to becoming "an economic imperative for our sustainability and competitive existence" (Mamedova et al., 2022; Huynh, 2021).

In order to execute these innovations, this approach requires overcoming certain challenges that SFBs face, such as financial limitations and more entrenched, linear thinking practices that can prevent the adoption of circular innovations (Gatto & Re, 2021; Kurek et al., 2023). As a result, this study seeks to identify novel pathways that SFBs can utilise with the aim of improving the integration of CE principles. We synthesise the insights from innovation studies, family entrepreneurship, and circular economy literature, and develop a framework for approaching circular innovations specifically for SFBs. This work effectively addresses an academic gap by placing family businesses in the CE narrative, as well as providing lessons for setting appropriate public policies that integrate the opportunities and challenges of family firms in resource-poor environments (Geissdoerfer et al., 2017; Rehman et al., 2022; Gil-Lamata & Martínez, 2022).

In conclusion, although the development of circular business models is a strategic necessity for SFBs in developing countries, it may only become a productive strategy through the integration of sustainable concepts, innovative practices, and supportive policies. Such a multifaceted approach requires collaboration among stakeholders to bridge the transition to a circular economy and ultimately position SFBs as key actors in seeking sustainability in both local and global contexts (Yew, 2021).

Despite growing interest in circular economy practices, research on small family businesses—particularly in emerging economies—remains scarce. Existing studies mostly examine large corporations or generic SMEs, neglecting the specific features of family-owned firms. This study addresses that gap through a conceptual, literature-based approach that integrates circular economy, innovation, and family business research, and proposes a framework showing how product, process, and business model innovation can foster circular economy adoption in small family businesses.

LITERATURE REVIEW

The notion of a circular economy (CE) is gaining more and more popularity as an innovation paradigm that aims to encourage sustainable growth and resource efficiency. It supports a transition from the typical linear process

of "take-make-dispose" to a more regenerative model in which raw materials are reused repeatedly and value accrues along the product life cycle (Goyal et al., 2016). Although prominent literature has tended to emphasise large businesses and institutions, there is a growing recognition of the significant role that Small and Medium-sized Enterprises (SMEs) have to play in the adoption of CE. While many of the opportunities associated with a circular economy include the use of renewable energy and automation, one segment we have not discussed is SMEs' ability to drive long-term sustainable innovations through unique attributes such as long-term engagement with the community (Min et al., 2021; Mitropoulos et al., 2023).

Innovation plays an important role as a catalyst for CE adoption, consisting of three main types: product, process, and business model innovation. While traditional CE models are a driving force behind technological advancements, new CE models focus on sustainability and innovation. Innovation in products, especially, revises products to create features such as longevity and recyclability (Halog et al., 2021). Such innovations are frequently derived from deep familiarity with specific local consumer demands and from a family-oriented quality commitment of SFBs (Min et al., 2021). Process innovations focus on improving economies of resources, which family businesses are adept at with a long-term focus, as well as a higher propensity for financial investment, as an example (Mitropoulos et al., 2023). Business model innovation is a strategic priority for SFBs because it involves the development of PaaS and leasing practices, which not only help reduce resource consumption, but also redefine the mechanisms that create and deliver value (Geissdoerfer et al., 2020; Min et al., 2021). Studies reveal that business model innovations are one of the most powerful levers for SMEs on their journey towards a CE, transforming their customer engagement and resource utilisation (Rizos et al., 2016).

Family firms have specific features that drive the acceleration of their CE innovation efforts. SFBs exhibit a longer planning horizon compared to non-family firms, enabling them to prioritise sustainability as a keystone approach rather than short-term profits (Min et al., 2021). Family members engaging in the process will typically bring greater agility in decision-making and, therefore, create an environment where experimentation with circular practices can be encouraged (Mitropoulos et al., 2023). Furthermore, SFBs have local embeddedness enabling them to engage in industrial symbiosis through collaborative initiatives, converting waste to value (Min et al., 2021).

SFBs, although having their own comparative advantages, encounter significant challenges in adopting CE innovations, such as financial barriers, lack of access to specialised knowledge, and the dominant linear ways of thinking

(Halog et al., 2021). According to the literature, supportive public policy interventions are needed to bridge the gaps created by such barriers. The adoption of policy measures, including financial incentives, knowledge transfer programmes, and collaboration networks among relevant parties in the organisation, is imperative to support SMEs (of which family businesses are vital) in integrating CE principles into their business practices (Rizos et al., 2016; Min et al., 2021). Despite the existing resource constraints and environmental pressures to promote circular practices, institutional weaknesses and little to no infrastructure could present barriers to implementation (Halog et al., 2021; Min et al., 2021). Research indicates that SFBs in these areas may need flexible strategies, taking into account product, process, and business model innovations tailored to local needs, as well as maximising resource utilisation (Mitropoulos et al., 2023).

Thus, based on the available literature, it was found that SFBs possess a unique potential to function as catalysts for CE adoption due to their long-range orientation, community relatedness, and potential for innovation. Innovation in product, process, and business models is necessary to make this shift. Research on SFBs within the CE context is also needed, particularly in developing economies, regarding the potential development of SFBs as a catalyst for creating strategic channels for circular and sustainable business expansion, as well as economic growth and development strategies, in order to ensure that circular practices are sustainable.

METHODOLOGY

The decision to adopt a conceptual and literature-based methodology is motivated by the limited number of empirical studies examining circular economy adoption specifically within small family businesses. The existing research is fragmented across several fields, including sustainability studies, innovation management, and family business research. A conceptual synthesis, therefore, allows the integration of these perspectives and facilitates the identification of common patterns and mechanisms that may support circular transformation. Such an approach also provides a theoretical foundation that can guide future empirical investigations.

This study adopts a conceptual and qualitative approach to examine the process of innovation and how the modalities of innovation enable small family businesses (SFBs), especially in emerging economies, to adopt a circular economy (CE) approach. Considering that there are limited empirical stud-

ies on CE among SFBs, the qualitative conceptual framework was chosen because it permits the identification and synthesis of patterns, themes, and mechanisms from the existing literature (Goyal et al., 2016; Lodh et al., 2013).

RESEARCH DESIGN

The study, theoretical and exploratory, seeks to develop a more nuanced understanding of the interrelationships between family firms, innovation modalities, and CE adoption. Qualitative research is important because of limited empirical data about SFB practices in the circular economy, especially as it pertains to emerging economies. This requires the integration of understanding from different domains such as entrepreneurship, sustainability, and innovation management (Ullah et al., 2021; Geissdoerfer et al., 2017). The research study is structured around the following three main investigation questions:

1. Which types of innovation (product, process, business model) are most critical for CE adoption in SFBs?
2. What role do the unique characteristics of SFBs (long-term orientation, intergenerational knowledge, community embeddedness) play in supporting or constraining CE innovation?
3. What external factors, including public policies and infrastructure, facilitate or limit the integration of circular practices into emerging economies?

LITERATURE REVIEW PROCEDURE

In order to enhance methodological transparency, the literature selection process followed the principles derived from the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Page et al., 2021). Although the present study does not constitute a fully systematic review, PRISMA guidelines were used to structure the identification, screening, and eligibility assessment of relevant academic publications. The literature selection procedure is illustrated in *Figure 1*, which presents the PRISMA flow diagram summarising the stages of the review process.

Relevant publications were identified through database searches conducted in Scopus and Web of Science, with Google Scholar used as a complementary source to capture additional relevant studies. The search focused on

peer-reviewed articles published between 2010 and 2024, addressing themes related to circular economy implementation, innovation in small and medium-sized enterprises (SMEs) and family businesses, and sustainability transitions in emerging economies.

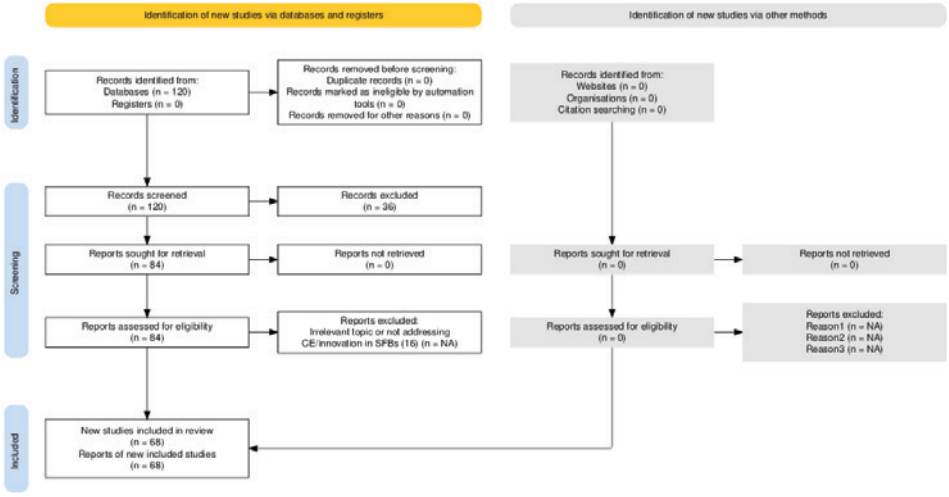
The inclusion criteria consisted of:

(1) studies addressing circular economy implementation;
(2) research examining innovation in SMEs or family businesses; and
(3) publications discussing sustainability transitions in emerging economies.

Exclusion criteria included non-peer-reviewed publications, conference abstracts without full papers, and articles not written in English.

The search process initially generated 120 publications. After screening the titles and abstracts for relevance, 36 records were excluded, leaving 84 articles for full-text assessment. Following the eligibility evaluation, 16 studies were excluded due to limited relevance to circular economy innovation in small family businesses. The final corpus, therefore, consisted of 68 publications, which formed the basis of the qualitative content analysis.

Figure 1. PRISMA flow diagram illustrating the literature selection process



Source: Authors' elaboration based on PRISMA guidelines (Page et al., 2021). The diagram was generated using the PRISMA 2020 Shiny application (Haddaway et al., 2022).

The review focused on three core thematic areas:

- **Circular Economy (CE):** Principles, frameworks, and implementation strategies, particularly in relation to SMEs and lifecycle management.
- **Innovation in SMEs and family businesses:** Typologies of innovation (product innovation, process innovation, and business model innovation) and the strategic capabilities supporting their implementation.
- **Small family businesses (SFBs):** Organisational structures, intergenerational succession, long-term orientation, and community embeddedness influencing strategic decision-making.

The search strategy involved combinations of keywords such as "family business" AND "circular economy", "SME" AND "innovation" AND "sustainability", and related terms referring to innovation types within the context of the circular economy in emerging economies. Only English-language, peer-reviewed publications published within the last 15 years were considered in order to ensure relevance and contemporary applicability (Rehman et al., 2022; Kuik et al., 2023; Gil-Lamata & Martínez, 2022). The final corpus of **68 publications**, identified through the PRISMA-guided screening process illustrated in **Figure 1**, formed the basis of the conceptual analysis (Geissdoerfer et al., 2020; Bocken et al., 2019).

CONCEPTUAL FRAMEWORK DEVELOPMENT

The conceptual framework was developed through a thematic and integrative analysis of the selected literature. The analysis synthesised insights from research on the circular economy, innovation management, and family business studies to identify the key mechanisms through which small family businesses (SFBs) can adopt circular economy (CE) practices. The framework focuses on three main innovation pathways—product innovation, process innovation, and business model innovation—which represent the primary strategic mechanisms enabling the transition from linear to circular production systems.

Product innovation refers to the redesign of products to enhance durability, reparability, and recyclability, thereby extending product life cycles and reducing material waste. Family businesses often leverage their close relationships with local customers and suppliers to introduce incremental product improvements aligned with sustainable consumption patterns (Mamedova et al., 2022; Huynh, 2021).

Process innovation focuses on improving operational efficiency by reducing energy consumption, optimising resource utilisation, and implementing

closed-loop production systems. Such improvements are particularly relevant for family firms, which frequently rely on incremental operational adjustments and long-term investment strategies to improve sustainability performance (Gatto & Re, 2021; Kurek et al., 2023).

Business model innovation represents the most transformative pathway for circular economy adoption. This form of innovation involves redefining how value is created and delivered, for example through product-as-a-service (PaaS) models, leasing arrangements, or industrial symbiosis initiatives that allow firms to retain ownership of resources while reducing waste generation (Yew, 2021).

The three innovation pathways identified in the literature and their key characteristics are summarised in *Table 1*.

Table 1. Innovation pathways supporting circular economy adoption in small family businesses

Innovation pathway	**Key mechanisms**	**Contribution to circular economy**	**Key references**
Product innovation	Development of durable, repairable, and recyclable products based on local market knowledge	Extends product life cycles and reduces waste generation	Mamedova et al. (2022); Huynh (2021)
Process innovation	Optimisation of production processes, reduction of energy consumption, improved resource efficiency	Enhances resource utilisation and supports closed-loop production systems	Gatto & Re (2021); Kurek et al. (2023)
Business model innovation	Adoption of circular models such as Product-as-a-Service (PaaS), leasing, and industrial symbiosis	Enables systemic circularity and long-term value creation	Yew (2021); Geissdoerfer et al. (2020)

Source: Authors' elaboration based on the reviewed literature

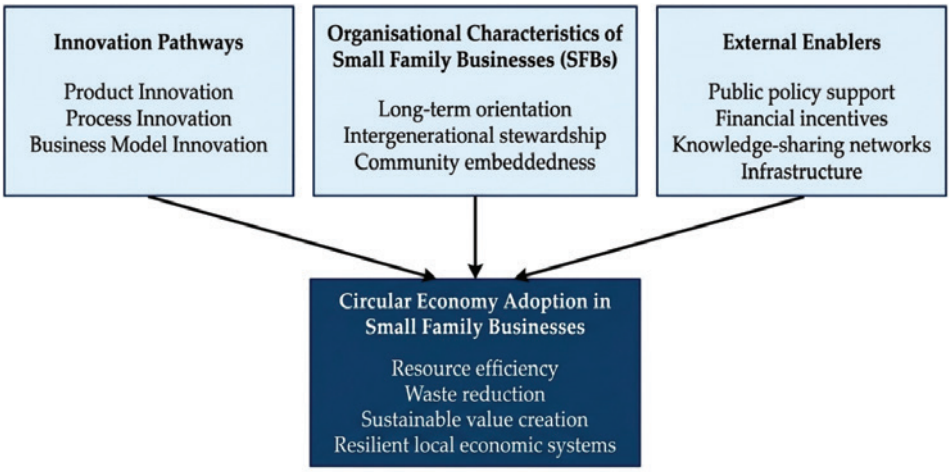
Beyond innovation mechanisms, the literature also highlights the importance of specific organisational characteristics typical of family-owned businesses. These include a long-term strategic orientation, intergenerational stewardship of resources, and strong community embeddedness. Such attributes can encourage sustainable decision-making and facilitate collaboration with local stakeholders.

At the same time, external enabling conditions play a crucial role in supporting circular transitions. These include public policy support, financial incentives for green innovation, knowledge-sharing networks, and the avail-

ability of appropriate infrastructure. Together, these organisational and institutional factors create the conditions under which innovation pathways can effectively translate into circular economy practices.

Figure 2 presents the integrated conceptual framework proposed in this study. The model illustrates how innovation pathways interact with organisational characteristics and external enabling factors to facilitate circular economy adoption in small family businesses.

Figure 2. Conceptual framework for circular economy adoption in small family businesses



Source: Authors' conceptualisation. Diagram generated using R software. R Core Team (2024)

The framework suggests that circular economy adoption in SFBs is the result of a multi-level interaction between internal innovation capabilities, organisational values, and supportive external environments. By integrating these elements, the framework provides a structured analytical model that can guide future empirical research on sustainability transitions in family-owned businesses.

SPECIFICATION OF CONSTRUCT RELATIONSHIPS AND CONCEPTUAL PROPOSITIONS

The framework proposes that the three innovation pathways (product, process, and business model innovation) have direct relationships with circular economy adoption outcomes, while organisational characteristics of SFBs function

as moderating variables, and external institutional factors operate as contextual moderators. Specifically, the organisational characteristics of SFBs—long-term orientation, intergenerational stewardship, and community embeddedness—are expected to strengthen the relationship between innovation pathways and circular economy adoption. External factors such as public policy support, financial incentives, and knowledge-sharing infrastructure moderate the overall capacity of SFBs to translate internal innovation efforts into sustained circular practices. To sharpen the explanatory value of the framework and facilitate future empirical testing, the following conceptual propositions were developed:

P1: Long-term orientation positively influences product innovation with circular characteristics (durability, reparability, and recyclability) in small family businesses.

P2: Intergenerational knowledge mediates the relationship between process innovation and resource efficiency outcomes in small family businesses.

P3: External institutional support (e.g., public policy incentives, financial instruments, and knowledge-sharing infrastructure) positively moderates the relationship between business model innovation and circular economy adoption in small family businesses.

P4: Business model innovation has a stronger systemic effect on circular economy adoption than product or process innovation alone, as it redefines value creation mechanisms.

These propositions transform the conceptual framework into a testable analytical model and provide a foundation for future empirical research.

DATA ANALYSIS

A qualitative content analysis of 68 peer-reviewed articles identified themes focused on three innovation types—product, process, and business model innovation—in small family businesses (SFBs) and SMEs. It examined the organisational attributes influencing circular economy (CE) adoption, including intergenerational orientation, family involvement, and decision-making structures, as well as external factors such as public policy, financial support, and institutional infrastructure, especially in emerging economies. These themes were integrated into a conceptual framework linking innovation pathways, organisational characteristics, and external enablers to CE adoption outcomes, strengthening its analytical foundation and highlighting gaps for further empirical research (Prieto-Sandoval et al., 2019; Gatto & Re, 2021; Scipioni & Niccolini, 2021).

In order to ensure methodological transparency, the thematic analysis followed a two-stage coding procedure. In the first stage (open coding), key concepts were identified from each article in relation to the three innovation types, organisational characteristics of SFBs, and external enabling conditions. Each article was read systematically and relevant passages were assigned to initial codes reflecting mechanisms, barriers, enablers, or outcomes associated with circular economy adoption. In the second stage (axial coding), initial codes were grouped into higher-order thematic categories: (1) circular innovation mechanisms (product, process, and business model innovation); (2) organisational facilitators (long-term orientation, intergenerational knowledge, community embeddedness); and (3) external contextual factors (policy support, financial instruments, institutional infrastructure). The synthesis strategy consisted of identifying recurring mechanisms and relationships across categories, with the aim of constructing an integrated conceptual framework. Divergent findings and contradictory evidence from the literature were noted and discussed as boundary conditions of the proposed framework.

This procedure allowed the analysis to move beyond descriptive literature mapping toward conceptual synthesis, by identifying how innovation pathways, organisational characteristics, and institutional factors interact in shaping circular economy adoption.

SCOPE AND LIMITATIONS

This study examines small family businesses (SFBs) in emerging economies, where circular economy adoption is strategically important but institutionally difficult. As a conceptual work based on secondary literature, it offers a theoretical synthesis rather than empirical evidence. The proposed framework should, therefore, be seen as an analytical model outlining potential innovation pathways, and not as empirically tested causal relationships. Future research should contribute empirical studies—such as case studies, surveys, or cross-country comparisons—on circular practices in family businesses.

CONTRIBUTION TO KNOWLEDGE

The method used enables the detection of specific innovation levers with which SFBs can implement CE principles successfully. Moreover, it sheds light on the interplay between organisational characteristics and external sup-

ports, offering actionable insights for policymakers and practitioners aiming to foster circular economy adoption within family-owned SMEs. Through an integrated theoretical perspective, this research fills an important gap in the literature at the confluence of family business research, innovation studies, and the circular economy. Additionally, it not only broadens our understanding of SFBs' role in promoting CE, but also sets a precedent for future empirical investigations that may validate and expand upon these theoretical contributions (Arsawan et al., 2025; Ferreira & Matias, 2021).

This study contributes to the literature in three main ways. The theoretical novelty of the proposed framework lies in its triadic integration of three analytical dimensions that the existing models treat separately. Unlike prior circular economy frameworks that focus primarily on large corporations or generic SMEs (Geissdoerfer et al., 2017; Bocken et al., 2019), and unlike family business research that rarely engages with circular economy mechanisms (Min et al., 2021), the present framework explicitly incorporates the distinctive organisational characteristics of small family businesses—long-term orientation, intergenerational stewardship, and community embeddedness—as moderating variables shaping the effectiveness of three circular innovation pathways. Furthermore, the framework situates these dynamics specifically within the institutional context of emerging economies, where structural barriers differ substantially from those addressed in the existing Western-centric models. The conceptual contribution, therefore, lies in the original triadic linkage between: (1) types of circular innovation (product, process, and business model), (2) family firm organisational characteristics, and (3) external institutional enabling factors, conceived as an integrated explanatory system rather than a collection of independent variables.

RESULTS AND ANALYSIS

The analysis of 68 peer-reviewed publications identified the key capabilities and constraints shaping circular economy (CE) adoption in small family businesses (SFBs). The findings are structured around three innovation modalities—product, process, and business model innovation—and examine how organisational characteristics and external enablers influence their effectiveness.

1. Product Innovation in SFBs

Product innovation emerges as the most immediate pathway for circular economy adoption in SFBs. Firms leverage their close understanding of cus-

tomer needs and long-term commitment to product quality to develop solutions characterised by durability, reparability, modularity, and recyclability (Prieto-Sandoval et al., 2019). Evidence from sectors such as textiles and furniture shows a strong emphasis on high-quality materials and repairable designs to reduce product obsolescence (Huynh, 2021; Toromade & Chiekezie, 2024). In addition, local embeddedness facilitates co-design practices aligned with sustainable consumption patterns (John et al., 2023).

2. Process Innovation in SFBs

Process innovation focuses on improving resource efficiency through the optimisation of production methods, energy use, and waste reduction. SFBs benefit from agile decision-making structures and long-term investment perspectives, enabling incremental improvements in sustainability performance. Closed-loop production and recycling practices are particularly evident in smaller manufacturing contexts, often supported by informal knowledge-sharing within the firm (Arsawan et al., 2025). Despite technological constraints, gradual adaptation strategies contribute to cumulative efficiency gains (Ferreira & Matias, 2021).

3. Business Model Innovation in SFBs

Business model innovation represents the most transformative pathway for circular economy adoption. Models such as Product-as-a-Service (PaaS) and industrial symbiosis enable firms to retain resource ownership, extend product life cycles, and generate recurring revenue streams (Huynh, 2021). Empirical evidence from emerging economies indicates that such models enhance both the profitability and sustainability outcomes (Rehman et al., 2022; Gil-Lamata & Martínez, 2022). Furthermore, local collaboration networks facilitate resource exchange and strengthen community-level circularity (John et al., 2023).

4. Key Organisational Features and Facilitators

The effectiveness of innovation pathways is strongly influenced by family-specific organisational characteristics. Long-term orientation supports investment in sustainable practices, while intergenerational knowledge enhances the implementation of circular solutions (Prieto-Sandoval et al., 2019; Gatto & Re, 2021). Community embeddedness further enables collaboration and trust-based partnerships. At the same time, external institutional support—such as public policies, financial incentives, and knowledge-sharing platforms—plays a critical role in enabling circular transitions (Scipioni & Niccolini, 2021; Piller, 2022).

5. Barriers and Constraints

Despite these enabling factors, SFBs face persistent barriers to circular economy adoption. Financial limitations restrict access to advanced technologies and innovative business models (Huynh, 2021; Toromade & Chiekezie, 2024). In addition, entrenched linear mindsets and institutional weaknesses, particularly in emerging economies, hinder the implementation of circular strategies (John et al., 2023). Addressing these challenges requires both internal cultural change and coherent external support mechanisms (Rehman et al., 2022; Gil-Lamata & Martínez, 2022).

Finally, though SFBs are a necessary part of promoting circular economy behaviour, their development effectiveness will depend on their internal composition and external facilitating conditions.

The synthesis provides evidence that small family businesses (SFBs) have a unique opportunity to act as accelerators of the introduction of circular economy (CE) concepts and principles, especially by being able to use:

1. **Product Innovation** for sustainable, durable goods;
2. **Process Innovation** for enhancing operational efficiency and waste minimization;
3. **Business Model Innovation** for systemic impact and long-term value creation.

The convergence of characteristic family business traits—long-term thinking, intergenerational culture, and embeddedness in the community—with these and alternative innovation modalities and external enablers forms a comprehensive model for CE adoption in emerging economies. This model provides a foundation for further empirical exploration, and informs the design of policies within the SFB space.

MANAGERIAL IMPLICATIONS

The study provides some pragmatic recommendations applicable to SFB managers and owners, as follows:

- **Embrace Business Model Innovation:** Managers should prioritise the development of circular business models, such as Product-as-a-Service (PaaS) or local industrial symbiosis, which help extend product life cycles and support sustainable revenue generation.
- **Use Intergenerational Knowledge:** Intergenerational knowledge can support the development of sustainable products and improve long-term strategic decision-making in family businesses.

- **Introduce Incremental Changes:** Given their limited resources, SFBs may adopt circular practices gradually, starting with small-scale improvements in products or processes.
- **Promote Local Collaborations:** Collaboration with suppliers, customers, and local partners can facilitate industrial symbiosis and improve resource efficiency.

POLICY IMPLICATIONS

The study illustrates how important it is for external institutional structures to support the implementation of CE norms for SFBs, especially those in newly developing countries, as follows:

- **Financial Incentives:** Subsidies, low-interest loans, and tax benefits are critical to reducing the costs incurred upfront for new circular technologies or business model innovations, thereby helping SFBs cope with financial uncertainties.
- **Building Capacity and Transfer of Knowledge:** Training programmes, workshops, and knowledge transfer networks can be vital in enabling SFBs to acquire the requisite skills and knowledge required to implement circular practices. Such policies may represent useful steps in closing skill gaps and strengthening the technical skills of family businesses.
- **Regulatory Frameworks:** Governments have the opportunity to promote CE with appropriate regulations encouraging circular adoption, investing in recycling infrastructure, encouraging businesses to share in activities through collaboration, and building good business practices.
- **Context-Specific Policy:** Government regulations specifically intended for SFBs in emerging markets, taking into account their idiosyncratic characteristics, such as their local embeddedness, limited resources, and long-term development goals, should be carefully designed by policymakers. General SME policies may not fully represent the unique demands and opportunities of family-owned businesses.

INTEGRATIVE IMPLICATIONS

Our findings highlight a multi-level strategy aimed at supporting CE adoption among SFBs. Internally, enterprises can leverage their established organisational culture, intergenerational knowledge, and long-term vision as

agents of sustainable innovation. The idea behind integrating product, process, and business model innovations strategically is that this will provide the best mix of both economic and environmental results. On the external side, supportive policies, financial incentives, knowledge-sharing mechanisms, and appropriate infrastructure are extremely important to ensure the adoption of circular practices. This integrative vision indicates that SFBs cannot achieve circular model transition in isolation, as successful implementation depends on the integration of internal capabilities with external support.

Future Research Directions

Although a strong research agenda has been defined by previous findings relating to CE adoption in SFBs, empirical research is necessary to confirm and clarify these insights, as follows:

- **Comparative Research**: To measure the specific effect of family ownership on circular practices in SFBs and non-family SMEs, compare the differences in CE adoption rates and innovation practices.
- **Sector-Specific Analyses:** Finding sectors that are more receptive to CE practices in family-owned firms to enable sector-specific policy and intervention.
- **Longitudinal studies:** Monitor the intergenerational adoption of CE practices in SFBs and the impact it may have on financial performance, the sustainability effect of the companies, and its community impact.
- **Cross-Country Comparison:** Investigate the policy environment and cultural situations that contribute to the capacity of SFBs to shift toward CE paradigms, enriching the knowledge base regarding international best practices.

DISCUSSION

Innovation can accelerate circular economy adoption in small family businesses, but several structural constraints persist. In emerging economies, these firms often face limited finance, weak technological capabilities, and unsupportive regulations. A key challenge is scalability: many circular initiatives are local and incremental, restricting systemic impact. Weak institutional conditions—such as poor regulatory frameworks, inadequate recycling infrastructure, and limited financial instruments—also hinder investment in advanced circular technologies.

Internal governance can further constrain innovation. Although family ownership supports long-term commitment and sustainability, it can also entrench

conservative decision-making and risk aversion, slowing disruptive innovation. These dynamics call for managerial strategies that balance tradition with innovation-oriented thinking. Thus, effective scaling of circular practices requires both internal organisational change and supportive institutional ecosystems.

This study has several limitations. It relies on a non-validated conceptual framework derived from the existing literature. The literature review may suffer from selection bias and a scarcity of sources on small family businesses in emerging economies. Cross-country contextual differences may also restrict the transferability of circular practices. Future research should empirically test the framework, for instance through surveys or case studies of family firms engaged in circular initiatives.

CONCLUSION

Building on the literature review and conceptual analysis, this study develops an integrated framework explaining how innovation pathways enable circular economy adoption in small family businesses (SFBs), particularly within emerging economies.

The findings highlight that circular transformation in SFBs is driven by the interaction between three core innovation pathways—product, process, and business model innovation—and the distinctive organisational characteristics of family firms. While product and process innovation support incremental improvements in resource efficiency and waste reduction, business model innovation emerges as the most transformative mechanism, enabling systemic changes in value creation and long-term sustainability.

At the same time, the study underscores that these innovation pathways do not operate in isolation. Their effectiveness is shaped by family-specific attributes such as long-term orientation, intergenerational knowledge, and community embeddedness, as well as by external institutional conditions, including policy support, financial instruments, and knowledge-sharing infrastructures. Persistent barriers—particularly financial constraints, entrenched linear mindsets, and weak institutional environments—continue to limit the capacity of SFBs to fully implement circular practices.

From a theoretical perspective, this research contributes by integrating circular economy, innovation, and family business literature into a unified analytical framework. It advances the current understanding by conceptualising circular economy adoption as a multi-level process, shaped by the interaction between internal organisational capabilities and external enabling conditions.

From a practical perspective, the findings suggest that managers should prioritise business model innovation while leveraging the existing organisational strengths, and that policymakers should design targeted, context-sensitive support mechanisms that reflect the specific needs of family-owned firms in emerging economies.

As a conceptual study, this research provides a foundation for future empirical work. Further studies should test the proposed framework across sectors and national contexts, in order to validate the identified relationships and refine the understanding of circular economy adoption in small family businesses.

Ultimately, recognising the role of small family businesses as active agents of circular transformation is essential for achieving inclusive and sustainable economic transitions.

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