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Editorial Introduction

Welcome to the Inaugural Issue of the Journal of Regenerative Economics

The launch of the Journal of Regenerative Economics (JRE) signifies the opening of a crucial dialogue that extends beyond academic circles to address broader societal challenges. This journal emerges from the recognition that regenerative economics holds vital significance for regions grappling with pressing ecological, economic, and social issues—challenges that often stem from the insufficient application of regenerative principles.

Regenerative economics is not merely an extension of sustainability studies but a transformative approach that envisions economic systems capable of restoring and enhancing ecological, social, and financial resilience. In contrast to traditional models focused on minimizing harm, regenerative economics aspires to design systems that actively regenerate, renew, and replenish the resources upon which all life depends. By moving beyond linear, extractive economic models, regenerative economics aims to foster thriving ecosystems and communities that operate in harmony with the biosphere (Shannon et al., 2022).

This journal arises from the need to confront the intersecting crises of environmental degradation, social inequality, and economic instability. Grounded in systems thinking, regenerative economics acknowledges the intricate interdependencies between natural and human systems. By transcending extractive and linear economic frameworks, this field offers innovative pathways to foster thriving ecosystems and resilient communities.

A foundational pillar within regenerative economics is the integration of circular, green, and sharing economies into a cohesive and adaptable framework. The three-tier model introduced by Avdokushin and Kuznetsova (2023) exemplifies this holistic approach, emphasizing the need for economic systems that prioritize ecological regeneration while ensuring equitable resource distribution. On the other hand, sector-specific applications, from regenerative agriculture to urban planning and tourism, from waste management and circular economy, to biodiversity and inter-dependence between economy and pollution, showcase the breadth of regenerative economics' transformative capacity and put JRE not just grounded in the social sciences, but encompassing multidisciplinary research approach.

The decision to establish this journal stems from the ongoing CROSS-REIS project, funded by the European Union under Grant Agreement 101136834. However, JRE aspires to transcend its project roots and establish itself as a vital platform for the broader scientific community across the Balkans, South-Eastern Europe (SEE), and beyond. The need for interdisciplinary approaches that bridge economics with ecology, technology, and social sciences is more pressing than ever. Our mission is to foster cross-border collaborations and publish cutting-edge research that advances regenerative economic practices globally.

The Journal of Regenerative Economics seeks to contribute not only to regional discourse but to shape international narratives on economic transformation. We

invite researchers, policymakers, and practitioners from diverse fields to join us in exploring innovative solutions that respond to the urgent ecological and socio-economic challenges of our time. Through this journal, we aim to catalyse dialogue, inspire action, and contribute to the global movement towards regenerative futures. We are excited to embark on this journey with you, and we look forward to publishing rigorous, impactful research that drives systemic change.

Key Contributions and Emerging Themes: Volume 1, Issue 1

The inaugural issue of the Journal of Regenerative Economics (JRE) offers a compelling exploration of how regenerative economic principles can address contemporary challenges across various sectors and regions. Through a diverse range of articles, this issue sheds light on the interconnected dimensions of sustainability, governance, and economic transformation, reflecting the growing recognition of regenerative practices as essential tools for fostering resilience and prosperity.

This issue presents a collection of six scholarly articles that collectively explore topics such as urban resilience, biodiversity conservation, governance, and the application of regenerative principles in economic development.

A comprehensive review of the literature on regenerative economics sets the stage for this issue in the paper *Exploring the Regenerative Economy: A Comprehensive Review of Literature* by Saša Čegar, Saša Drezgić, and Dragan Čišić. By analyzing 84 scholarly articles, the authors provide a structured overview of the field, clustering existing research into seven thematic areas, including sustainability, climate change, urban development, economic systems, and governance. This synthesis not only maps the current landscape but also highlights the necessity for integrated approaches that span multiple disciplines, reinforcing the importance of technological innovation and inclusive policy frameworks.

Urban resilience takes center stage in the study by Matjaž Hribar, Žiga Turk, and Mateja Šmid Hribar, titled *A Regenerative Approach to Urban Heat-Island Resilience Planning*. This paper addresses the pressing issue of urban heat islands by integrating functionally degraded areas (FDAs) with green-blue infrastructure. The authors propose a regenerative approach to urban planning, revealing how revitalizing even small FDAs can significantly improve green space access and mitigate urban heat. This work underscores the potential of nature-based solutions to reshape urban environments, bridging gaps in conventional planning methodologies.

The focus on governance continues in the paper *Development of New Types of State Audit in the Context of Achieving the Goals of Sustainable Development From the 2030 Agenda* by Ljiljana Bonić, Bojan Krstić, and Jovana Milenović. This article examines the evolving role of Supreme Audit Institutions (SAIs) in the implementation of the 2030 Agenda for Sustainable Development. A comparative analysis of Western Balkan countries highlights how SAIs are emerging as critical oversight mechanisms, conducting specialized performance audits to monitor progress towards sustainable development goals. This article sheds light on the transformative potential of audits as tools for driving national and regional sustainability agendas.

Biodiversity conservation is another vital theme explored in *Biodiversity Conservation Policies in Serbia and the European Union: A Comparative Analysis of Regulatory Frameworks and Implementation Challenges* by Dragana Radenković Jocić and Ružica Petrović. This comparative study examines regulatory frameworks in Serbia and the European Union, identifying key implementation challenges and advocating for stronger alignment between national policies and EU standards. The analysis emphasizes the ecological imperative of biodiversity protection and illustrates the legislative hurdles that must be overcome to achieve meaningful progress.

In the paper *Regenerative Economy through the Prism of Montenegro - Challenges and Limitations*, authors Ana Lalević Filipović, Milan Raičević, and Milena Lipovina-Božović provide valuable insights into the practical application of regenerative economic principles in Montenegro. Despite facing socio-economic and political challenges, Montenegro's unique ecological assets and tourism potential provide fertile ground for regenerative initiatives. The authors highlight the importance of sustainable tourism, regenerative agriculture, and waste management as pillars for fostering long-term environmental and economic health.

Finally, *Fostering Sustainable Regions in Serbia: Strategic Approach, AI, and Regenerative Economics* by Aleksandar Manasijević explores the interplay between strategic governance, artificial intelligence, and regenerative economics in the context of regional development in Serbia. By advocating for smart technologies and AI-driven solutions, the article envisions a future where economic growth harmonizes with ecological sustainability. The proposed framework calls for stronger governmental involvement and policy innovation to reduce regional disparities and enhance competitiveness.

Together, these papers open critical scientific debates on the operationalization of regenerative principles across diverse fields. They underscore the necessity of interdisciplinary collaboration, community-driven initiatives, and forward-thinking governance to drive systemic change. As regenerative economics continues to gain traction, this issue provides a foundational contribution to the field, offering both theoretical insights and practical solutions for navigating the complexities of sustainable development.

Acknowledgement

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EXPLORING THE REGENERATIVE ECONOMY: A COMPREHENSIVE REVIEW OF LITERATURE

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Abstract: Contemporary global challenges such as climate change, resource depletion, ecosystem degradation, and social inequities require comprehensive and integrated approaches to achieve sustainable development. While existing development and sustainability paradigms address specific aspects of sustainability, they often fall short in driving systemic transformation and ensuring long-term resilience. In response to these limitations, the concept of the regenerative economy emerges as a holistic framework that integrates ecological restoration, social equity, and economic vitality. This study conducts a systematic literature review of 84 scholarly articles to synthesize and cluster existing research within the regenerative economy domain. Utilizing a Large Language Model (LLM) for zero-shot classification, the analysis identifies seven primary clusters—Sustainability and Environmental Impact, Climate Change and Energy, Urban and Built Environment, Economic and Industrial Systems, Education and Social Impact, Technological Innovations and Systems, and Policy, Governance, and Standards—further subdivided into 21 subgroups. Each cluster encapsulates key themes and interdisciplinary approaches essential for advancing regenerative economy practices. The findings highlight the interconnectedness of various sustainability dimensions and underscore the necessity of integrated governance, innovative technological solutions, and inclusive policy frameworks. By mapping the current state of regenerative economy research, this study provides a structured overview that facilitates deeper understanding and informs future strategic initiatives aimed at achieving a resilient and prosperous sustainable future.

Keywords: regenerative economy, systematic literature review, large language model, LLM-based cluster analysis, policy implications

Original scientific paper
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1. Introduction

Contemporary global challenges such as climate change, food and energy security, ecosystem degradation, human health, poverty, and the restructuring and green transition of national economies are interconnected and complex. This interconnectedness demands a comprehensive approach, as partial, one-dimensional policies can create additional problems and generate negative feedback across social, economic, and environmental dimensions. To address this, concepts like the green economy, circular economy, and bioeconomy have been developed and integrated into strategic programs, such as those of the European Union, emphasizing their potential to foster development based on renewable resources and environmentally sound processes.

However, these concepts have shown limitations in addressing complex challenges. While the green economy focuses on reducing environmental harm, it often remains within sustainability frameworks, insufficiently addressing systemic transformation and root causes of ecosystem degradation (i.e. Unmüßig et al., 2012). The circular economy prioritizes technical aspects of resource loops and recycling, often overlooking broader social and ecological dynamics crucial for long-term resilience (i.e. Corvellec et al., 2022). The bioeconomy, while potentially innovative, can prioritize exploiting biological resources without sufficient emphasis on regenerative processes that ensure long-term availability (i.e. Allain et al., 2022). A shared weakness of these approaches is their partial application, where progress in one area can negatively impact others. Their technical-economic focus often neglects the fundamental interconnectedness of humans, nature, and economic systems, leading to fragmented and poorly coordinated interventions. In the face of challenges like climate change, resource depletion, and growing social inequality, these limitations are significant.

This necessitates a more comprehensive concept: the regenerative economy. This paradigm offers a holistic approach by actively enhancing the capacity of natural and social systems for long-term resilience and prosperity. It moves beyond simply maintaining the status quo, enabling systemic transformation and renewal to address the needs of contemporary societies and the planet. The regenerative economy is grounded in natural processes, promoting partnership with ecosystems rather than exploitation. This shifts the focus from sustaining existing resources to improving the capacity of fundamental ecological and social systems. The regenerative economy integrates the best aspects of the green, circular, and bioeconomy into a unified approach. It adds active ecosystem restoration to the green economy, situates the circular economy within a broader regeneration strategy, and grounds the bioeconomy in regenerative processes that ensure the long-term health of biological resources. It aims to restore and revitalize environmental, social, and economic capital, improving ecosystem health, strengthening community resilience, and enhancing human well-being. Key aspects include holistic systems thinking (understanding interdependencies), circularity (eliminating waste and regenerating natural systems), resilience (adapting to change), equity (fair distribution of resources and opportunities), and biodiversity (protecting and enhancing ecological health). Therefore, the regenerative economy seeks to create a system where

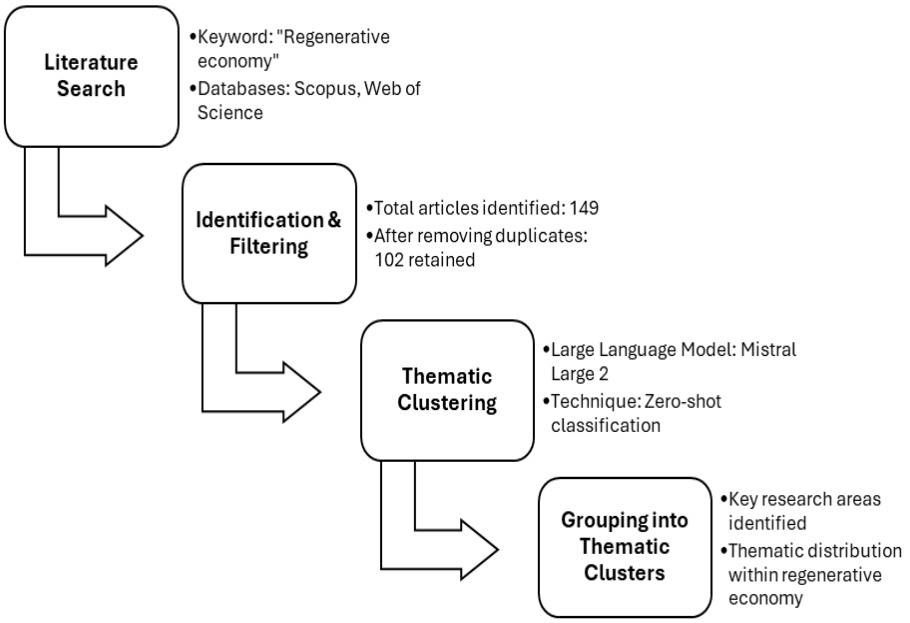
economic activities positively contribute to the world, generating abundance and prosperity for all. It fosters transformative innovations in business and governance, offering a comprehensive solution to contemporary challenges by combining sustainability, innovation, and resilience for a healthier and fairer future (i.e. Konietzko et al., 2023; Fath et al., 2019; Unter et al., 2024).

Nevertheless, existing knowledge relevant to the regenerative economy is dispersed and fragmented across various fields that are often researched independently. This fragmentation hinders a comprehensive understanding of the phenomena and challenges critical to its development. Therefore, this study undertakes an analysis and synthesis of these dispersed findings to facilitate deeper insights. Furthermore, by examining recent articles that directly address the regenerative economy, this study aims to enrich the existing knowledge base and provide a broader context for understanding its key aspects. The purpose of this study is to conduct a systematic review and clustering of the existing literature through the lens of the regenerative economy, demonstrating how it connects and complements previous approaches to offer integrated solutions to contemporary development challenges.

2. Methodology

This study conducts a systematic literature review aimed at providing a comprehensive synthesis of the theoretical foundations, practical applications, and interdisciplinary approaches that define and shape the field of regenerative economy. The following diagram outlines the key steps involved in the process of conducting the literature review.

Figure 1. Methodology applied



Source: Prepared by the authors

In the first step, a comprehensive search and article selection process was carried out. This review critically analysed regenerative economic practices by synthesizing 102 distinct articles indexed in Scopus and Web of Science. A search was conducted using the keyword "Regenerative economy" in titles, keywords, and abstracts. Initially, 149 articles were identified (69 from Scopus and 80 from Web of Science). After removing duplicates, 102 articles were retained for detailed analysis.

In the second step, the thematic structure of the identified articles was analysed. Of the 102 articles selected for detailed analysis, 84 were included in the thematic synthesis, while 18 were excluded due to the absence of author-provided keywords necessary for the analysis. This selective process ensured that the review concentrated on studies with clearly defined keywords, enabling a more accurate and comprehensive examination of regenerative economic practices. The goal was to uncover the underlying thematic clusters within the field of regenerative economy. To achieve this, a Large Language Model (LLM) called Mistral Large 2 was employed.[2] LLMs are advanced neural networks trained on massive datasets of text, capable of understanding and generating human-like text. The Mistral Large 2 large language model was utilized for a method called zero-shot classification, allowing predictions of categories not encountered during training by leveraging pre-trained language models and transfer learning. This method proved particularly useful for smaller datasets, which is often the case in emerging research fields (Gretz et al., 2023).

In the final step, the 84 scientific articles were grouped into distinct thematic clusters. This clustering process facilitated the identification of key research areas and provided insights into the thematic distribution within the field of regenerative economy. These clusters represent significant aspects of research within this emerging field and offer a structured overview of the current state of knowledge. Each cluster is characterized by shared themes and concepts, enabling a more nuanced understanding of diverse perspectives and approaches in the field. Given that some articles address different aspects of the same topic, certain articles were assigned to more than one cluster, depending on the specific focus of each thematic interpretation. This approach allowed for a more comprehensive representation of the articles' contributions, capturing the complexity of the subject matter and reflecting the interconnectedness of the various research dimensions

3. Results and Analysis

In accordance with the methodology described earlier, this chapter presents the analysed results and insights obtained in each research step.

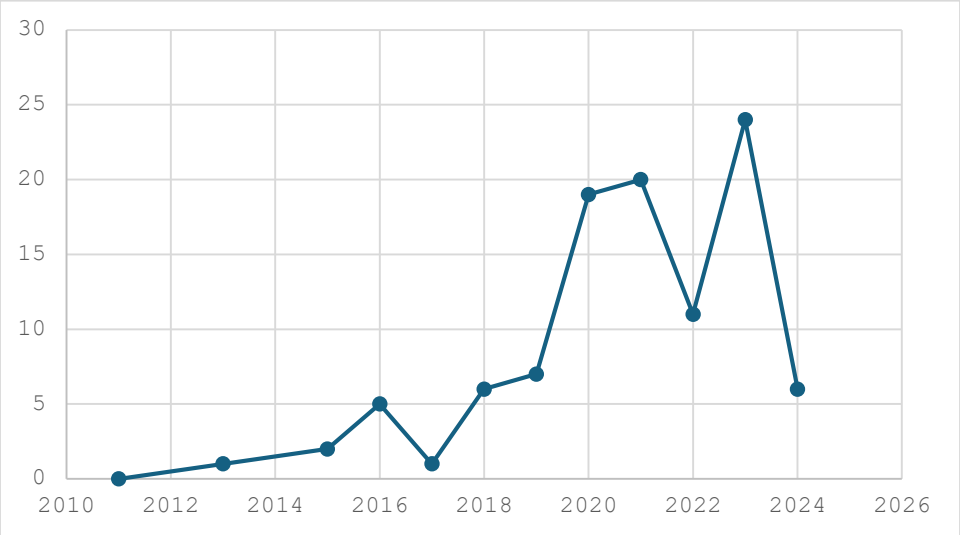
3.1. Trends in Research on Regenerative Economy

To examine the research trajectory of the regenerative economy, the yearly distribution of publications was analysed (see Figure 2). Although the relatively

[2] The model used in this study is available at https://mistral.ai/news/mistral-large-2407/ (accessed on September 24, 2024).

modest total number of publications reflects the early stage of this field within broader academic discourse, the noticeable rise in recent years signals growing interest and recognition of regenerative practices in economic research. This trend aligns with a broader academic shift towards sustainability, driven by heightened awareness of pressing economic, environmental, and social challenges. The increasing engagement with principles of regeneration underscores its relevance as a response to global issues such as resource depletion, environmental degradation, and social inequity.

Figure 2. Number of articles published per year



Source: Prepared by the authors

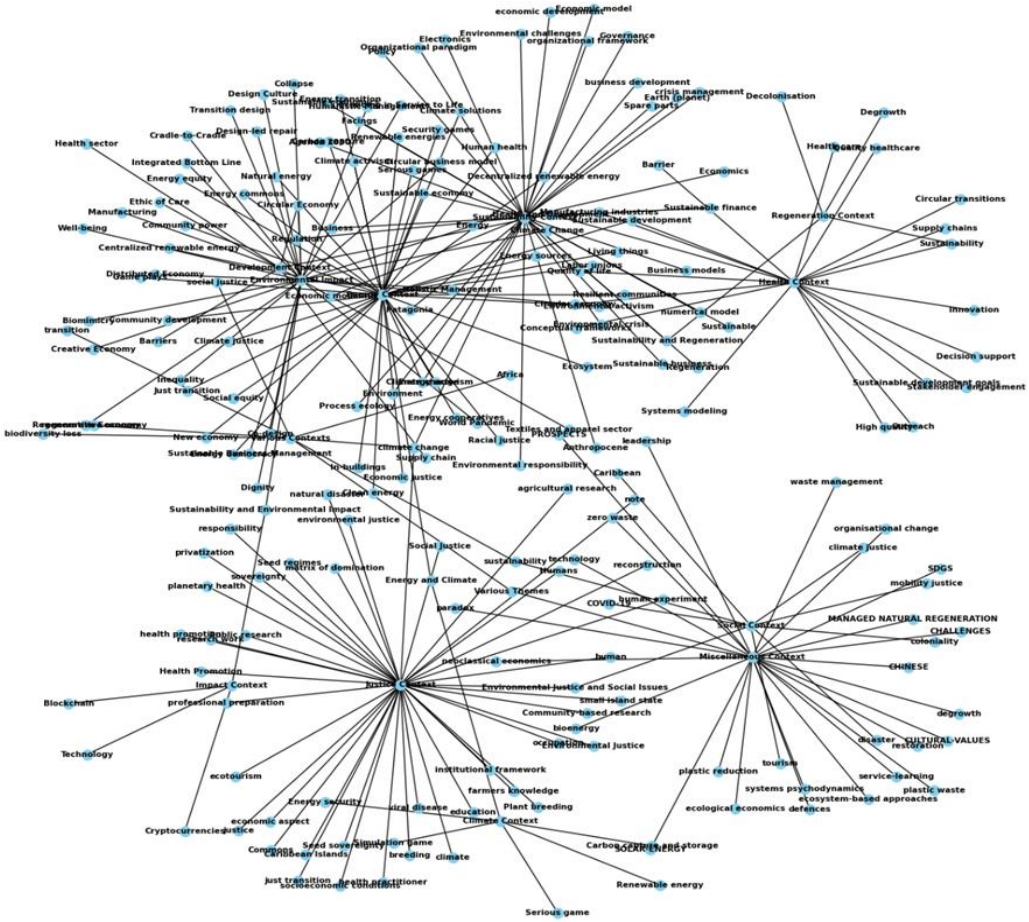
This surge in scholarly attention highlights the field's rising prominence and potential to address global challenges. Growing awareness of environmental and social issues has spurred more research into the regenerative economy, expanding its scope and significance. As the body of literature continues to grow, further diversification in research topics and methodologies is expected, offering scholars, policymakers, and practitioners new opportunities to develop innovative strategies for restoring and sustaining natural and social capital.

3.2. Clusters and Key Terms in Regenerative Economy Research

The analysis conducted using the LLM zero-shot classification method on 84 articles resulted in the categorization of author and index keywords into seven distinct clusters: Sustainability and Environmental Impact, Climate Change and Energy, Urban and Built Environment, Economic and Industrial Systems, Education and Social Impact, Technological Innovations and Systems, and Policy, Governance, and Standards. The interrelationships among these clusters are visually represented in Figure 3. This figure underscores the multifaceted nature of regenerative economy research, illustrating the interconnectedness of economic, technological, social, and

policy-related themes. By offering a holistic view of these clusters, the analysis highlights the complexity and interdisciplinary nature of pursuing a truly sustainable and regenerative economic system.

Figure 3. Keywords cluster graph



Source: Prepared by the authors

The identified clusters provide valuable insight into the thematic diversity and interdisciplinary scope of research in this field. Each cluster represents a core aspect of regenerative economy research, covering topics from economic models and frameworks to industry-specific applications and innovative technological solutions. In the table below, the key terms associated with each cluster are presented, offering a detailed overview of the main topics and keywords that define the different areas of study within regenerative economy.

Table1. Clusters and keywords

Clusters	Keywords
1. Sustainability and Environmental Impact	• **Regenerative economy**: regenerative economy, regenerative sustainability, regenerative design, regenerative development • **Circular Economy**: circular economy, circular business model, end of waste, industrial symbiosis, life-cycle thinking (LCT), material and energy flow analysis • **Sustainable Development Goals (SDGs)**: sustainability, sustainable development, sustainable business management, SDGs implementation • **Environmental Economics**: ecological economics, degrowth, green economy, ecological impact
2. Climate Change and Energy	• **Climate Adaptation and Mitigation**: climate change, resilience, retrofitting buildings, urban microclimate, climate action, energy transition • **Renewable Energy and Energy Systems**: solar energy, renewable energy, clean energy, energy booking, energy system sizing • **Green Technologies and Solutions**: green facades, green finance, green investment, energy savings, energy security
3. Urban and Built Environment	• **Urban Design and Infrastructure**: urban design, built environment, urban buildings resilience, urban farming • **Construction and Building Practices**: construction sites, building certification, wood frame construction, building performance simulation • **Waste Management and Recycling**: waste management, disaster waste, recycling, zero waste
4. Economic and Industrial Systems	• **Economic Models and Systems**: economic inclusion, monetary ecosystem, financial viability, economic transitions • **Industry-Specific Practices**: textiles and apparel sector, bio-industry, industrial ecology, manufacturing industries • **Business and Investment**: environmental projects, investment, business models, green finance
5. Education and Social Impact	• **Learning and Development**: education for sustainable development, problem-based learning, service-learning, transformative learning • **Social Equity and Justice**: social equity, climate justice, environmental justice, social justice • **Health and Wellbeing**: health and wellbeing, indoor environmental quality, thermal comfort, acoustic design
6. Technological Innovations and Systems	• **Information and Communication Technologies (ICT)**: artificial intelligence, big data, digital intelligence, ICT • **Tools and Simulation**: Ladybug Tools, GIS, modeling framework, simulation game • **Materials and Manufacturing**: supramolecular polymers, perovskite solar cells, natural dyes, materials innovations
7. Policy, Governance, and Standards	• **Regulation and Standardization**: standardization, regulation, best available techniques (BAT), integrated pollution prevention and control (IPPC) • **Governance and Policy**: governance, public policy, policy frameworks, environmental regulations

Source: Prepared by the authors

Based on the previously identified clusters and their corresponding keywords, the analysed articles were grouped and sub-grouped to highlight the most critical aspects of research in the field of the regenerative economy. This thematic organization, presented in Table 1, provides a structured framework for exploring the intersections of various dimensions and contributing factors that shape the regenerative economy.

The following chapter summarizes and analyses these themes in greater detail, emphasizing their implications for advancing both theoretical and practical knowledge in regenerative economy research. The analysis highlights the interdisciplinary nature of the studies, focusing on how the identified clusters address global challenges such as climate change, resource management, and social equity.

3.3. Grouping and Sub-Grouping of Key Themes

This chapter further elaborates on the key themes identified in the previous section, categorizing them into relevant subgroups for a more in-depth analysis.

3.3.1. Group 1: Sustainability and environmental impact

Sustainability and environmental impact constitute the foundational keystones in advancing a regenerative and responsible economy. Articles in this cluster broaden our understanding of how ecosystems, social well-being, and economic models intersect in a constantly evolving world. While traditional approaches once focused primarily on mitigating harm or reducing resource use, these works underscore the importance of going further—actively restoring and regenerating ecosystems, promoting circular flows of materials, and aligning economic activities with planetary limits. Multiple theoretical perspectives converge here, from examining how local communities can benefit from more equitable resource management to rethinking the global economic system's fundamental design principles. By exploring the underlying concepts of regenerative economy, circular economy, sustainable development goals (SDGs), and environmental economics, the cluster captures a holistic picture of how we might move from mere sustainability to genuine socio-ecological flourishing.

The Sustainability and Environmental Impact group represents the largest collection of articles in the research. This group is further composed of the following subgroups:

- 1A: Regenerative Economy
- 1B: Circular Economy
- 1C: Sustainable Development Goals (SDGs)
- 1D: Environmental Economics

Subgroup 1A: Regenerative Economy

Regenerative economy proposes an economic model that does not simply minimize harm but rather revitalizes ecosystems, communities, and social systems. Unlike business-as-usual approaches that emphasize limitless consumption and

distant markets, regenerative frameworks seek to realign production and exchange with local, place-based values, ensuring healthier interdependence between humans and the living world. As illustrated in diverse contexts—such as tourism, agriculture, and organizational leadership—regenerative economy can manifest through social entrepreneurship, restorative design processes, and not-for-profit business structures. These perspectives demonstrate a shared vision of an economy that nourishes cultural and biological diversity, prioritizes social equity, and maintains the carrying capacity of our planet. By spotlighting transformative experiences, new institutional arrangements, and innovative metrics, the articles below collectively argue for an "economics of harmony and quality"—one that moves from mere sustainability to active renewal, shared prosperity, and holistic well-being.

Within this group, Tomljenovic & Ateljevic (2017) explore concepts such as "restorative economics" and emphasize the role of transformative tourism and social entrepreneurs in shifting towards healthier local economies. Building on this, Daum (2019) investigates how denial and splitting mechanisms in mainstream businesses mask their damaging social and ecological impacts, advocating for the acknowledgment of these issues as a pathway to genuine regenerative practices and purposeful leadership. Hărmănescu et al. (2018) present activities from COST Action CA16114 "RESTORE," focusing on restorative design that regenerates local natural systems through adaptive urban methods and case studies tailored to various climate scenarios. Similarly, Walls & Vogel (2023) argue for a regenerative economy in Africa, driven by clean innovation, decentralized systems, and African values of horizontal collectivism to ensure sustainable growth amidst rapid economic and population changes.

Agricultural sustainability is addressed in da Silva et al. (2023), which examines different agricultural approaches and suggests that regenerative frameworks can harmonize ecological integrity with equitable food systems. Bellato & Pollock (2023) seek to refine the concept of regenerative tourism by advocating for place-based and community-centric approaches, critiquing the dominance of Western academic perspectives, and promoting plural knowledge systems aligned with regenerative principles.

Institutional initiatives are highlighted in Bexell et al. (2023), which chronicles the establishment of a Regenerative Future Centre at the University of Denver, advocating for holistic worldviews to tackle eco-anxiety, systemic inequities, and ecological destruction. The transformation of the tourism sector is further explored in Ateljevic (2020), linking post-COVID tourism transformations to regenerative approaches and emphasizing the role of transformative travel and regenerative agriculture in resetting global tourism systems.

In the hospitality industry, Inversini et al. (2024) investigate the evolution of hospitality beyond sustainability, introducing the concept of regenerative hospitality that leverages place and people intelligence as foundational elements for the future of travel. Sheldon (2022) challenges neoliberal assumptions by advocating for inclusive capital frameworks and positioning the regenerative economy alongside collaborative, circular, creative, and gift economies to mature the tourism sector.

Island economies are examined in Zisopoulos et al. (2023), which utilize flow-based and network-based indicators to analyse socio-economic metabolism, demonstrating how enhanced internal feedback loops and resilience can support regenerative reinvestment strategies that protect local resources. Additionally, emerging strategies in regenerative economies are suggested in Peia (2021), which, despite limited abstract data, likely focuses on system-changing approaches such as smallholder farming and water management in Mexico's rural communities.

Fair Trade initiatives are discussed in Kiessel (2022b), which calls for expanding Fair Trade beyond traditional sectors to integrate it within a broader movement towards justice and inclusivity in economic systems. The importance of non-profit models is emphasized in Hinton (2022), proposing that a not-for-profit market system can better align financial resource circulation with social benefits, thereby supporting regenerative sustainability ideals. Lastly, Fath et al. (2019) outline ten principles derived from network science and nonlinear dynamics to quantify and guide the regenerative vitality of economic networks, providing a robust toolkit for assessing systemic economic health.

Subgroup 1B: Circular Economy

Circular economy strategies emphasise closed-loop systems where products, components, and materials circulate for as long as possible, thereby minimising waste and environmental harm. In contrast to a linear "take-make-dispose" model, circular approaches seek to extend product lifespans, promote reuse and recycling, and align production processes with ecological principles. The articles in this subcluster delve into various facets of the circular economy—ranging from consumer awareness and digital re-commerce to hazardous waste management and seaweed-based nutrient recovery. Collectively, they illustrate how circularity can serve as a practical pathway to a more regenerative, low-impact economy.

Gonella et al. (2023) is included in this subgroup as it focuses on developing a measurement tool to assess public awareness of the circular economy. By gauging people's understanding, this study underscores the importance of awareness in fostering a more circular and regenerative economic system. Similarly, Stoenoiu & Jäntschi (2024) analyse circular economy indicators across multiple Eastern European nations, demonstrating how a shared focus on circular practices can drive sustainable economic progress at the national level.

Consumer behaviour is also a critical component addressed in Arman & Mark-Herbert (2021), which investigates the role of consumer-driven product resale on platforms like Facebook. This study illustrates how extending product life cycles through re-commerce can promote circular consumption behaviours, thereby reducing waste and enhancing resource efficiency. Additionally, Beamer et al. (2023) highlight the value of indigenous Hawaiian knowledge and ancestral circular economy principles. This research emphasises how these traditional practices can inform and guide universally applicable circular economy policies, particularly within diverse socio-cultural contexts.

Understanding the human dimension of circular transitions is further explored in Gonella et al. (2024), as this study examines how psychological barriers and social

influence impact individuals' adoption of circular economy strategies, shedding light on the behavioural factors that facilitate or hinder circular transitions. In the realm of industrial processes, Sevilla et al. (2022) focus on redesigning hazardous waste management systems to better align with circular principles. By reducing waste and enabling resource recovery, this research demonstrates practical applications of circular economy concepts in industrial settings.

Conceptual clarity is provided by Morseletto (2020), which critically examines the relationship between restoration, regeneration, and the circular economy. This study clarifies the conceptual underpinnings that inform core circular economy frameworks, ensuring a robust theoretical foundation for practical implementations. Lastly, Seghetta et al. (2016) showcase an innovative closed-loop solution through seaweed-based bio-extraction. This approach recovers and recycles nutrients, addressing eutrophication while supporting a regenerative circular economy model.

Subgroup 1C: Sustainable Development Goals (SDGs)

The SDGs represent a global roadmap for reconciling economic, environmental, and social objectives in ways that safeguard future generations. As nations and institutions grapple with climate change, resource depletion, and systemic inequalities, the SDGs provide frameworks to integrate multiple stakeholder needs—from preserving soil health to innovating new metrics that capture regenerative potential. Nevertheless, realising these goals often demands holistic, cross-sector approaches—bridging traditional divides between economics, ecology, and public policy. The works below illustrate this by examining theoretical tensions between reform and revolution, introducing inclusive metrics for environmental and social impact, and outlining nature-based pathways for land degradation neutrality.

Patterson (2011) delves into the debate on whether a restorative economy can be realised through incremental reforms or necessitates revolutionary changes. By bridging sustainable development paradigms with regenerative approaches, this study situates itself within the broader discourse on meeting the SDGs through either gradual or radical transformations, thereby contributing to the understanding of effective pathways for sustainable economic systems.

In Vineis & Mangone (2022), the focus is on developing more inclusive and comprehensive frameworks that encompass climate change, circularity, biodiversity, and health. This article argues for the alignment of new metrics with the SDGs, integrating scientific, economic, and technological perspectives to facilitate a truly regenerative economy. By proposing SDG-aligned metrics that consider climate impact and co-benefits, this study highlights the necessity of evolving measurement tools to better capture the multifaceted nature of sustainability in the Anthropocene era.

Keesstra et al. (2018) examines the integration of SDG-related targets on land use and water systems with regenerative economic practices. Utilizing systems thinking and nature-based solutions, this research explores how land degradation neutrality (LDN) and restoration can be achieved by 2030. By directly referencing the SDGs and emphasising soil-water system management, this study provides actionable insights into how regenerative frameworks can support the restoration and sustainable management of vital natural resources.

Subgroup 1D: Environmental Economics

Environmental economics provides a framework for understanding how economic systems interact with natural ecosystems—informing policies, valuation methods, and strategic decisions that can foster long-term ecological integrity. From applying cybernetics to reshape economic institutions toward regenerative pathways, to quantifying the social cost of carbon under deep uncertainty, this subcluster illuminates the economic tools and concepts necessary to steer away from extractive, growth-based paradigms. This subgroup encompasses studies that bridge the gap between traditional economic models and environmental considerations, emphasising sustainable resource use, carbon pricing, and the development of eco-centric economic frameworks. Additionally, it integrates emerging perspectives such as the "blue economy," highlighting how regenerative principles can be applied to marine-based production and coastal development. In the end, these articles suggest that robust environmental-economic analysis is essential for managing planetary limits, ensuring just transitions, and guiding the evolution of industries and communities toward genuinely sustainable futures.

Perkins & Jessup (2021) employ second-order cybernetics to reimagine economic institutions for a regenerative economy. By merging ecological and economic thinking, this study aligns with ecological economics and degrowth concepts, proposing innovative designs that foster sustainable and resilient economic systems. Similarly, Harbi et al. (2023) delves into the complexities of calculating the social cost of carbon amidst deep uncertainty and the pursuit of robust climate policies. This research links environmental impact with economic assessments, addressing critical aspects of carbon pricing and risk management within environmental economics.

The exploration of marine and ecological resource management is further developed in Nikitenko et al. (2022) as a Basis for Sustainable Development. This article examines the "blue economy" model, applying ecological principles to economic production and aligning with the focus of environmental economics on sustainable resource utilisation. It highlights the integration of agro-ecology and the concept of ecopolises, demonstrating how marine resources can be managed sustainably to support economic growth without compromising ecological integrity. Building on the blue economy framework, Auad & Fath (2022) propose ten nature-based principles for a regenerative blue economy. This study exemplifies the integration of socio-ecological dynamics into economic strategies, addressing the challenges and pathways necessary for developing a resilient and sustainable blue economy. By discussing regenerative and green economic frameworks, it underscores the importance of socio-ecological resilience in achieving long-term sustainability goals.

3.3.2. Group 2: Climate Change and Energy

The urgency of climate change compels societies worldwide to accelerate decarbonisation while reinforcing resilience in the face of increasingly unpredictable conditions. Many of the works in this cluster examine strategies that range from large-scale transitions—such as investing in renewable energy systems and

implementing energy booking frameworks—to localized interventions like green roofs, retrofitting buildings, and adjusting urban microclimates. By blending top-down policy measures with grassroots innovations, these studies demonstrate that sustainable energy solutions can also address social equity, economic growth, and environmental health. The articles in this cluster highlight that tackling climate change goes well beyond reducing carbon emissions; it requires rethinking how we produce, consume, and manage energy in ways that align with regenerative principles.

This group is further structured by the following subgroups:

- 2A: Climate Adaptation and Mitigation
- 2B: Renewable Energy and Energy Systems
- 2C: Green Technologies and Solutions

Subgroup 2A: Climate Adaptation and Mitigation

Climate change demands a twofold response—adapting built environments and societal frameworks to withstand escalating environmental stressors, while reducing or preventing further greenhouse gas emissions. Research in this subcluster underscores that resilience must be woven into the fabric of our buildings, infrastructure, and planning decisions, but not at the expense of long-term climate goals. Instead, these articles illustrate that climate-adaptive solutions often pair seamlessly with mitigation measures, whether through nature-based interventions, the optimisation of building energy performance, or holistic planning tools that consider future climate projections. In doing so, adaptation and mitigation operate in tandem: one addressing immediate concerns such as urban heat islands or extreme weather, and the other ensuring deeper structural changes for a carbon-neutral future. By examining multiple contexts—from tropical to Nordic climates and from densely populated cities to smaller communities—this subcluster illuminates the shared strategies and technologies that can guide us toward a more climate-resilient world.

Majumdar et al. (2023) link the concept of a "just transition" to nature-based solutions, highlighting how climate mitigation efforts in India can be both equitable and environmentally restorative. By focusing on climate justice and the transformation of energy systems, this study underscores the importance of integrating social equity with ecological sustainability in climate action plans. In Naboni et al. (2020), the research investigates how building facade properties can lower outdoor temperatures and reduce urban heat. This study demonstrates the localised mitigation potential of façade-level interventions, contributing to urban microclimate regulation and the overall reduction of mean radiant temperature in built environments. Cirrincione et al. (2021) analyse green roofs as a long-term climate adaptation tool. The study highlights how green roofs can lower building energy demand, improve indoor comfort, and mitigate heat island effects, thereby enhancing the resilience of urban buildings to climate change.

Mauree et al. (2019) provide a comprehensive review of assessment methods that integrate urban climate modelling, outdoor comfort, and energy systems. This article advocates for a more holistic approach to urban climate adaptation and

mitigation, summarising various tools and methods that support the development of effective strategies in urban settings. In Gremmelspacher et al. (2020), the focus is on how informed retrofit decisions under future climate projections can maintain residential comfort while contributing to emission-reduction goals. This study emphasises the importance of strategic retrofitting in enhancing the resilience of buildings and reducing their carbon footprint in the face of evolving climate conditions. De Luca et al. (2021) examine how the layout of tall buildings in Nordic settings can optimise both indoor and outdoor comfort. This research reflects climate-adaptive planning that not only enhances energy efficiency but also curbs energy use, demonstrating the potential of thoughtful urban design in mitigating climate impacts in cold climates.

Finally, Naboni et al. (2019) propose a digital workflow for regenerative urban design that accounts for climate change scenarios. By blending adaptation strategies, such as thermal comfort, with mitigation efforts focused on energy use, this study offers a quantifiable approach to integrating regenerative principles into urban planning, ensuring that cities can adapt to and mitigate the effects of climate change effectively.

Subgroup 2B: Renewable Energy and Energy Systems

In the face of escalating climate concerns, renewable energy sources and efficient energy systems have become essential for decarbonising economies and ensuring resilient, equitable growth. By broadening access to solar energy, internalising the true cost of carbon emissions, or fostering circular approaches to resource use, the articles in this subcluster highlight strategic innovations for an effective clean-energy transition. Based on diverse methodologies—from spatial analyses that prioritise underrepresented communities to accounting provisions that incentivise lower-carbon production—these works examine both technological and socio-economic dimensions of energy transformation. Together, they paint a picture of an evolving global landscape where policy, market forces, and scientific insights converge to redesign how we produce, distribute, and consume power. The basic goal is not simply to replace fossil fuels but to reimagine energy systems in ways that support sustainability, inclusivity, and long-term ecological balance.

Duguma et al. (2020) propose ecosystem-based, regenerative energy supply strategies tailored to the African context. This study emphasises the importance of leveraging natural ecosystems to produce bioenergy in a manner that supports ecological balance and sustainable development, aligning with the broader goals of a regenerative economy. By integrating bioenergy production with ecosystem conservation, the article highlights how renewable energy initiatives can simultaneously address energy needs and environmental preservation, fostering a harmonious relationship between economic growth and ecological integrity.

Schunder et al. (2020) investigate the spatial opportunities and socio-demographic factors influencing the adoption of rooftop and community solar energy systems. Utilising advanced tools such as LiDAR, this research illustrates how renewable energy access can be expanded to diverse populations by identifying optimal locations for solar installations. This article addresses both the technical and social dimensions of scaling solar power infrastructure, demonstrating how targeted

spatial planning and an understanding of socio-demographic dynamics can enhance the uptake of solar energy, thereby promoting broader access to clean energy and reducing reliance on fossil fuels.

In Valayer et al. (2019), a novel cost-accounting mechanism based on thermodynamics is proposed to expedite the shift from fossil fuels to cleaner energy sources. This study introduces a groundbreaking pathway for driving vigorous decarbonisation by providing a robust economic framework that accounts for the full energy costs associated with carbon avoidance. The article emphasises the necessity of integrating thermodynamic principles into energy accounting to create incentives for renewable energy adoption, thereby facilitating a more accurate and effective transition to a low-carbon economy.

Subgroup 2C: Green Technologies and Solutions

Green technologies and solutions play a pivotal role in driving the global economy toward reduced resource consumption and lower carbon emissions. By utilising informatics tools, digital intelligence, and circular manufacturing principles, businesses and policymakers are developing new methods to optimise material use and embed sustainability in product lifecycles. The articles in this subgroup highlight practical and financial levers—ranging from safer chemical selection in solar cell production to distributed manufacturing and green finance—to advance a regenerative economy that benefits both people and the planet. The following papers provide an indication of how technological innovation, economic inclusion, and circular strategies can converge to drive a greener, more resilient future.

Giri et al. (2022) demonstrate how natural language processing (NLP) can guide the environmentally conscious selection of solvents in solar cell manufacturing. By leveraging informatics-driven approaches, this study exemplifies a green chemistry innovation that not only optimises solvent use but also minimises the ecological footprint of solar cell production. The integration of NLP techniques with safer chemical practices highlights the potential of digital tools in advancing sustainable manufacturing processes, thereby contributing to more resilient and eco-friendly energy solution.

In Moreno and Charnley (2016), the research explores how re-distributed manufacturing, coupled with digital intelligence, can foster circular production models. This integrative literature review aligns with green solutions by reducing resource consumption and waste through decentralised manufacturing processes. By incorporating digital intelligence, such as automation and data analytics, the study illustrates how these technologies can enhance the efficiency and adaptability of production systems, supporting the principles of a circular economy and promoting sustainable industrial practices.

The study of van Niekerk (2024) highlights the vital role of green finance in bridging economic inclusion with resource regeneration. This study illustrates a financial pathway to cleaner and more sustainable economies by integrating economic inclusion initiatives with investments in regenerative projects. By aligning green finance strategies with the Sustainable Development Goals (SDGs), this paper

underscores the importance of financial mechanisms that support sustainable practices, thereby fostering economic opportunities while ensuring environmental stewardship. This alignment not only promotes social equity but also drives investments toward projects that regenerate natural resources and enhance ecological resilience.

Lastly, Lieder and Rashid (2016) propose a comprehensive framework for implementing circular economy practices within the manufacturing sector. This review foregrounds the transition to a regenerative economy through the adoption of green technologies and strategic methodologies. By providing a detailed roadmap for integrating circular principles into manufacturing processes, the paper facilitates the shift towards more sustainable and regenerative industrial practices. The study emphasises the importance of systemic changes, including resource optimisation, waste reduction, and the adoption of sustainable materials, to enhance both environmental sustainability and economic resilience within the manufacturing industry.

3.3.3. Group 3: Urban and Built Environment & Energy

Cities and buildings lie at the heart of both energy consumption and opportunities for sustainable innovation. Many of the works in this cluster take a holistic approach to the built environment, exploring how thoughtful urban design, resilient construction practices, and efficient energy systems can mitigate environmental impacts while enhancing liveability. From harnessing nature-based solutions (e.g., biophilic corridors, green roofs) to employing advanced simulation tools that optimise microclimates, these studies illustrate that well-planned urban settings can significantly reduce energy demand and foster climate resilience. At the same time, they show how reimagined building standards, retrofitting methods, and community-oriented infrastructure can directly influence energy transitions, cutting emissions and promoting healthier living spaces.

This group is further divided into the following subgroups:

- 3A: Urban Design and Infrastructure
- 3B: Construction and Building Practices
- 3C: Waste Management and Recycling
- 3D: Energy Integration in the Built Environment

Subgroup 3A. Urban Design and Infrastructure

Urban design and infrastructure profoundly shape the ecological footprint, liveability, and resilience of cities worldwide. In an era of rapid population growth and environmental shifts, innovative approaches—ranging from biophilic design and nature-based solutions to digital workflows—are essential for revitalising urban rivers, repurposing heritage structures, and planning for future climatic scenarios. These articles illustrate how thoughtful, evidence-based methodologies can enhance human well-being, reduce heat island effects, enable local food production, and systematically integrate buildings with surrounding ecosystems. By centring both social and environmental needs, urban planners and architects can create

neighbourhoods that adapt to and even thrive under changing conditions, ultimately moving beyond sustainability toward regenerative urbanism.

Blau et al. (2018) demonstrates how restoring an urban river culvert through nature-based and biophilic design can significantly improve city resilience. By incorporating natural elements and fostering a connection between urban infrastructure and the natural environment, this study underscores the profound impact that thoughtfully designed infrastructure can have on both ecological health and the well-being of city inhabitants. The restoration project in Albufeira serves as a model for how urban rivers can be revitalised to support biodiversity, enhance aesthetic value, and contribute to the overall sustainability of urban areas.

Matacz and Swiatek (2021) showcase the innovative repurposing of underground wartime air raid shelters for hydroponic farming. This study highlights the potential of integrated urban design to renew legacy structures for community benefit, exemplifying how historical infrastructure can be adapted to meet contemporary sustainability goals. By transforming unused underground spaces into productive agricultural sites, this research demonstrates a hallmark of regenerative urban design that promotes food security, reduces urban heat islands, and fosters community engagement through sustainable practices.

Andreucci et al. (2021) emphasises the capacity of biophilic urban design to enhance health and foster a strong sense of place among urban residents. This study links infrastructure decisions directly to both ecological and social outcomes, illustrating how the incorporation of natural elements into urban planning can lead to improved mental and physical health, increased social cohesion, and a heightened appreciation for the natural environment. By addressing the challenges and opportunities associated with biophilic design, this research provides valuable insights into creating urban spaces that are both aesthetically pleasing and functionally supportive of human well-being.

Naboni et al. (2019) propose a digital workflow for assessing regenerative performance at the urban scale, exemplifying how data-driven methods can inform innovative infrastructure solutions. This study illustrates the use of parametric urban design tools to evaluate factors such as microclimate and daylight exposure, enabling planners and designers to make informed decisions that enhance the regenerative potential of urban environments. By leveraging digital technologies, this research provides a quantifiable approach to integrating regenerative principles into urban planning, ensuring that infrastructure developments are both resilient and adaptive to climate change. Finally, Mauree et al. (2018) integrates future climate scenarios into campus-level energy and design strategies. This study highlights the importance of local microclimatic modelling in guiding resilient urban infrastructure development, demonstrating how predictive modelling can inform sustainable design choices that mitigate the impacts of climate change. By incorporating climate projections into the planning process, this framework ensures that urban designs are not only sustainable but also capable of adapting to evolving environmental conditions, thereby enhancing the long-term resilience and functionality of urban spaces.

Subgroup 3B: Construction and Building Practices

Construction and building practices lie at the nexus of environmental responsibility, technological innovation, and social well-being. While energy efficiency, resource optimisation, and low-impact materials have long been central to 'green building', a new paradigm—often termed 'regenerative' or 'circular'—aims to further restore and revitalise natural and social systems. This shift demands not only advanced techniques and materials but also holistic thinking that embraces stakeholder engagement, updated standards, and supportive governance mechanisms. This subgroup encompasses studies that explore both the macro-level transformation of neighbourhoods and the micro-level innovations in building practices, emphasising the integration of sustainability into every facet of construction and urban development.

Haselsteiner et al. (2021) examine the various factors that influence the implementation of regenerative principles in buildings and districts. This study emphasises how cultural mindsets, legislative frameworks, and financial incentives can either propel or hinder the transition toward more holistic and sustainable construction practices. By addressing both the drivers and barriers, this article provides valuable insights into the systemic changes required to foster a paradigm shift toward regenerative sustainability at both the neighbourhood and building levels.

In Quintana-Gallardo et al. (2021), the research focuses on the environmental performance of wood frame construction across different European contexts. This comparative study highlights the life cycle impacts (LCA) of wooden buildings, demonstrating how regenerative sustainability is embodied through sustainable material choices and construction practices. This research underscores the importance of selecting environmentally friendly building materials to reduce the ecological footprint of construction projects, thereby contributing to resource efficiency and the broader goals of environmental stewardship within the construction industry.

Subgroup 3C: Waste Management and Recycling

Waste management and recycling sit at the core of a truly regenerative and circular economy. Moving beyond disposal or one-off bans, the works in this subcluster stress the importance of designing closed-loop systems that minimise resource depletion, reduce pollution, and create new economic opportunities. From innovations in plastic-free business models to post-disaster deconstruction methods, these studies underscore how rethinking 'waste' as a valuable resource can support healthier societies and ecosystems. Moreover, they reveal how policy, social norms, and technological solutions intersect to drive systemic shifts in how materials are consumed and recirculated. This subgroup encompasses studies that explore diverse approaches to effective waste management, resource efficiency, and sustainability across various contexts.

Conlon (2023) investigates zero-waste entrepreneurship in India to demonstrate how plastic reduction efforts and circular economy strategies can significantly minimise waste and transition toward a regenerative model. This study emphasises

the importance of grassroots initiatives and entrepreneurial ventures in driving systemic changes in waste management, showcasing how innovative business models can contribute to reducing plastic pollution and fostering sustainable consumption pattern.

In Pradhananga & ElZomor (2023), the research highlights the role of deconstruction and circular principles in post-disaster scenarios. By focusing on the repurposing and recycling of materials after natural disasters, this study demonstrates how circular economy practices can reduce waste generation, enhance resource efficiency, and build resilience in reconstruction efforts. The adoption of these practices not only aids in sustainable recovery but also promotes long-term ecological and economic resilience within affected communities.

Sulis et al. (2021) highlight the environmental advantages of food donation over landfilling. This study illustrates a significant shift toward circular and regenerative outcomes in large-scale distribution centres by prioritising food donation as a waste prevention strategy. By diverting excess food from landfills and redistributing it to those in need, this research underscores the dual benefits of reducing waste and addressing food insecurity, thereby fostering a more sustainable and equitable food distribution system.

Additionally, van der Velden et al. (2023) explores the importance of independent repair services in reducing electronic waste. By promoting repair as a key waste-reduction strategy, this study bridges circular economy principles with regenerative practices, emphasising the need for accessible repair services, supportive business models, and appropriate regulations. The research highlights how extending the lifespan of electronic products through independent repair can significantly decrease waste generation and enhance resource efficiency, contributing to the overall goals of a circular and regenerative economy.

3.3.4 Group 4: Economic and Industrial Systems

Economic and industrial systems support the world's production, distribution, and consumption patterns and thus wield enormous influence over resource use, waste generation, and social well-being. The articles in this group examine how to reshape these systems through regenerative economic frameworks, industrial ecology, and more inclusive business models, thereby addressing the escalating demands on finite natural resources. By integrating ecological thinking into economic analysis, organisations can move beyond a profit-at-all-costs paradigm to one that balances financial viability with long-term sustainability and social equity. Beyond theory, these studies also offer case-specific insights—whether in textiles, bio-based industries, or manufacturing—on how to reduce environmental footprints, close material loops, and craft equitable economic opportunities. In doing so, they offer a glimpse of what a fundamentally reimagined economic and industrial landscape might look like, one that is more resilient, innovative, and mindful of the planet's boundaries.

This group is divided into the following subgroups:

- 4A: Economic Models and Systems

- 4B: Industry-Specific Practices
- 4C: Business and Investment

Subgroup 4A: Economic Models and Systems

Economic models and systems define the structural rules by which value is created, exchanged, and distributed—shaping everything from social welfare to environmental outcomes. This subgroup investigates theoretical and practical frameworks that challenge conventional approaches, especially those that maintain inequality, ecological harm, or a single-minded pursuit of profit. From reimagining monetary systems rooted in ecological principles to developing community-driven business models within forest economies, these studies demonstrate how emerging paradigms like regenerative finance can reinvigorate the governance of resources, rebalance power, and ensure more equitable and sustainable development. This subgroup encompasses studies that explore innovative economic theories, sustainable business models, and cutting-edge financial technologies, all aimed at fostering economic systems that support environmental integrity, social equity, and long-term resilience.

Alves et al. (2022) propose an ecological theory of money that fundamentally rethinks monetary design as a critical missing link in steering economies toward sustainability and regeneration. This study explores alternative monetary frameworks that integrate ecological principles, emphasising the need for a monetary ecosystem that supports regenerative outcomes. By challenging conventional monetary systems, the article highlights the potential for ecological monetary designs to facilitate economic transitions that are both sustainable and restorative, thereby aligning financial practices with environmental goals. Schletz et al. (2023) explore the transformative potential of blockchain technology, decentralised governance, and digital Monitoring, Reporting, and Verification (MRV) tools in driving "Regenerative Finance." This study examines how these technologies can reshape the governance of global commons and redefine economic paradigms to support regenerative practices. By leveraging blockchain's transparency and decentralisation, the authors highlight innovative financial mechanisms that enhance accountability, facilitate sustainable investments, and promote equitable resource distribution. This research positions blockchain as a key enabler of financial systems that are both resilient and aligned with regenerative principles, offering new pathways for managing and regenerating shared resources.

Harbi et al. (2023) focus on small forest enterprises utilising non-timber forest products (NTFPs) to optimise natural capital. This study demonstrates a locally adaptable regenerative business model that enhances financial viability while promoting the sustainable use of forest resources. By examining the economic transitions in rural forest contexts, the research underscores the importance of community-based enterprises in fostering economic resilience and environmental stewardship. The findings illustrate how NTFP-based businesses can serve as viable models for sustainable economic development, balancing profitability with ecological preservation.

Subgroup 4B: Industry-Specific Practices

Industry-specific practices reveal how regenerative and circular principles can be tailored to address the particular resource needs, waste streams, and market demands of individual sectors. Whether by transitioning from synthetic to natural dyes in the textiles and fashion industry or by designing manufacturing systems that facilitate remanufacturing and reuse, these articles demonstrate the granular, practical measures that companies and supply chains can adopt. By illustrating how environmental, social, and economic considerations align in distinct contexts—from fashion's dye variability to the complexity of metal recycling—these studies collectively highlight the creativity and collaboration required to achieve a net-positive impact at scale.

Doty et al. (2024) examine the practical and cultural factors behind the use of natural dyes in the U.S. fashion industry. This study illuminates the challenges and opportunities that arise when embracing environmentally responsible colourants, addressing both the technical aspects of natural dye application and the cultural shifts required within the fashion sector. By focusing on textiles and natural dyes, the authors highlight the industry's potential to transition towards more regenerative and circular dyeing practices, reducing reliance on synthetic chemicals and minimising ecological footprints.

Salatino et al. (2023) adopt an industrial ecology perspective to demonstrate how remanufacturing and recycling can transform chemical engineering processes. This study emphasises the reduction of material demand and the support of a regenerative economy through the integration of circular economy principles within industrial systems. By highlighting remanufacturing within industrial ecology frameworks, the authors show how chemical engineering can evolve to minimise waste, optimise resource use, and contribute to sustainable industrial practices that align with regenerative economic goals.

Lieder and Rashid (2016) propose a robust framework for adopting circular economy approaches within the manufacturing sector. This comprehensive review bridges the gaps between resource scarcity, waste generation, and economic viability, providing actionable strategies for manufacturing industries to implement circular principles effectively. By addressing the specific challenges faced by the manufacturing sector, the article facilitates the transition to a regenerative economy through enhanced resource management, waste reduction, and the adoption of sustainable production practices that ensure long-term environmental and economic sustainability.

Finally, Daňo et al. (2020) demonstrate how Slovakia's textiles and apparel industry can integrate circular business models. This study reflects the broader shift toward a regenerative economy by showcasing innovative product and process designs that enhance resource efficiency and reduce waste within the apparel sector. By focusing on industry-specific circular economy solutions, the article underlines the potential for the textiles and apparel industry to adopt sustainable practices that not only minimise environmental impact but also drive economic growth through innovative and resilient business models.

Subgroup 4C: Business and Investment

Business and investment strategies play a vital role in driving the transition to a regenerative economy. By aligning financial mechanisms with social and environmental objectives—rather than focusing solely on short-term returns—companies and policymakers can create models that incentivise sustainable resource use, economic inclusion, and long-term ecological health. The articles in this subcluster illustrate how green finance tools, thoughtful funding structures, and collaborative approaches to resource management can simultaneously preserve natural capital and meet human needs. They emphasise the importance of designing financial incentives, channels, and partnerships capable of accelerating global movements towards environmental stewardship and responsible economic growth.

Van Niekerk (2024) demonstrates how green finance can bridge the gap between economic inclusion and environmental preservation. This study highlights that investments aligned with the Sustainable Development Goals (SDGs) not only reduce resource depletion but also promote equitable development. By connecting inclusive business approaches with green investing, the author underscores the potential of financial mechanisms to support projects that are both economically viable and environmentally sustainable, thereby fostering a more inclusive and resilient economic landscape.

Gabriela-Cornelia et al. (2014) propose strategic funding methods for regenerative economic activities. This study emphasises how carefully orchestrated financial flows can ensure the long-term preservation of natural resources while meeting human needs prudently. By focusing on investment strategies and financing for circular economy (CE) projects, the authors provide both theoretical frameworks and practical solutions for mobilising capital towards sustainable and regenerative initiatives.

Schletz et al. (2023) explore the transformative potential of blockchain technology, decentralised governance, and digital Monitoring, Reporting, and Verification (MRV) tools in driving "Regenerative Finance." This study examines how these technologies can reshape the governance of global commons and redefine economic paradigms to support regenerative practices. By leveraging blockchain's transparency and decentralisation, the authors highlight innovative mechanisms that enhance accountability and promote sustainable investments, contributing to long-term ecological and economic resilience.

3.3.5. Group 5: Education and Social Impact

Education and social impact are closely intertwined, as learning environments and community dynamics directly influence people's ability to engage with sustainability and regenerative principles. The works in this cluster highlight how transformative approaches, such as problem-based learning, stakeholder-inclusive governance, and human-centric organisational management, can catalyse both individual behaviour change and broader systemic shifts. By emphasising participatory methods, values-based leadership, and attention to well-being, these studies underscore the power of education to build more equitable, inclusive, and supportive communities. Beyond formal classrooms, the social impact dimension emerges in contexts ranging from

corporate transformations to web-based collaborations outside traditional learning settings.

This group is further divided into the following subgroups:

- 5A: Learning and Development
- 5B: Social Equity and Justice
- 5C: Health and Wellbeing

Subroup 5A: Learning and Development

Learning and development initiatives are pivotal for cultivating the skills, mindsets, and collaborative methods needed to realise regenerative economic and social systems. In higher education, stakeholder prioritisation exercises, digital transformation strategies, and problem-based learning methods can stimulate deeper engagement with sustainability challenges—ranging from mental health and social equity to decarbonisation. Simultaneously, emerging leadership and HR paradigms underscore the importance of prioritising human well-being and ethical reasoning within digital-age organisations. Collectively, these studies illustrate how educational and human-resource reforms can empower future leaders and practitioners to reconcile economic imperatives with holistic, regenerative goals.

Osorio et al. (2024) present a strategic approach to organisational learning and governance. This study introduces a methodology for prioritising stakeholders within the framework of digital transformation and sustainable corporate governance, particularly in the context of Industry 5.0. By emphasising stakeholder engagement and strategic prioritisation, the authors demonstrate how organisations can align their learning and governance structures with sustainability goals, enhancing their capacity to adopt regenerative practices and navigate the complexities of digital and sustainable transformations. Similarly, Cherep et al. (2022) delve into the dynamics of organisational transformation from a learning and human resources (HR) perspective. Their research examines how digital advancements necessitate significant changes in management practices and HR strategies, highlighting the role of continuous learning and adaptability in fostering organisational resilience. This study stresses the importance of cultivating a culture of transformative learning and development to enable organisations to leverage digital tools effectively while maintaining a commitment to sustainability and regeneration.

Sonetti et al. (2019) focus on how universities can embed regenerative principles into their teaching and curricula. This study explores the integration of education for sustainable development (ESD) and transformative learning methodologies within higher education institutions to advance the United Nations Sustainable Development Goals (SDGs). Similarly, Friedrich (2019a) investigates innovative educational methods tailored to sustainability contexts. This study evaluates the effectiveness of peer review processes as a cooperative, web-based learning method, incorporating problem-based learning, role play, and self-study techniques.

Subgroup 5B. Social Equity and Justice

Social equity and justice lie at the heart of creating truly inclusive, resilient, and regenerative societies. Beyond merely reducing environmental harm, the works in this subcluster stress that economic and ecological well-being must be pursued alongside cultural respect, community empowerment, and structural fairness. Whether through co-creating centres for a regenerative future, integrating Indigenous knowledge into circular economy policy, or re-centring Fair Trade principles within broader social movements, these articles highlight the importance of prioritising people and relationships. This approach ensures that the benefits of regenerative efforts uplift everyone, not just a privileged few, and moves us from mechanistic, profit-driven paradigms towards holistic frameworks that honour both local contexts and global responsibilities.

Bexell et al. (2023) chronicle the establishment of a Regenerative Future Centre at the University of Denver. This study illustrates how commitments to social and ecological justice can galvanise university communities towards more equitable and holistic development. By advocating for holistic worldviews, the article underscores the role of educational institutions in addressing eco-anxiety, systemic inequities, and ecological destruction. Similarly, Beamer et al. (2023) examine how Hawaiian ancestral circular economy principles illuminate social and cultural dimensions often absent from mainstream circular economy discussions. This research advances Indigenous economic justice by emphasising the integration of traditional knowledge and cultural values into modern economic practices, thereby promoting a more inclusive and just regenerative economy.

Kiessel (2022a) explores how Fair Trade, once a cornerstone of alternative economics, can reengage the next generation by aligning with other social justice movements. This study demonstrates that Fair Trade can contribute to a just, inclusive, and regenerative economy by integrating its principles with broader social justice initiatives. This alignment fosters a more resilient and equitable economic system, benefiting marginalised communities while supporting environmental goals.

Subgroup 5C: Health and Wellbeing

This subgroup explores how regenerative economic practices and sustainable design can enhance human health, well-being, and overall quality of life. It encompasses studies investigating the interplay between the built environment, ecosystem restoration, workplace health initiatives, and broader economic models aimed at fostering a healthier and more resilient society. By integrating insights from architecture, ecology, organisational management, and economic theory, the Health and Wellbeing subgroup highlights the essential role of sustainability in promoting holistic human and environmental health.

Alba-Patiño et al. (2021) employ the ecosystem service framework to link farming activities with ecosystem restoration within the context of a circular economy. Focusing on semi-arid Mediterranean landscapes, this research uses social sampling to assess how almond tree restoration influences perceptions and preferences for ecosystem services. The study reveals that ecosystem restoration enhances service diversity, such as local identity and erosion control, and translates

social and cultural benefits into measurable indicators of human well-being, including improved health and access to goods. The authors advocate for the inclusion of social indicators in ecosystem restoration policies, emphasising their critical role in achieving circular economy transitions and addressing challenges outlined in the UN Decade on Ecosystem Restoration.

Görgenyi-Hegyes et al. (2021) investigate the relationship between health-related work benefits and employee well-being, satisfaction, and loyalty during the COVID-19 pandemic. Through a large-scale survey of 537 employees, this study examines how internal factors like mental and emotional health and external factors such as healthcare support influence workplace well-being. The findings reveal that while internal factors significantly impact well-being, employer-provided healthcare support plays a crucial role in enhancing employee satisfaction and loyalty.

Kristín Vala Ragnarsdóttir (2024) introduces the concept of the Regenerative Wellbeing Economy (RWE), which designs economic systems based on nature's principles, prioritising human well-being, environmental sustainability, and social equity. This concept challenges neoliberal economic frameworks by advocating for circular economy practices, recognition of natural capital, and the promotion of social and environmental justice. The study outlines eight guiding principles for the RWE, including maintaining a right relationship with nature, fostering innovative and adaptive systems, and emphasising community and place. The study argues that achieving the RWE requires fundamental transformations in economic systems, governance, and policy-making, supported by technological innovation and social mobilisation. By aligning economic activities with regenerative and equitable objectives, the RWE seeks to create a more just and sustainable society, addressing the shortcomings of current economic models exposed by the COVID-19 pandemic.

Torresin et al. (2020) address the evolving focus of the building industry on creating environments that not only meet basic standards of acceptability but also actively support task performance and enhance individuals' health and well-being. By using a thematic analysis of expert interviews, this study investigates indoor soundscapes, emphasising the importance of perceptual and multisensory approaches in designing buildings that positively impact occupants.

3.3.6. Group 6: Technological Innovations and Systems

Technological innovations and systems serve as crucial enablers for advancing sustainability and regenerative practices across multiple sectors. 1 By combining data-driven tools, digital intelligence, and novel materials, these solutions optimise resource use and redesign production processes for minimal environmental impact. In many cases, technology acts as a bridge between theory and action, turning concepts like circularity or regenerative design into tangible outcomes, whether through real-time monitoring, simulation-assisted planning, or new manufacturing methods. 2 These innovations also help empower decentralised approaches, allowing local stakeholders, SMEs, and large organisations alike to collaborate effectively.

This group is further divided into the following subgroups:

- 6A: Information and Communication Technologies (ICT)

- 6B: Tools and Simulation
- 6C: Materials and Manufacturing

Subgroup 6A: Information and Communication Technologies (ICT)

Information and Communication Technologies (ICT) are pivotal in driving the transition towards a regenerative economy by enabling more efficient, transparent, and inclusive systems of production and consumption. By integrating digital intelligence, artificial intelligence (AI), and innovative manufacturing processes, ICT facilitates the optimization of resource use, enhances decision-making, and fosters collaborative environments that support circular and regenerative practices. This subcluster explores how redistributed manufacturing models and human-centric design tools, powered by advanced ICT solutions, can revolutionize industries, promote sustainability, and enhance human well-being. The articles below highlight the transformative potential of ICT in creating resilient and regenerative economic systems, addressing both technological advancements and their socio-economic implications.

Moreno and Charnley (2016) conduct an integrative literature review to explore the concept of re-distributed manufacturing and its potential to deliver more regenerative and resilient systems of production and consumption through circular innovation. The study identifies multiple similarities between the drivers of re-distributed and circular models of production and consumption, emphasising how digital intelligence can foster these similarities. By developing a set of criteria for re-distributed manufacturing and circular innovation, this study analyses 33 existing case studies of consumer goods production, identifying three types of re-distributed manufacturing that integrate circular innovation characteristics.

Sonetti et al. (2018) aim to determine whether technologies and artificial intelligence (AI) can create systems that enhance the relationship between buildings and their inhabitants. The findings suggest that integrating ICT data can inform the design of spaces and smart systems that align with actual user needs, promoting regenerative design practices that consider technological, psychological, cognitive, cultural, social, political, and aesthetic impacts.

Hernández-Chover et al. (2024) examine the application of artificial intelligence (AI) methodologies in the wastewater sector to support the circular economy. The study highlights the potential of machine learning (ML) to project economic scenarios based on variables such as the quality and quantity of treated flows, resource generation, current demands, and substitute goods prices. By guiding the supply and demand of resources generated in wastewater treatment plants, the article demonstrates how AI can enhance resource efficiency and sustainability in urban water cycles.

Marinakis et al. (2021) explore the role of AI and data democratisation in intelligent energy management within the energy sector. Despite the prevalence of technology-intensive organisations, the study identifies a gap in corporate know-how and workforce skills necessary for successful AI service rollouts. The research emphasises the need for inclusive data and analytics processes to empower non-

expert end-users, thereby enhancing intelligent energy management and promoting sustainable energy practices.

Mlynar et al. (2022) critique the current technology-oriented and market-led development mechanisms of AI technologies, advocating for a more human-centred approach. Focusing on urbanism, this study conducts interviews with 16 urban experts to elicit their imaginaries of how AI can and should impact future cities. By integrating discursive standpoints from social sciences, the study aims to align AI development with societal needs and challenges, fostering intelligent systems that contribute to the creation of just, sustainable, and resilient future cities.

Subgroup 6B: Tools and Simulation

Tools and simulations are indispensable in the advancement of a regenerative economy, providing the necessary frameworks and methodologies to design, assess, and optimise sustainable systems. By leveraging advanced simulation software, process modelling, and analytical tools, stakeholders can predict outcomes, enhance resource efficiency, and mitigate environmental impacts before implementation. This subcluster explores how innovative tools and simulation techniques contribute to the circularity and resilience of industrial processes, urban design, and waste management. Through case studies and methodological advancements, these articles demonstrate the critical role of technological solutions in transforming traditional linear models into regenerative, closed-loop systems that support long-term ecological and economic health.

Sonetti et al. (2018) explore the underappreciated role of building facades in mitigating local climate impacts, specifically focusing on the Urban Heat Island (UHI) phenomenon. This study assesses how facade properties, such as window-to-wall ratios and surface finishes like reflectivity and emissivity, influence outdoor temperature ranges. Utilising a simulation workflow with Ladybug Tools, the research models urban canyons in three distinct climate types—temperate warm, temperate cold, and tropical arid.

Preut et al. (2021) delve into the application of digital twins in facilitating the circular economy within product and supply chain management. Digital twins, as digital replicas of physical assets, enable accurate information flow necessary for the effective circulation of materials and products. The research presents a derived and validated definition of digital twins, followed by a stakeholder analysis that outlines the potentials and information requirements for circular supply chains. Additionally, Núñez-Cacho Utrilla et al. (2020) address the integration of Circular Economy (CE) principles within the construction industry. The study introduces a CE-dashboard designed to measure key performance indicators (KPIs) related to circular practices in construction companies. Utilising a Monte Carlo simulation technique, the article assesses the probability of achieving sustainable CE metrics based on KPIs from a leading Spanish construction company.

Charnley et al. (2019) investigate the application of simulation techniques informed by Industry 4.0 and the Internet of Things (IoT) to accelerate circular economy practices in the UK manufacturing sector. The study maps and simulates a remanufacturing process using discrete event simulation to illustrate decision-

making at the shop-floor level. Through interviews and system dynamics modelling, the research develops the concept of Certainty of Product Quality which assesses product conditions to optimise remanufacturing decisions. This simulation-based approach highlights the potential of data-driven methodologies to inform optimal circular economy strategies and intervention timings within product lifecycles.

Subgroup 6C: Materials and Manufacturing

Materials and manufacturing are foundational pillars in the pursuit of a regenerative economy, driving innovations that enhance sustainability, reduce environmental impact, and promote circularity. This subgroup delves into cutting-edge research and practical applications that transform traditional manufacturing processes into eco-friendly, resource-efficient systems. By leveraging informatics, sustainable sourcing, advanced polymer technologies, and waste valorisation, these studies illustrate how industries can move beyond linear models of production and consumption. The focus is on developing safer, biodegradable, and renewable materials, as well as optimising manufacturing practices to align with regenerative principles.

Giri et al. (2022) demonstrate the application of natural language processing (NLP) in guiding the environmentally conscious selection of chemicals used in solar cell manufacturing. This study leverages data-driven approaches to optimise solvent choices, promoting safer and more sustainable material selections.

Guillouzo and Carpentier (2022) showcase the development of plant-based pigments as sustainable alternatives to synthetic dyes in the cosmetics industry. This study highlights innovation in natural material sourcing and green manufacturing processes, emphasising the shift towards regenerative practices in cosmetic formulation. The article illustrates how leveraging renewable plant-based resources can reduce reliance on harmful synthetic chemicals, thereby enhancing the sustainability and environmental friendliness of cosmetic products.

Wang et al. (2024) explore the creation of ultra-tough, recyclable supramolecular polymers that balance mechanical performance with sustainability. This study emphasises advancements in polymer science, focusing on the design of materials that are both highly durable and capable of being recycled multiple times. By developing recyclable and healable materials, the research contributes to the reduction of plastic waste.

Belviso et al. (2020) examine the incorporation of industrial waste (red mud) into the synthesis of zeolite LTA. This study illustrates innovative waste valorisation techniques that contribute to material circularity and reduce landfill dependency. By utilising red mud, a byproduct of the aluminium industry, the article demonstrates how industrial waste can be transformed into valuable materials, enhancing resource efficiency and promoting sustainable manufacturing processes.

3.3.7. Group 7. Policy, Governance, and Standards

Policy, governance, and standards sit at the intersection of collective decision-making and practical implementation of sustainability and regenerative principles. Effective regulation and standardisation can steer industries away from business-as-

usual models and towards more responsible, transparent, and innovative practices. Beyond formal rules, governance frameworks enable collaboration among governments, communities, and private entities, ensuring that diverse interests converge around shared ecological and societal goals. Standards not only set the benchmarks for quality and compliance but also foster early market alignment, reducing uncertainty and driving investments in greener, more regenerative technologies. The articles in this group illustrate how well-designed policies and robust governance structures are essential to transforming concepts like circularity and regenerative development into real-world impact.

This group is further divided into the following subgroups:

- 7A: Regulation and Standardization
- 7B: Governance and Policy

Subgroup 7A: Regulation and Standardization)

Regulation and standardisation are fundamental components in the advancement of a regenerative economy, providing the necessary frameworks and guidelines to ensure that sustainable practices are systematically adopted across various industries and regions. Effective regulatory policies and standardised protocols not only facilitate the integration of circular economy principles but also promote environmental stewardship, social equity, and economic resilience. By establishing clear benchmarks and incentives, governments and institutions can drive innovation, reduce environmental impacts, and create a level playing field that encourages all stakeholders to participate in regenerative initiatives. This subgroup explores how strategic regional planning, early standardisation, and integrated governance models contribute to the preservation of natural resources, the internalisation of environmental costs, and the fostering of sustainable industrial practices. The following articles illustrate the critical role that regulation and standardisation play in shaping policies, enhancing market dynamics, and enabling the transition towards a more equitable and sustainable economic system.

Frank and Marsden (2016) investigate the integration of statutory regional planning with multi-level governance frameworks to embed ecological sustainability and circular economy principles into regional development. This study explores how coordinated governance structures can foster sustainable urban forms by aligning spatial planning with regenerative practices. The article emphasises the role of regional spatial planning as a strategic tool for achieving sustainability goals, highlighting the importance of collaborative governance in addressing complex environmental challenges. By examining case studies and governance models, this research underscores how regulatory frameworks can facilitate the incorporation of circular economy principles into regional development plans.

Gabriela-Cornelia et al. (2014) delve into the strategic funding and regulatory approaches necessary for the effective implementation of circular economy (CE) practices. Although this document is also relevant to the Business and Investment subgroup, its focus on environmental projects and policy aspects makes it a fitting inclusion in the Regulation and Standardization subgroup. The article explores the

need for robust financial mechanisms and institutional frameworks that support the regeneration of environmental resources. The study emphasises how strategic funding, combined with supportive regulatory policies, can drive the adoption of CE practices across industries. By addressing both theoretical and practical dimensions, this research provides a comprehensive overview of how regulations and financial strategies can synergistically promote the preservation of natural resources within a regenerative economy framework.

Friedrich (2019b) analyses the economic impacts of early standardisation in the biobased materials sector. This study demonstrates how regulatory standards can enhance environmental quality, stimulate market demand, and support sustainable industry growth. The article conducts a descriptive policy analysis to explore how early standardisation efforts can shape emerging sectors, particularly focusing on the bio-industry. The research highlights the role of normative market regulations in creating a level playing field, ensuring product quality, and fostering consumer trust. This study underscores the importance of proactive standardisation in guiding the growth of environmentally friendly industries, thereby contributing to the broader goals of a regenerative economy.

Subgroup 7B: Governance and Policy

Effective governance and robust policy frameworks are essential for steering societies and economies towards sustainability and regeneration. In the context of a regenerative economy, governance encompasses the structures, rules, and processes that facilitate coordinated action among diverse stakeholders, ensuring that economic activities align with environmental and social objectives. This subgroup investigates the intersection of governance, policy-making, and sustainable development, highlighting how strategic planning, stakeholder engagement, and adaptive management can drive systemic change. By examining case studies and theoretical frameworks, the articles within this subcluster demonstrate the pivotal role that informed governance and progressive policies play in overcoming barriers, fostering innovation, and promoting equitable resource distribution. These insights are crucial for policymakers, organisational leaders, and community planners aiming to implement regenerative practices that are both effective and inclusive.

Osorio et al. (2024) present a pragmatic qualitative methodology for identifying, prioritising, and consulting stakeholder groups within a higher education institution (HEI) undergoing digital transformation and adapting to Society 5.0. This study emphasises the importance of stakeholder engagement in aligning organisational actions with the Sustainable Development Goals (SDGs). The research highlights how this methodology can lead to improved strategic alignment, enhanced reputation, risk mitigation, and the consolidation of long-term trustworthy relationships.

Cherep et al. (2022) explore the significant shifts required in organisational management and human resources (HR) to adopt a humanistic and adaptive approach in the digital era. This study explores how Information and Communication Technologies (ICT) influence global transformations in HR management, advocating for an anthropocratic model that prioritises people, relationships, and empowerment over traditional bureaucratic structures.

Li et al. (2020) investigate the impact of green technology innovation policies on marine enterprises in China. Utilising Ordinary Least Squares regression analysis based on surveys from enterprises in major regions like Beijing, Guangzhou, Wuhan, and Jinan, this study finds that voluntary agreement tools significantly enhance the environmental performance of green technology innovations. In contrast, other policy instruments do not show a significant effect on the benefits of green technology innovation. This study underscores the need for targeted policy instruments to effectively support green innovations in specific industries, thereby contributing to the broader goals of a regenerative economy.

Meckling et al. (2017) examine the strategic sequencing of policies aimed at decarbonising energy systems. This study critiques the traditional reliance on carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems, and explores how green innovation and industrial policies can complement these approaches. The article analyses the policy pathways of low-carbon leaders like California and the European Union (EU), highlighting how these regions have built support for decarbonisation by fostering economic interest groups and reducing technology costs. This research emphasises the critical role of strategic policy sequencing in overcoming political and economic barriers, ensuring the effectiveness of decarbonisation initiatives, and advancing the transition to a low-carbon economy.

Walravens and Ballon (2017) address the challenges cities face in adopting the "Smart City" concept. Based on a comprehensive value network analysis of 37 international Smart City services conducted in a doctoral study, this research formulates a set of policy recommendations. These recommendations culminate in the development of a new methodological tool that local governments can use to establish their Smart City principles and priorities.

4. Conclusion

This comprehensive analysis underscores the imperative for a paradigm shift towards a regenerative economy to effectively address the multifaceted and interconnected global challenges of our time. The systematic literature review, encompassing 84 scholarly articles, reveals that the regenerative economy framework successfully amalgamates the strengths of the green, circular, and bioeconomy paradigms while addressing their inherent limitations. The identification of seven primary clusters and 21 subgroups illustrates the diverse and interdisciplinary nature of regenerative economy research, encompassing environmental sustainability, climate resilience, urban planning, economic systems, social equity, technological innovation, and governance.

Key insights from the study emphasise the critical role of integrated governance and policy frameworks in embedding sustainability and circularity into regional and industrial development. The findings also highlight the importance of stakeholder engagement, transformative organisational practices, and innovative technological solutions in fostering a resilient and regenerative economic system. Moreover, the analysis reveals that effective regulation and standardisation, coupled with strategic

policy sequencing, are essential for driving green innovation and ensuring the long-term viability of sustainable practices across various sectors.

The study's methodological approach, leveraging advanced machine learning techniques for thematic clustering, demonstrates the potential of artificial intelligence in synthesising and organising complex research landscapes. This approach not only enhances the comprehensiveness of the literature review but also provides a nuanced understanding of the interconnected themes that underpin the regenerative economy.

Moving forward, the regenerative economy framework offers a robust foundation for developing holistic and adaptive strategies that promote ecological restoration, social justice, and economic prosperity. Future research should continue to explore the synergies between different sustainability dimensions, emphasising the need for collaborative and cross-disciplinary efforts. Additionally, empirical studies that evaluate the effectiveness of regenerative practices in real-world contexts will be crucial for refining theoretical models and informing policy development.

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ISTRAŽIVANJE REGENERATIVNE EKONOMIJE: SVEOBUHVATNI PREGLED LITERATURE

Abstract: Savremeni globalni izazovi kao što su klimatske promene, iscrpljivanje resursa, degradacija ekosistema i društvene nejednakosti zahtevaju sveobuhvatne i integrisane pristupe za postizanje održivog razvoja. Iako se postojeće paradigme razvoja i održivosti bave specifičnim aspektima održivosti, one često ne uspevaju u pokretanju sistemske transformacije i obezbeđivanju dugoročne otpornosti. Kao odgovor na ova ograničenja, koncept regenerativne ekonomije se pojavljuje kao holistički okvir koji integriše ekološku obnovu, socijalnu jednakost i ekonomsku vitalnost. Ova studija sprovodi sistematski pregled literature od 84 naučna članka kako bi se sintetizovala i grupisala postojeća istraživanja u domenu regenerativne ekonomije. Koristeći model velikog jezika (LLM) za nultu klasifikaciju, analiza identifikuje sedam primarnih klastera — održivost i uticaj na životnu sredinu, klimatske promene i energija, urbano i izgrađeno okruženje, ekonomski i industrijski sistemi, obrazovanje i društveni uticaj, tehnološke inovacije i sistemi i Politika, upravljanje i standardi — dalje podeljeni u 21 podgrupu. Svaki klaster obuhvata ključne teme i interdisciplinarne pristupe neophodne za unapređenje praksi regenerativne ekonomije. Nalazi ističu međusobnu povezanost različitih dimenzija održivosti i naglašavaju neophodnost integrisanog upravljanja, inovativnih tehnoloških rešenja i inkluzivnih okvira politike. Mapiranjem trenutnog stanja istraživanja regenerativne ekonomije, ova studija pruža strukturirani pregled koji olakšava dublje razumevanje i daje informacije za buduće strateške inicijative usmerene na postizanje otporne i prosperitetne održive budućnosti.

Ključne reči: regenerativna ekonomija, sistematski pregled literature, model velikog jezika, klaster analiza zasnovana na LLM, implikacije politike.

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A REGENERATIVE APPROACH TO URBAN HEAT-ISLAND RESILIENCE PLANNING[1]

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Abstract: This research addresses the growing impact of urban heat islands on city dwellers' quality of life, exacerbated by increasing urbanization and global warming. A regenerative approach is proposed, exploring the potential of integrating revitalized functionally degraded areas (FDAs) with strategically implemented green-blue infrastructure (GBI). This integration aims to mitigate urban heat island effects while ensuring all residents have access to public green spaces within a 300m radius. A decision-making framework, pairing FDA characteristics with GBI types to maximize benefits, guides this process. Analysis of the FDA inventory revealed that 68% of larger FDAs are already undergoing development, exacerbating urban heat island effects. However, this analysis also identified nine smaller FDAs (minimum size 0.2 ha) within 300m of four densely populated areas lacking adequate green space access. These smaller FDAs offer strategic opportunities for implementing multifunctional GBI to mitigate urban heat. Results indicate that by revitalizing four selected FDAs, representing only 0.04% of the study area, can effectively provide necessary green space access. The study also identifies a conceptual gap in current planning frameworks, which prioritize conventional development over multifunctional GBI for addressing environmental challenges. This highlights the need for actionable guidelines and criteria for regenerative spatial planning,

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providing a clear "how-to" framework for utilizing nature-based solutions to enhance climate mitigation and develop more resilient cities.

Keywords: regenerative spatial planning, urban heat islands, green-blue infrastructure, functionaly degraded areas.

1. Introduction

The urban heat island (UHI) effect is driven by both urbanization and climate change. Urbanization's replacement of natural surfaces with heat-absorbing materials, reduced vegetation, and altered urban geometry creates the UHI (Urban…, 2024, Sixth…, 2023). Climate change then intensifies this effect by increasing baseline temperatures and the frequency of heat waves, leading to more extreme urban heat events. (Urban…, 2024).

The escalating UHI effect poses a threat to the health and well-being of urban residents, particularly those without access to private green space or air-conditioned living or working spaces. Consequently, the role of urban green spaces—including parks, recreational green areas, and green corridors—in mitigating UHI effects has gained considerable attention. Researches focuses (Urban, 2024) on two approaches: (1) utilizing green infrastructure for strategic cooling of the built environment and (2) establishing green "shelters" where urban residents can find respite from the heat. This study focuses on the latter, investigating the design and implementation of accessible and effective green spaces that provide effective relief from urban heat for residents of UHI-impacted areas who lack private green spaces.

Regenerative design offers a valuable framework for enhancing these green spaces (Davidson, 2022). This approach, which aims to restore and revitalize natural systems rather than simply sustain them (Plessis and Brendon, 2015), fosters multi-functional solutions that benefit both people and the environment. It extends beyond temperature regulation to encompass climate change adaptation strategies like water management. This facilitates a transition towards integrating carbon-reducing green infrastructure with existing grey infrastructure (e.g., water pipes, air conditioning), which can contribute to issues like increased runoff, reduced groundwater recharge, and the urban heat island effect. This integrated approach seeks to enhance the functionality of grey infrastructure while mitigating its environmental impact.

This research investigates how green-blue infrastructure (GBI), implemented through a regenerative design lens, can create effective and resilient "cooling shelters" able of withstanding and adapting to the challenges posed by a warmer climate. (Radinja et al., 2021, Severin and Michalikova, 2024) A particular emphasis is placed on the revitalization of underutilized urban spaces, transforming them into critical climate adaptation infrastructure.

Implementing GBI is simpler in new spatial designs where the need for green and water spaces can be considered from the initial planning stages. In existing urban environments, however, GBI planning is more challenging due to limited space and pre-existing infrastructure. (Radinja et al., 2021) Therefore, our proposed solution is

particularly relevant for spatial planning in urban areas facing the negative impacts of climate change and possessing limited spatial resources

The aim of our research is to develop a framework for decision-making regarding the use of the regenerative potential of FDAs with implemented GBI to address the challenges of climate change. Specifically, we investigate the following research question: To what extent can the strategic revitalization of functionally degraded urban areas, using GBI, enhance urban resilience to heat zones?

2. Methods

2.1. Selecting a Study Area for Validating a Regenerative Spatial Planning Framework

The Municipality of Ljubljana (MOL) was selected as the study area for model testing because it represents an urban environment with a high proportion of green spaces (46% of MOL's area) (ICLEI, 2024), yet still experiences UHIs (Komac et al., 2016). To assess the accessibility of public green spaces for residents within UHI-affected areas, we applied the 3-30-300 rule proposed by Konijnendijk (2021). This rule establishes minimum standards for urban nature access, stipulating that every dwelling should be within 300 meters of a public green space with a minimum size of 1 hectare. Our analysis encompassed a variety of public green spaces within MOL, including parks, green corridors, riverbanks etc. Areas within MOL that fell both within identified heat zones and beyond a 300-meter radius of accessible public green spaces were identified through spatial analysis using ArcGIS Pro software. This analysis employed an overlay method integrating three key datasets:

- Delineation of densely built-up areas: Land use data (Raba…, 2024) was used to identify built-up areas within the urban environment. These areas were further refined using orthophotos and field observations to pinpoint densely built-up zones where residents of multi-story buildings typically lack access to private green spaces.
- Inventory of public green spaces: A comprehensive data layer encompassing all public green spaces managed by the Municipality of Ljubljana was acquired. (Public…, 2024)
- Heat zone data: Due to the unavailability of specific UHI data for the MOL, we utilized accessible data on heat zones as a proxy (Oštir et al., 2014). These data provide insights into spatial temperature variations within the urban area.

By overlaying these datasets, we identified critical areas within the designated heat zones where residents lack the required access to public green spaces, as defined by the 300-meter criterion of the 3-30-300 rule.

2.2. Developing a Blue-Green Infrastructure (GBI) Typology

GBI typology, specifically tailored for urban heat mitigation and climate resilience, was developed through a two-stage literature review of 11 scientific articles.

Stage 1: The initial stage focused on identifying and refining GBI types relevant to the research context. GBI types that did not align with established definitions or were deemed unsuitable for this study's scope (e.g., urban beekeeping, green spaces at elderly care homes, archaeological parks, and green traffic islands) were systematically excluded. Synonymous terms, such as "green roofs," "eco-roofs," and "vegetated roofs," were consolidated to ensure clarity and consistency within the typology.

Stage 2: In the second stage, we assigned potential benefits[2] to the refined list of GBI types based on the reviewed literature. This process resulted in a curated GBI typology, where each type is accompanied by a description of its potential benefits, such as heat reduction, stormwater management, and biodiversity enhancement. We used a multi-criteria analysis (MCA) for assessing each GBI type's suitability for this research. The MCA evaluated GBI types based on their potential to deliver key benefits and meet study objectives. Values reflected performance against predetermined criteria. We assigned values to the legend descriptions based on their relevance to the proposed criteria, ordering them from most to least relevant. Unassessed criteria received a default value of 1.

- **P:** Primary function - assigned a value of 5
- **S:** Secondary function - assigned a value of 4
- **x:** Incidental function - assigned a value of 3
- **!:** Added benefit - assigned a value of 2

This evaluation enabled us to prioritize criteria based on their relative importance, assigning higher values to those deemed most critical for achieving the study's objectives. The developed typology, in conjunction with the MCA, served two primary purposes: (1) it provided a catalog of potential GBI solutions for addressing urban heat and enhancing climate resilience, and (2) it established criteria for selecting suitable FDAs for GBI implementation.

2.3. Inventory of FDAs

To identify, categorize, and map areas that have lost their original function and could potentially benefit from GBI implementation, an inventory of FDAs was conducted within the study area. The existing dataset (Lampič, 2024) only included areas with a minimum size of 2 hectares. To ensure a comprehensive inventory, smaller areas meeting the size criteria for local pocket parks - up to 0.2 ha (Jones et al., 2022) were also included.

- Initial inventory development: potential FDAs were identified by combining the existing FDAs dataset for the MOL (Lampič, 2024) with an analysis of current orthophotos.
- Field validation and refinement: a targeted field survey was conducted to validate the initial inventory, refine FDA boundaries, and gather detailed site-specific

[2] Benefits considered in this paper are closely related to ecosystem services, however as GBIs are not ecosystems we avoided to use the term ecosystem services.

data. This step ensured the accuracy and completeness of the FDA inventory. A structured survey form, incorporating criteria from the existing MOL FDA dataset (Lampič, 2020) was used for data collection during the field survey.

The survey form was based on the methodology developed by Lampič (2024) and included the following criteria:

- Type of FDAs: (e.g., agricultural, service, industrial, craft, tourism, defense, mineral extraction, infrastructure, transitional land use, residential)
- Degree of dereliction: partial (10–50%), substantial (50–90%), complete
- Environmental degradation: water, air, soil, vegetation, surface
- Potential contamination: yes/no
- Current ownership: private, state, municipal, public-private, unknown
- Size and form of FDAs
- Protection regimes: cultural, nature conservation, water protection
- Accessibility of stormwater runoff: estimation of the contributing area from built structures (excluding runoff coefficient considerations). This criterion assesses the potential for capturing and utilizing stormwater runoff from impermeable surface (e.g. roofs, parking lots…).

2.4. Framework for developing spatial guidelines based on regenerative potential assessment

Using the collected data, we evaluated the potential for revitalizing FDAs through GBI implementation, specifically focusing on mitigating urban heat island effects. This assessment was based on pairing on GBI benefits and FDA characteristics:

1. GBI Benefits:

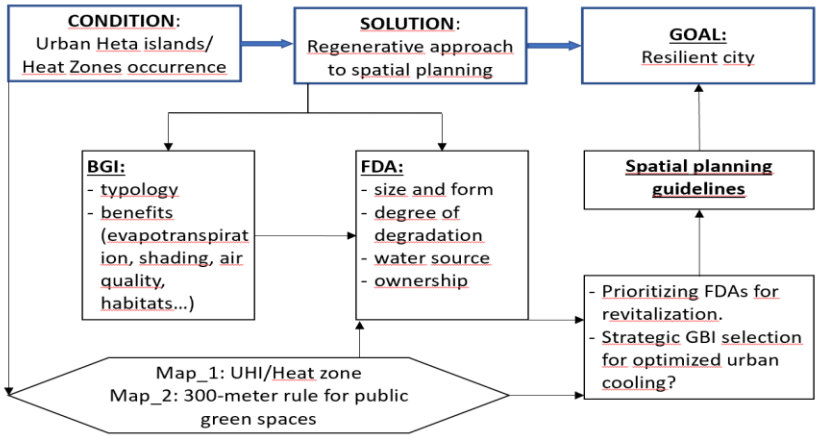
- Temperature reduction: the capacity of GBI to reduce air and surface temperatures through mechanisms such as evapotranspiration and shading was assessed.
- Biodiversity enhancement (habitat factor): the potential for GBI to increase local biodiversity was considered.

2. FDA characteristics influencing GBI feasibility and effectiveness:

- Municipal ownership: preference was given to municipally-owned land to facilitate project implementation.
- Size and shape: the size and shape of the FDA were assessed to determine suitability for different GBI types and their spatial requirements.
- Proximity to water source for runoff capture: the potential to capture and utilize stormwater runoff from surrounding impervious surfaces was evaluated, prioritizing FDAs with good accessibility to this source.

This two-pronged assessment framework, combining FDA characteristics with the potential benefits of GBI, allowed for a systematic evaluation of the revitalization potential of each FDA. The results informed the prioritization of FDAs for GBI implementation aimed at mitigating urban heat island effects and enhancing urban resilience.

Figure 1: A Framework for Assessing FDA Suitability for GBI implementation

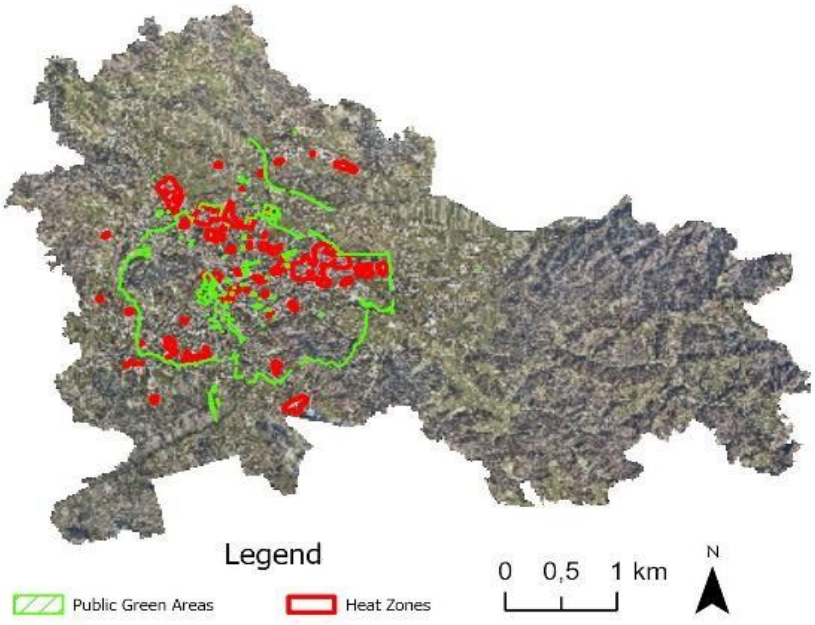


3. Results

3.1. Study Area for Validating a Regenerative Spatial Planning Framework

Built-up areas, characterized by various land cover types such as roads and buildings (LANDUSE_ID attribute code: 3000; description: Built-up and related land), constitute 28.83% (79.28 km²) of the total area of the MOL. This area encompasses all zones relevant to this study, including green spaces, densely populated areas, and UHIs.

Figure 2: MOL with designated heat zones and public green spaces.



Heat zones within the study area encompass 4.51 km², representing 5.7% of the study area. Public green spaces comprise 1.38 km², a 1.7% of the study area. This analysis excludes significant green spaces managed by public companies, such as Castle Hill, and Rožnik and Šiška hill, despite their public accessibility. Of particular concern is the concentration of dense urban development within or adjacent to urban heat zones, encompassing 28,600 m² across four distinct zones. These densely populated areas lack adequate access to public green spaces, falling outside the recommended 300-meter radius. This deficiency highlights a need for improved green space provision in these vulnerable areas to mitigate the urban heat island effect and enhance residents' well-being.

Table 1: Identified threaten areas in MOL.

	Location	Size
Threaten Area_1	Cerkova street	11699m²
Threaten Area_2	Milcinskega street	5532m²
ThreatenArea_3	Devova street	7452m²
ThreatenArea_4	Ramovseva street	3916m²

3.2 GBI Typology Catalog

The first part of the analysis resulted in a set of 45 GBI types, predominantly consisting of structural solutions (green roofs, green walls, reservoirs, permeable surfaces), green infrastructure (parks, gardens, green corridors), and blue infrastructure (permeable surfaces, bioretention units, infiltration basins). We excluded GBI types that could not be used as solutions within the context of our research because they do not provide evapotranspiration and shading functions and are therefore unsuitable as heat island mitigation measures. These exclusions were made because the GBI types:

- Are not applicable (e.g., cemeteries, urban farms, theme parks, green railway corridors, green parking lots).
- Do not achieve the desired effects (e.g., balcony plants, green art, art installations, flower meadows).
- Represent overly broad categories (e.g., general green spaces, forest, lake, canal, buffer zones, public open spaces).
- Are unsuitable due to the geographic characteristics of the study area (e.g., mangroves, estuaries, coastal zones, floodplains).
- Represent private property (gardens).
- Are structural solutions and cannot be used as public spaces (e.g., green roofs, green walls).
- Are entirely intended for water management (e.g., bioretention units, infiltration basins).
- The final selection consisted of 7 GBI types.

Table 2: Identified GBIs that can potentially contribute to Heat zones mitigation in cities.

Benefits / GBI types	Min. size	Long-term water detention	Evapotranspiration	Shade	Habitat	Air quality improvement
City park[1]	from 20.000m²*	x	S	P	P	P
Pocket park[1]	to 20.000m²*	x	S	P	S	S
Tree-lined Park[2]	-	S	P	P	S	S
Rain garden[2]	10-20% of the impervious drainage area	S	S	!		
Wetland[2]	approx. 100m²	x	P	x	!	!
Water square[2]	-	P	S	x	!	!
Pond[2]	-	P	!		!	

Legend: P = Primary function, S = Secondary function, x = Random, ! = Added benefit

[1]The evaluation of the selected benefits was based on assessment (Jones et al., 2022)

[2]The evaluation of the selected benefits on assessment (Coletti et al., 2013) adapted by Radinja et al. (2021)

Assigned values were subsequently utilized in the Multi-Criteria Analysis (MCA) to rank the GBI types according to their overall benefits, from highest to lowest.

Table 3: Weighted assessment of GBIs performance.

GBI types / Benefits	Weight (%)	Weight (value)	Park	Pocket park	Tree-lined park	Rain garden	Water square	Pond	Wet-land
Evapotranspiration	30%	0,3	4	4	3	4	4	2	5
Shade	30%	0,3	5	5	5	2	3	1	3
Long-term water detention	20%	0,2	2	3	2	4	5	5	3
Improving air quality	10%	0,1	5	4	2	1	2	1	2
Habitat	10%	0,1	5	4	4	1	2	1	2
Total weighted score			4,1	4,1	3,4	2,8	3,5	2,1	3,4

Among the top five most suitable solutions, three are classified as green infrastructure (park, pocket park, and treelined park) and two as a blue infrastructure (water square and wetland). Notably, rain gardens and ponds received lower scores than initially anticipated due to the unavailability of certain data points. However, combining different infrastructure types yields enhanced solutions.

Table 4: Weighted assessment of combined GBIs performance.

Comb. of GBI types / Benefits	Weight (%)	Weight (value)	Combination: Pocket Park & Rain Garden	Combination: Pocket Park & Water Square
Evapotranspiration	30%	0,3	4	4
Shade	30%	0,3	5	5
Long-term water detention	20%	0,2	4	5
Improving air quality	10%	0,1	4	4
Habitat	10%	0,1	4	4
Total weighted score			4,3	4,5

These findings suggest that integrating specific types of GBI, particularly those that combine blue and green elements, offers the most substantial benefits within the context of this study's objectives. A ranking of GBI types, based on their assessed potential to deliver these benefits, is presented below in descending order of overall value:

1. The combination of a Water square and a Pocket park
2. The combination of a Rain garden and a Pocket park
3. Park
4. Pocket park
5. Water square
6. Tree-lined park
7. Wetland
8. Rain garden
9. Pond

3.2. Mapped FDAs in Threaten areas

We reviewed the existing inventory of functionally degraded areas (FDAs) within our study area, cross-referencing their current status with records from Lampič (2020). Of the FDAs initially identified (minimum size of 2 hectares), approximately 68% of them are already in the construction phase. A field survey identified nine more suitable areas.

Table 5: Green Space Enhancement Potential of FDAs in 4 Critical zones.

Critical zones and their FDAs	Type of functional degradation	Degree of degradation	Size	Shape	Environmental degradation	Potential contamination	Access to a water source (estimated size of the contributing area)
Critical zone 1							
FDA 1-1	Agricultural activities	Substantial	4601 m²	Square	Soil	Use of herbicides and biocides	No
FDA 1_2	Agricultural activities	Substantial	2173 m²	Non-uniform shape	Soil	Use of herbicides and biocides	Yes (19462m²)
FDA 1_3	Agricultural activities	Complete	7015 m²	Non-uniform shape	Vegetation	No	Yes (6738 m²)
FDA 1_4	Transitional land use	Partial	1420 m²	Square	Surface	No	No
Critical zone 2							
FDA 2_1	Transitional land use	Substantial	3550 m²	Non-uniform shape	Soil, Surface	No	No
Critical zone 3							
FDA 3_1	Agricultural activities	Partial	14514 m²	Non-uniform shape	Soil	Use of herbicides and biocides	Yes (5788 m²)
Critical zone 4							
FDA 4_1	Transitional land use	Complete	2091 m²	Elongated rectangle	Soil	No	No
FDA 4_2	Agricultural activities	Partial	3437 m²	Elongated rectangle	Vegetation	No	Yes (2275 m²)
FDA 4_3	Transitional land use	Partial	6688 m²	Non-uniform shape	Vegetation	No	Yes (13044m²)

Figure 2: A map of FDAs and heat zone on densely populated area on Critical zone 1.

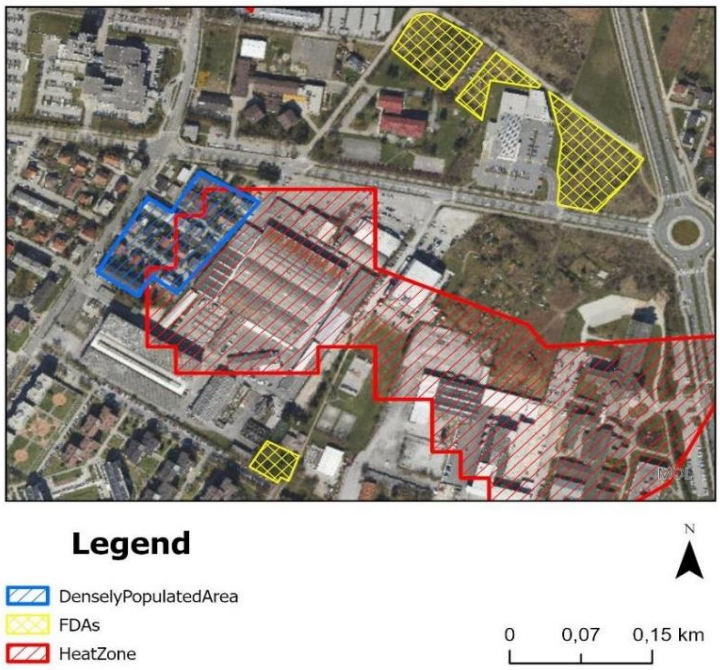


Figure 3: A map of FDA and heat zone on densely populated area on Critical zone 2.

Figure 4: A map of FDA and heat zone on densely populated area on Critical zone 3.

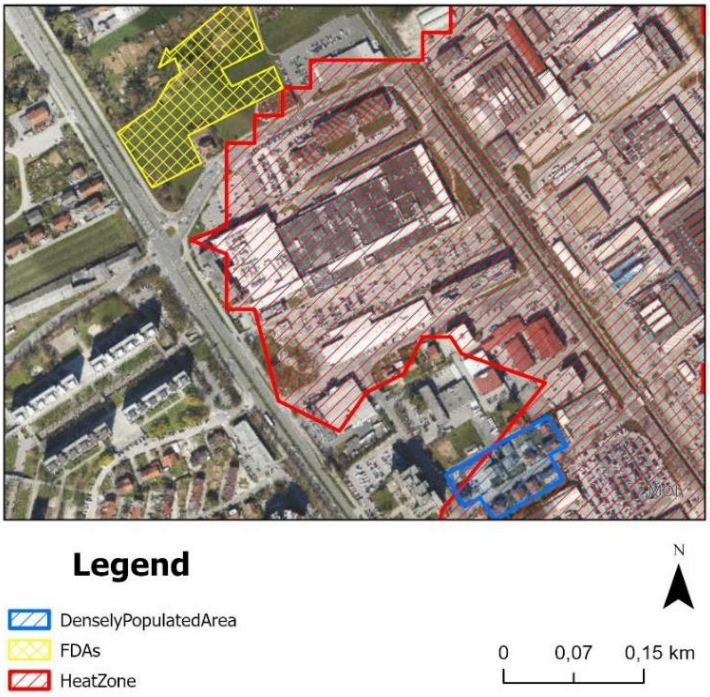


Figure 5: A map of FDA and heat zone on densely populated area on Critical zone 4.

3.3. Optimizing Functionally Degraded Areas with Green-Blue Infrastructure for enhanced urban resilience

Using a decision-making framework, we compared the characteristics of each FDA with the requirements for implementing selected types of GBI.

Table 9: Comparison matrix of identified FDAs with selected GBI.

	FDAs 1-1	**FDAs 1-2**	**FDAs 1-3**	**FDAs 1-4**	**FDAs 2-1**	**FDAs 3-1**	**FDAs 4-1**	**FDAs 4-2**	**FDAs 4-3**
Water source (est. size of contr. area)	-	Yes (19462 m²)	Yes (6738m²)	-	-	Yes (5788m²)	-	Yes (2275m²)	Yes (13044 m²)
Shape	Square	Non-uniform shape	Non-uniform shape	Square	Non-uniform shape	Non-uniform shape	Elongated rectangle	Elongated rectangle	Non-uniform shape
Size	4601m²	2173m²	7015m²	1420m²	3550m²	14514m²	2091m²	3437m²	6688m²
Comb.: Pocket park& WaterSquare	No	No	No	No	No	No	No	No	No
Comb.: Pocket park&Rain garden	No	No	**Yes**	No	No	**Yes**	No	Yes	**Yes**
Pocket park	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes	Yes	Yes
Water square	Yes	No	No	No	No	No	No	No	No
Tree-lined Park	No	No	No	No	No	Yes	Yes	Yes	Yes
Rain garden	No	Yes	Yes	No	No	Yes	No	Yes	Yes

4. Discussion

Investigating the primary research question—to what extent can the strategic revitalization of FDAs using GBI contribute to greater urban resilience against climate change impacts—has yielded both key insights but also raised further questions.

Analysis of the FDA inventory data layer (Lampič, 2024) reveals that approx. 68% of the mapped FDAs with a minimum size of 2 ha within the built-up area of the MOL are already undergoing development or redevelopment. This trend of urbanisation, coupled with rising average temperatures, will further intensify the

thermal pressure on the urban environment. Therefore, the importance of high-quality public green spaces will be further amplified in the coming years. The reduction of larger FDAs as revealed in this study will further limit the city's opportunities to create larger parks. Additional field research of FDAs revealed that within 300m of each threaten area, smaller degraded sites (0.2 ha) exist, offering opportunities for developing smaller-scale GBI (e.g. local park…). With the use of proposed framework we deduced that with minimal spatial interventions within the four selected FDAs, totaling a combined area of 0.03 km² (representing 0.04% of the study area), MOL can provide the necessary access to green space for all residents living in densely populated areas within or adjacent to heat zones who lack access to private green spaces. Three of the four selected FDAs can be upgraded from green infrastructure to GBI (for example by adding water element to pocket park) to enhance their benefits for climate change adaptation and urban resilience. The current strategic planning framework, as reflected in the Municipal Spatial Plan (MSP) (OPN…, 2010), presents a critical barrier to GBI implementation, which confirms the observations of Radinja et al. (2021). While the MSP acknowledges FDAs as priority areas for urban renewal, it focuses primarily on land-use changes for residential densification, habitat revitalization, and green space restoration within green wedges. This approach neglects the potential of GBI to address environmental challenges. The MOL Environmental Report (Okoljsko…, 2022) further underscores this limitation, indicating an expansion of green infrastructure within degraded areas that does not prioritize areas with high population density. The article focuses on pairing GBI with FDAs but it does not address the influence of the size and density of urban heat islands and population concentration on the effectiveness of the proposed solutions. Future research should develop models that simulate the impact of these factors on temperature and optimize the placement of green spaces for maximum heat island reduction. Furthermore, to gain a more precise understanding of the benefits provided by different GBI types, more refined and elaborate assessment methods are needed. This would enable a more accurate evaluation of their effectiveness in mitigating urban heat island effects and inform decision-making for optimal GBI implementation.

Developing a typology of GBI has shown inconsistencies across various studies (Blue…, 2019, Niedzwiecka-Filipiak, 2022). For example, some proposed types, such as green spaces at elderly care facilities (Niedzwiecka-Filipiak, 2022), do not clearly align with the GBI concept. The highest level of consistency was found in catalogs that list GBI types within the context of hydrological solutions (e.g. USEPA, 2024, Blue…, 2019). This suggests that the GBI concept remains largely confined to its original focus on water management (Radinja et al., 2021). The MCA analysis supports enhancing green areas with multifunctional GBI, demonstrating the benefits of combining different types, such as local parks and rain gardens, to maximize their positive impacts in the face of climate change. Further research is needed to assess the specific benefits of individual GBI types and explore additional typologies for a more comprehensive understanding.

Our study also highlight a significant conceptual gap in regenerative spatial planning of public green spaces for climate change mitigation. The initial concept lacks clear guidelines and criteria for regenerative design and implementation in this

context. The literature on regenerative design and development emphasizes a fundamental shift from merely mitigating environmental harm to actively restoring and enhancing the health and resilience of both natural and human systems. This involves a new design paradigm that promotes a co-evolutionary relationship between human activities and natural processes (Reed, 2007). The concept champions a holistic approach, aiming for a net-positive impact by integrating human habitats with nature (Plessis & Brandon, 2015), and striving for the continuous renewal and improvement of ecosystem functions (Morselleto, 2020; Unter et al., 2024), even suggesting its potential to enhance adaptive capacity in the face of climate change (Plessis, 2012). Future research should prioritize developing tangible, measurable guidelines for the regenerative spatial planning of green areas. This includes creating a composite index to quantify the multifaceted benefits of diverse nature-based solutions, enabling informed decision-making and maximizing the potential for resilient cities. Advanced simulation tools are needed to analyze the complex interactions between heat island characteristics (size, proximity) and nature-based solutions (size, type, proximity). This will facilitate the development of more effective strategies for implementing GBI and fostering truly regenerative urban environments.

5. Conclusions

This research demonstrated the potential of pairing FDAs with GBI to mitigate the urban heat island effect in three out of four threatened zones. As urbanization rapidly diminishes larger FDAs within cities, it is crucial to utilize smaller FDAs (up to 0.2 ha) to create vital green spaces.

Upgrading green spaces with blue infrastructure to create GBI not only provides multifunctional benefits—including improved air quality, enhanced biodiversity support, and increased evapotranspiration—but also amplifies these benefits, contributing to a more resilient urban environment.

Further research is needed to develop clear guidelines and measurable criteria for regenerative spatial planning, including the creation of composite indices that enable a comprehensive assessment of the benefits of various nature-based solutions, including GBI.

Better simulation tools are needed to compute interactions between the size and vicinity of the heat islands to the size, type and vicinity of the FDA/GBI. This will facilitate the development of more effective strategies for implementing GBI and creating regenerative urban environments.

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REGENERATIVNI PRISTUP PLANIRANJU OTPORNOSTI NA FENOMEN URBANIH TOPLOTNIH OSTRVA

Apstrakt: Ovo istraživanje se bavi rastućim uticajem urbanih toplotnih ostrva na kvalitet života stanovnika gradova, koji je dodatno pogoršan povećanom urbanizacijom i globalnim zagrevanjem. Predložen je regenerativni pristup koji istražuje potencijal integracije revitalizovanih funkcionalno degradiranih područja (FDAs) sa strateški implementiranom zeleno-plavom infrastrukturom (GBI). Cilj ove integracije je ublažavanje efekata urbanih toplotnih ostrva, uz obezbeđivanje pristupa javnim zelenim površinama svim stanovnicima u radijusu od 300 metara. Proces je vođen okvirom za donošenje odluka, koji povezuje karakteristike FDAs sa tipovima GBI kako bi se maksimizirale koristi. Analiza inventara FDAs pokazala je da se 68% većih FDAs već nalazi u fazi razvoja, čime se dodatno pogoršavaju efekti urbanih toplotnih ostrva. Međutim, identifikovano je devet manjih FDAs (minimalne veličine 0,2 ha) unutar 300 metara od četiri gusto naseljena područja koja nemaju adekvatan pristup zelenim površinama. Ova manja FDAs pružaju strateške prilike za implementaciju multifunkcionalne GBI kako bi se ublažila urbana toplota. Rezultati pokazuju da revitalizacijom četiri odabrana FDAs, koja predstavljaju samo 0,04% istraživanog područja, može efikasno da se obezbedi potreban pristup zelenim površinama. Studija takođe identifikuje konceptualni jaz u postojećim planerskim okvirima, koji daju prioritet konvencionalnom razvoju u odnosu na multifunkcionalnu GBI u rešavanju ekoloških izazova. Ovo naglašava potrebu za praktičnim smernicama i kriterijumima za regenerativno prostorno planiranje, pružajući jasan okvir "kako" za korišćenje rešenja zasnovanih na prirodi radi unapređenja klimatskih mera i razvoja otpornijih gradova.

Ključne reči: regenerativno prostorno planiranje, urbana toplotna ostrva, zeleno-plava infrastruktura, funkcionalno degradirana područja.

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DEVELOPMENT OF NEW TYPES OF STATE AUDIT IN THE CONTEXT OF ACHIEVING THE GOALS OF SUSTAINABLE DEVELOPMENT FROM THE 2030 AGENDA

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Abstract: *By adopting the 2030 UN Agenda in 2015, UN members committed to the implementation of 17 Sustainable Development Goals (SDGs) and at the same time mobilized numerous international and national organizations and institutions to help the national governments of UN member countries. 170 UN member states have started the COR implementation process. In process of implementing COR at the global level, Supreme Audit Institutions (SAIs) are recognized as an independent control and advisory mechanism of national governments. Also, the International Organization of SAIs (INTOSAI) is involved in this process with activities on the development of guidelines for SAIs in performing special types of performance audits (2030 Agenda preparedness performance audit and SDGs implementation performance audit). SAIs in 73 UN member countries, in 7 regions (AFROSAI-E, ASOSAI, CAROSAI, CREFIAF, EUROSAI, OLACEFS, PASAI), had preparedness performance audit, and most of them have started with the development of special types of SDGs performance audit. Conducted research showed that the implementation process of the 2030 Agenda, halfway to the deadline, did not produce the desired results and that a transformation is necessary on the way to sustainable development in a global framework. SAIs have become involved in this process as a control and advisory mechanism of national governments by conducting new types of performance audits connected with CORs. The*

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development of expediency reviews related to COR is conditioned by the level of implementation of the 2030 Agenda at the national level of the UN members. A comparative analysis of SAIs in the countries of the Western Balkans (Bosnia and similar level of development of new types of performance reviews. Most of them have audited their readiness for the implementation of the 2030 Agenda and, at the same time, started performance audits which is linked with COR, most often in the area of environmental audits, with a tendency to follow the guidelines of international professional organizations in the further development of new types of performance audits.

Key words: *Agenda 2030, COR, Supreme Audit Institutions, expediency audit*

1. Instead of introduction

„Sustainable development has emerged as a need to align the goals of technological progress and economic growth and development, with the goal of preserving the quality of the living environment“ (Marković et al, 2020). In 2015, the UN adopted the Resolution "Transforming our World: The 2030 Agenda for Sustainable Development" – 2030 Agenda (UN a, 2015). The 17 Sustainable Development Goals (SDGs) stem from the Millennium Declaration and the MDGs of 2000–2015. The development of 2030 Agenda is based on eight MDGs and their criticism on three grounds: a) they are not global goals and are not binding on UN members, b) they are short to medium-term, and c) central areas of sustainable policies (environment and poverty goals) are generally not reflected in all areas of development (Loewe, 2012).

By adopting 2030 Agenda, UN member states committed to a series of measures and activities to contribute to the achievement of the SDGs and remain permanently dedicated to improving living conditions in the economic, social, and environmental spheres. “Sustainable development seeks to establish a balance between the various dimensions of the development of economic, environmental and social“ (Krstić, 2018, p. 26). In order for development to be sustainable, growth must be inclusive i.e., no one should be left behind (Georgeson & Maslin, 2018; Cordery et al., 2023). This can be achieved by addressing issues such as social exclusion, inequality, and inconsistent adoption and implementation of public policies in the areas of human rights and environmental protection.

In the process of implementing the 2030 Agenda, the UN encouraged not only its member states, but also numerous international organizations and institutions to support the process of achieving the SDGs globally. The International Organization of Supreme Audit Institutions (INTOSAI) has joined this process, providing guidelines for State Audit Institutions (SAIs) to help governments at the national level in preparing for the implementation of Agenda 2030 and later in monitoring progress in achieving the SDGs (Ali Alagla, 2019).

The research objectives of this review are set in three directions. First, to investigate the extent to which UN countries have managed to establish the institutional framework and mechanisms for implementing the 2030 Agenda and progress towards achieving the SDGs. Second, to identify the activities of

INTOSAI and its competent bodies (INTOSAI Development Initiative (IDI), Knowledge Sharing and Knowledge Services Committee (KSC), and others) that are helpful to the SAIs in developing new types of performance audits that follow the implementation of the 2030 Agenda. Third, to examine the level which Serbia has reached in the implementation of the 2030 Agenda and in which fields the SAI in Serbia has managed to be included as a control and advisory mechanism in that process by conducting performance audits, with a comparative review of the scope of SAIs in the Western Balkans region.

2. Scope of the implementation of 2030 Agenda and progress in achieving the SDGs

The grouping of SDGs is done in five areas, starting with the "five Ps"- People, Planet, Prosperity, Peace, and Partnerships. At the halfway point to the end of the implementation period of 2030 Agenda, it has been shown that the most significant SDGs are SDGs 12, 13, and 14 (addressing environmental protection and climate change issues), SDG 1 (addressing poverty issues), and SDG 17 (partnerships for the goals) (Carlsen & Bruggemann, 2021). Although in 2023–2024, addressing peace issues in a global framework (SDG 16) is becoming increasingly important.

Key challenges in achieving the SDGs lie in three areas: a) the implementation of 2030 Agenda, b) monitoring the implementation of the SDGs (tracking, evaluation, and review), and c) finance (increasing and improving global finance flows for the SDGs) (Georgeson & Maslin, 2018). Critical attention to the implementation, monitoring, and finance framework is vital to ensure accountability and transparency from an ever-growing number of actors in this process. Additionally, the trend of the circular economy is becoming a means of achieving the SDGs (Rodriguez-Antón et al., 2022).

Particular emphasis is placed on the risks in the implementation of 2030 Agenda related to establishing the institutional framework and network of actors to carry the process of achieving the SDGs (Dalampira & Nastis, 2019; Breuer et al., 2023). Many countries are still facing the establishment of the institutional framework (National Road Map on Statistics for SDGs, Web Platform for Data on SDGs, and National Indicators for SDGs). According to national data from 63 UN member states, The United Nations Economic Commission for Europe (UNECE) research in 2023 regarding progress in establishing the institutional framework for the SDGs, showed that only 22 member states have established to establish this framework, while other UN member states are still facing some problems of mapping, tracking SDGs, developing national indicators for SDGs, and developing a web platform for data ona SDGs (see Table 1).

Table 1: UN countries according to the extent of establishing the National Road Map on Statistics for SDGs, web platform, and national SDG indicators according to UN data for 2023.

Country	National road map on statistics for SDGs	Web platform for data on SDGs	National indicators for SDGs
Armenia, Belarus, Belgium, Canada, Denmark, Estonia, Finland, France, Georgia, Greece, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Lithuania, Mexico, Montenegro, Romania, Slovakia, Switzerland, Uzbekistan (22)	Yes	Yes	Yes
Albania, Iceland, Japan, United Kingdom, United States of America (5)	Yes	Yes	No
Austria, Azerbaijan, Bosnia and Herzegovina, Colombia, Czechia, Germany, Hungary, Liechtenstein, Luxembourg, Netherlands, Norway, Poland, Republic of Moldova, Russian Federation, Slovenia, South Africa, Sweden, Tajikistan, Turkey, Ukraine (20)	No	Yes	Yes
Australia, Croatia, Portugal, Serbia (4)	No	Yes	No
Latvia, Monaco (2)	No	No	Yes
Cyprus, Malta, North Macedonia, San Marino, Turkmenistan (5)	No	No	No
Spain (1)	Pending	Yes	Yes
Mongolia (1)	Pending	Yes	/
New Zealand (1)	Pending	Pending	Yes
Andorra, Bulgaria (2)	Pending	No	No

Source: Table prepared by the authors according to data from the website UNECE, 2023

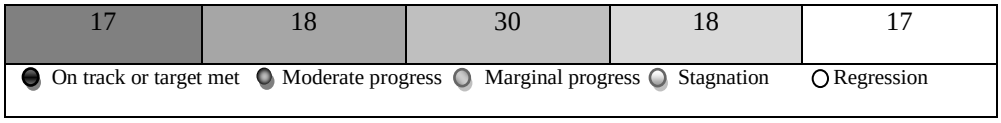
There is the need that establishing a national road map of statistics for SDGs globally solve by applying statistical knowledge (Kraak et al., 2018; Dalampira & Nastis, 2019), which resulted in the adoption of the Guidelines: The Road Map on Statistics for SDGs (UN f, 2022) adopted by the Conference of European Statisticians in 2021 and published in February 2022. Particular challenges have also been identified in tracking general (common) and national (specific) indicators for SDGs (Lyytimäki et al., 2022; Carlsen & Bruggemann, 2021). Statistics have also helped address these challenges, which are shaped through open-source tools for SDGs: Matrix on Capacity Development (Statistics tools for SDGs a); Guidelines for the Capacity Development Matrix (Statistics tools for SDGs b); Merging JsonStat and GeoJson formatted data to create and visualize a GeoDataFrame and write it to an ESRI Shapefile (Statistics tools for SDGs c); Extract and join statistical data from the CSO Ireland database with geographic data in Python (Statistics tools for SDGs d).

The 2024 SDGs Report highlights that nearly half the 17 targets are showing minimal or moderate progress, while over one-third are stalled or reversed since they were adopted by UN member states back in 2015 to bring peace and prosperity to people and the planet. From 2024, the global indicator framework

includes 231 unique indicators. The total number of indicators listed in the global framework of SDGs indicators is 248, but 13 indicators repeat at two or three different targets.

The progress assessment carried out in 2024 reveals that the world is severely off track to realize the 2030 Agenda. As illustrated in Figure 1, out of 135 targets, only 17% show progress as expected to be reached by 2030. Almost, nearly half (48% of total number of targets) show moderate to severe deviations from the desired trajectory, 30% showing marginal progress and 18% of total number of targets indicate moderate progress. Alarmingly, 18% show stagnation, and 17% of total number of targets indicate regression below the baseline levels of 2015.

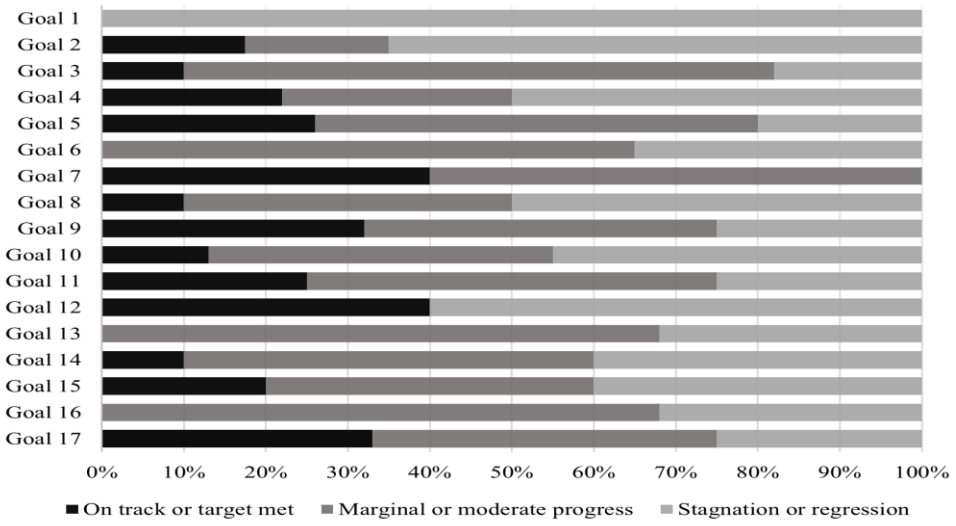
Figure 1. Overall progress assessment across targets (2015–2024 trend data)



Source: UN b, 2024, p. 4.

A progress assessment of each Goal is provided in Figure 2. It should be emphasized that differences in country data coverage play out across the SDGs, with major shortfalls in priority development areas, such as gender equality (SDG 5), climate action (SDG 13), and peace, justice, and strong institutions (SDG 16). Approximately one-third of indicators lack data for the past three years, hampering policymakers' ability to make timely, informed decisions and course corrections. Therefore, the timeliness of data remains a challenge.

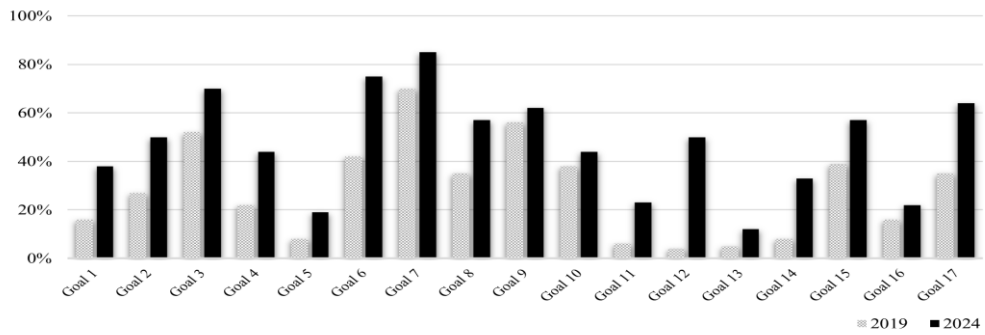
Figure 2. Progress assessment of the 17 SDGs based on assessed targets by Goal (2015–2024 trend data)



Source: UN b, 2024, p. 4.

As illustrated in Figure 3, progress has been made in improving data availability to monitor the SDGs when comparing the Global SDGs Indicators Database for 2019 with that for 2024. In 2016, when the global indicator framework was initially adopted, only about one-third of the indicators had good data coverage, and 39% of the SDGs indicators lacked internationally established methodologies or standards. In 2024, 68% of the SDGs indicators have good data coverage, and 231 indicators have a well-established and internationally agreed methodology. Also, trend data are available for 51% of the SDGs indicators in more than half of all countries.

Figure 3. Proportion of countries or areas with available data (at least two data points since 2015) with a comparison of the databases from 2019 and 2024 by Goal



Source: UN b, 2024, p. 4.

The listed challenges, risks, and the current situation of achieving the SDGs indicate that changes are necessary (Cameron & Shirin, 2023). According to the 2023 SDGs Report (UN d, 2023), the SDG transformation should take place in six entry points (with five levers for each of them: governance; economy and finance; individual and collective action; science and technology; capacity building) to accelerate progress towards the SDGs in the period until 2030 (UN d, 2023):

1. *Human well-being and capabilities* (investment in primary health care; accelerating secondary education enrollment and completion ensuring all girls are enrolled; investment in water and sanitation infrastructure);

2. *Sustainable and just economies* (encouraging inclusive pro-poor growth progressive redistribution measures; doubling welfare transfers in low-income countries; rollout of good practice climate policies and global carbon pricing; investment in green innovation; circular and sharing economy models);

3. *Sustainable food systems and healthy nutrition* (mix of measures: supply-side measures improving affordability increasing yields sustainably while reducing inputs and negative impacts; measures in retailing processing and distribution; measures on the demand side like food waste and others);

4. *Energy decarbonization and universal access* (deployment of renewables and best available technologies; infrastructure investment and support for universal

electricity access; phasing down of fossil fuels by 2030; major changes in global consumer behavior to reduce energy consumption);

5. *Urban and peri-urban development* (doubling the recycled and composted waste by 2030; more circular waste cycle; greater use of electric vehicles; better public transport with cities' infrastructure oriented to people and pedestrians and not cars; good-practice policies for the development of smart communities);

6. *Global environmental commons* (expanding protected areas; abandoning intensive agricultural practices; reforestation; conservation land use; reducing water consumption; adopting an agriculture sector roadmap to 1.5°C).

Capacity-building will also be critical for effectiveness of deployment of these entry points. Transformations to sustainable pathways should be rooted in science (UN d, 2023). Based on observation and testing hipotheses, the scienfitic method reduces uncertainty, identifies tipping points, accelerates the uptake of innovations, and lays the foundations for the next frontier of ideas. This 2023 SDGs Report argues for science that is multidisciplinary, equitably and inclusively produced, openly shared, widely trusted and embraced, and "socially robust" and relevant to society. Science has already provided answers and solutions in many areas of the implementation of Agenda 2030 (Cameron et al., 2021) starting with consideration of sustainable development transformations, modeling and their accelerators, impediments, enablers, and interlinkages (Cameron et al., 2023), through the development of methodologies for monitoring SDGs progress (Cameron & Shirin, 2023) to the application and development of information and communication technologies, including artificial intelligence (Palomares et al., 2021).

3. Activities of INTOSAI and its bodies with the aim of guiding SAIs in the process of implementing 2030 Agenda

On the path to achieving the SDGs envisaged by 2030 Agenda, the UN mobilized numerous international organizations and institutions. INTOSAI has been recognized as a significant control and advisory mechanism for the efficient, effective, and transparent fulfillment of the SDGs. This led to one of the priorities of the INTOSAI Strategic Plan for the period 2023–2028 being the contribution to achieving the 2030 Agenda as well as monitoring and assessing progress in achieving the SDGs in the context of specific efforts each country is making in the field of sustainable development (INTOSAI b, 2022). As a contribution to the efforts of SAIs, INTOSAI has mandated the INTOSAI Development Initiative – IDI to develop new types of state performance audits to help SAIs:

a) performance audit of SDGs preparedness and

b) performance audit of SDGs implementation (IDI c, 2024).

Besides these SDGs audits, SAIs may also carry out audits somehow related to SDGs where their work's scope and methodology are not designed on a specific SDG or target but produce evaluations about the efficiency and effectiveness of the SDGs related actions ultimately. The said audit exercise provides strategic

recommendations on how to integrate SDGs in national planning processes with special emphasis on coordination and implementation of SDGs and assessing/monitoring performance of implementation.

It should be noted that even before the adoption of 2030 Agenda, in the context of combined audits, SAIs carried out audits in the area of environmental protection (green audit) and in areas of significance to citizens, and that within INTOSAI a special Working Group on Environmental Auditing (WGEA) had already been functioning since 1996 to stimulate and support the development of environmental audits. By 2017, WGEA had focused on green audits, which work plans for 2017–2019 (INTOSAI WGEA a, 2017) and 2020–2022 (INTOSAI WGEA b, 2020) shifted towards performance audit SDGs (Flavian et al., 2023). The first WGEA strategy for 2023–2030 (INTOSAI WGEA d, 2023) supported by the work plan for 2023–2025 (INTOSAI WGEA c, 2023) initially provides support for the provisions of Agenda 2030 and new types of audits in the context of SDGs (performance audit preparing for the implementation of the 2030 Agenda and performance audit SDGs) from the perspective of environmental protection. By the end of the period, the focus of the strategy will shift to preparing a new Agenda that will follow Agenda 2030, which INTOSAI WGEA will also support (Bonić & Milenović, 2023).

3.1. Performance audit of SDGs preparedness

IDI, NTOSAI Knowledge Sharing, and Knowledge Services Committee (KSC) and other partners have launched the "Audit of SDGs" initiative to support SAIs in conducting high-quality audits of SDGs. As part of this initiative, 73 SAIs and one sub-national audit office in Africa, Asia, the Caribbean, Europe, and Latin America and the Pacific conducted performance audits of SDGs preparedness. The results of these audits are documented 2019 in the IDI-KSC publication "Are States Ready to Implement the 2030 Agenda? Insights and Recommendations from SAIs" (IDI KSC, 2019). The results presented so far indicate that SAIs have encouraged national governments to take action in countries where it was lacking, providing independent control of the implementation of 2030 Agenda in national contexts. SAIs have also made recommendations to strengthen readiness for the implementation of 2030 Agenda and contributed to raising awareness among citizens and stakeholders about the importance of its implementation. In this context, guidelines have been developed: Auditing Preparedness for Implementation of SDGs - Guidance for Supreme Audit Institutions (UN, IDI, & KSC, 2019) which are based on: a) ISSAI 12 (INTOSAI-P-12- The Value and Benefits of Supreme Audit Institutions – making a difference to the lives of citizens) b) ISSAI 300, ISSAI 3000, GUID 3910, GUID 3920 and c) IDI's ISSAI Implementation Handbook on Performance Audit (IDI d, 2023).

The role of SAIs in preparing for the implementation of SDGs in accordance with ISSAI 12 (INTOSAI-P-12, 2019) is described through three objectives that SAIs should achieve:

- Strengthening accountability, transparency, and integrity of government and public sector entities;

- Disclosing relevant audit results to citizens, parliament, and other stakeholders;
- Being a model organization for others by example.
- Guidelines for auditing preparedness for the implementation of SDGs are also based on the INTOSAI Strategic Plan for the period 2017–2022, which specified four areas where SAIs can contribute to achieving SDGs at national, regional, and global levels (INTOSAI a, 2017):
- Assessing the readiness of national systems to report on progress in achieving SDGs and then conducting audits of SDG achievements by those systems;
- Conducting performance audits to assess the economy, efficiency, and effectiveness of key government programs that contribute to specific aspects of the SDGs;
- Assessing and supporting the implementation of SDG 16, which partially relates to transparency, effective and accountable institutions;
- Being a model of transparency and accountability in their own activities, including auditing and reporting.
- Guidelines for performance SDGs' preparedness audits refer to conducting audits through the following phases (UN, IDI, & KSC, 2019):

1. *Planning the audit of preparedness for implementing the SDGs* (defining the scope, timeline for the audit; understanding 2030 Agenda; defining audit objectives; establishing audit criteria for conducting the audit; developing a matrix for conceptualizing the audit; developing tools for data collection and analysis; finalizing the plan);

2. *Conducting the audit of preparedness for implementing the SDGs* (collecting evidence on - institutional arrangements and processes related to integrating 2030 Agenda into government activities, budget alignment with 2030 Agenda, communication and coordination mechanisms; analyzing collected evidence; developing a findings matrix for the audit);

3. *Reporting and communicating the results of the audit of preparedness for implementing the SDGs* (drafting a report with recommendations; reviewing comments; finalizing the report; issuing and publishing the report to stakeholders);

4. *Monitoring* (tracking the implementation of recommendations, assessing conditions for conducting an SDGs audit, including results in national sustainable development reports and voluntary national reports to the UN).

The challenges in auditing preparedness for implementation of SDGs are varied (Ali Alagla, 2019): the absence of data at the national level to national audit bodies; lack of independence of SAIs; diversity in the involvement of SAIs in requests for support in implementing SDGs; the trade-off between complexity and quality in SAIs work; adopting a holistic approach to auditing; the thematic approach to audit plan needs to be developed; adopting integrated reporting, which is moving away from purely financial reporting and always be aligned with national capacities.

3.2. Performance audit of SDGs implementation

In 2019, SAIs showed strong willingness to transition from audit of SDGs preparedness to audit of SDGs implementation. The Moscow Declaration from the INTOSAI Congress in 2019 declared that future directions of public sector audits will depend on INTOSAI's and SAIs commitment to providing independent external oversight over the implementation of nationally agreed sub-goals, including those related to general SDGs (INTOSAI c, 2019). In light of INTOSAI and SAIs great interest in conducting audit of SDGs, IDI decided to continue supporting SAIs in this direction. The starting point of this support is the development of IDI's SDGs Audit Model (ISAM) (IDI a, 2020) designed for the process of auditing SDGs' implementation. ISAM is based on the application of five principles: 1) focus on outcomes of processes and programs 2) recognize SAI diversity 3) ISSAI-based 4) inclusiveness 5) add value. ISAM was updated in 2024. The new ISAM focused on (IDI b, 2024): 1) sets the context of the 2030 Agenda; 2) audit of SDGs' implementation and key concepts; 3) strategic and annual audit planning audit of SDGs' implementation; 4) stages of the audit process in an audit of SDG implementation (for that purpose, new ISAM used real examples from ISAM pilots and checklists to confirm that relevant ISSAI requirements have been complied with (especially performance audit ISSAIs) as well as spotlights on "audit impact" highlighting questions that the SAI may want to ask at each stage of the audit to enhance audit impact).

2024 ISAM defines audits of SDGs' implementation as "an ISSAI-compliant performance audit to examine the implementation of the SDGs at the national level using a whole-of-government approach". The characteristics of an audit of SDGs' implementation are as follows: understanding processes to implement the SDGs and set SDGs targets at the national level; audit impact considerations; inclusiveness, i.e., leave no one behind (LNOB) (Cordery et al., 2023); impact-driven performance audit process that mainstreams key SDGs considerations; ISSAI compliant performance audit; audit multi-stakeholder engagement; use of a whole-of-government approach to auditing of SDGs implementation (auditing national processes and programs as a factor in achieving progress SDGs (Fedchenko et al., 2023)). 2024 ISAM specifies entry points for conducting performance audits of SDGs implementation (Table 2).

IDI is currently piloting 2024 ISAM by supporting 170 auditors from 55 SAIs across INTOSAI regions. In this way, 2024 ISAM promotes and prioritizes cooperative audits of (IDI e, 2024): strong and resilient national public health systems (linked to SDG 3.d) for 39 SAIs; sustainable public procurement (linked to SDG 12.7) for 14 SAIs in Latin America; audit of elimination of intimate partner violence against women (linked SDG 5.2) for SAI of Uganda. The support model for these audits includes innovative mechanisms like the use of data analytics, integrated education and audit support framework, and support for facilitating audit impact.

Table 2. Two entry points for carrying out a performance audit of SDGs implementation

Processes	Programs
Auditing the performance of government processes to implement the SDGs at the national level	Auditing the implementation of the set of programs that contribute to the achievement of selected target(s) linked with one or more SDG global targets
Auditing processes to implement the SDGs at the national level across sectors and levels of government (whole-of-government approach).	The programmatic audit to conclude on government efforts to ensure policy coherence and integration in the implementation of programs that contribute to the achievement of selected SDGs.
Auditing processes related to multi-stakeholder engagement, leave no one behind, and/or other processes.	The programmatic audit could also include questions that allow the auditor to conclude on government efforts at realizing the principles of LNOB and multi-stakeholder engagement.

Source: IDI b, 2024, p.11

During 2022, IDI promoted equal futures audit (EFA) in areas of vulnerability and marginalization (IDI f, 2023). In this context, IDI launched the initiative EFA Changemakers (2023–2024) as an initiative to transform a pool of SAI auditors into change agents who develop EFA strategies for their SAIs and lead an EFA audit in the SAI. EFA is a performance or compliance audit of equality and inclusion in a high-priority area of marginalization in the national context. Six key areas of marginalization were identified—poverty, gender, ethnicity, migration, age, and disability—which the EFA pilot audit conducted by the changemaker could focus on. The scope of the audits can vary from looking at entities, projects, and programs to examining institutional frameworks and national outcomes. IDI will support these EFA changemakers by setting up a professional education, reflection, and audit support platform.

In 2022, to help SAIs provide a relevant audit response to climate change, IDI and WGEA agreed to cooperate in facilitating a global audit of climate change adaptation actions (IDI, WGEA, 2022). To contribute to climate change adaptation actions, SAIs will need to achieve high-quality audits (global cooperative audits of climate change adaptation actions - CCAA) and recommendations of government efforts for climate change adaptation in relevant areas (disaster risk reduction, water resource management, sea level rise and coastal erosion, implementation of climate change adaptation planning or actions (SDG 13)).

Also, the INTOSAI Working Group on SDGs and Key Sustainable Development Indicators (WGSDG KSDI) refocused its activities in 2019 in line with the 2030 AGENDA. WGSDG KSDI then set the following goals: to facilitate information and knowledge sharing among member SAIs and INTOSAI partners to carry out evaluations and to render services on knowledge acquisition. The working group intends to enhance the role of SAIs in assessing the efficiency and effectiveness of national resources, to strengthen the credibility of INTOSAI at the international level, and to encourage the design and control of key national

indicators in every possible way (INTOSAI WGSDG KSDI, 2019). The Working group considers its long-term objective to help national governments promote an incresement in efficiency, transparency, and public trust to fight against corruption and to assess the effectiveness of national resources in the interest of countries and peoples.

4. Activities of SAIs in EUROSAI and Western Balkan region in the process of implementation 2030 Agenda - comparative approach with a focus on Serbia

The X EUROSAI Congress in 2017 endorsed the second EUROSAI Strategic Plan (ESP) for 2017–2023 (EUROSAI a, 2017). Following a mid-term review of the ESP's implementation, the XI EUROSAI Congress in 2021 updated the plan and extended its time frame. The ESP 2017–2024 (EUROSAI b, 2021) outlines EUROSAI's mission, vision, and values, with two strategic goals:

- *Strategic Goal 1* (ESP SG 1): Supporting effective, innovative, and relevant audits by promoting and facilitating professional cooperation (co-led by the SAIs of Lithuania and Germany).

- *Strategic Goal 2* (ESP SG 2): Helping SAIs address new opportunities and challenges by supporting and facilitating their institutional capacity development (co-led by the SAIs of Poland and Sweden).

EUROSAI has collaborated with INTOSAI bodies to develop new audits related to the SDGs. As established in ESP 2017–2024, Working Groups are formed by the Congress to tackle issues of mutual interest for member SAIs and professional issues related to broader audit practices. EUROSAI has two working groups dealing with SDG issues: INTOSAI WGEA and the EUROSAI Working Group on the Audit of Funds Allocated to Disasters and Catastrophes. Additionally, the EUROSAI WGEA Work Plan 2024–2027 (EUROSAI WGEA, 2024) aims to support cooperation within and outside the SAI community and facilitate knowledge and experience sharing on common environmental auditing topics, tools, and methods. EUROSAI also has a long-standing collaboration with INTOSAI IDI to support effective, innovative, and relevant audits and help SAIs address new opportunities and challenges by facilitating institutional capacity development.

EUROSAI has also undertaken projects to assist SAIs in conducting performance audits of SDGs preparedness for the 2030 Agenda and SDGs. One such project was conducted by the Belgian Court of Audit (CoA) (EUROSAI c, 2020), which examined how various governments in Belgium commit to and organize themselves regarding the SDGs.

A particularly significant project related to SDG audits was led by the Turkish Court of Accounts (TCoA) in collaboration with UN bodies in Turkey. The project resulted in the documents "Collaboration with National-Level UN Agencies in the Context of SAIs' SDG-Related Audit Processes" and "UN-SAI Country-Level

Collaboration on SDGs Audits: Recommendations for Auditors" (EUROSAI d, 2023). In this project, 27 EUROSAI members responded to a survey based on individual experiences with SDG-related audit question sets, which were categorized under four main categories: macro-level policy framework for SDGs, institutional-level policy framework for SDGs, SDGs implementation level, and monitoring and evaluation status. The recommendations provided are significant for auditing SDGs preparedness and implementation, based on the personal experiences of SAIs in these areas.

The extent of SAI activities within EUROSAI shows variation in the development of SDGs-related audits, which is linked to the degree of implementation of the 2030 Agenda in certain countries. Previous studies have indicated that SAIs from veteran EU member states are more similar among themselves, as are SAIs from Nordic countries (Johnsen et al., 2019), Baltic countries, Western Mediterranean countries, and Eastern countries (Hancu-Budui & Zorio-Grima, 2021).

There are specific challenges for SAIs in the Western Balkan countries, which are at a similar level of SDG audit development. Most of these countries have conducted audits of SDG preparedness for the 2030 Agenda following the Moscow Declaration in 2019. Tetteh et al. (2022) highlight that SAIs in underdeveloped countries face specific challenges similar to those in developing countries like the Western Balkans. The authors suggest that institutional pressures from INTOSAI, government auditees, and political executives affect SDG audit implementation.

They argue that constructive dialogue with accountable parties, especially politicians and auditees, can improve SAIs' response in underdeveloped and developing countries to SDG audits. This applies to the Western Balkan countries as well. Table 3 provides a review of Western Balkan SAIs and their types of audits related to SDGs, along with the ranking of Western Balkan countries by SDG performance among all 193 UN member states.

Hancu-Budui and Zorio-Grima (2021) concluded that younger staff within institutions tend to make them more transparent and that more transparent SAIs are more likely to report on environmental audits covering SDGs. This is also true for most Balkan countries, which have similar statuses regarding SDG implementation. Dionisijev and Bozhinovska-Lazarevska (2024) conducted research in SAIs in some Balkan countries (Croatia, Montenegro, North Macedonia, and Slovenia). The authors noted that the CoA Slovenia provides comprehensive reports about SDG topics, followed by SAO North Macedonia and SAO Croatia, while SAI Montenegro conducted the fewest performance audits of SDGs. The study also showed no significant link between EU membership and SAIs' reporting on SDGs.

Table 3: Ranking of Western Balkan Countries by SDG Performance of all UN member states and review of performance audits of SDG preparedness and implementation

Western Balkan countries	Rankings Balkan states by SDGs performance of all UN member states		Audits / EUROSAI members in the Western Balkans	Performance audit of SDG preparedness	Performance audit of SDGs implementation
	Renk	Performance by SDG (% of SDG achievement)			
Bosnia and Herzegovina	50	73,99	Audit Office of the Institutions in Bosnia	2019	environmental audits Audits related with: SDG 5, SDG6, COR 14
Bulgaria	41	75,54	Bulgarian NAO	-	environmental audits Audits related with: SDG3, SDG4, SDG 9
Croatia	8	82,19	SAO of the Republic of Croatia	2020	environmental audits Audits related with: SDG 1, SDG 3, SDG 6, SDG 9
Montenegro	57	73,05	SAI of Montenegro	2023	environmental audits Audits related with:
North Macedonia	51	73,80	SAO of Nort Macedonia	(cooperative audit with SAI of Serbia) 2024	environmental audits Audits related with: SDG 3, SDG 4, SDG 7, SDG 13,
Serbia	35	77.03	SAI of Serbia	2023	environmental audits Audits related with: SDG 2, SDG 3, SDG 5, SDG 7, SDG 15,

Source: The table was prepared by the authors according to data from UN g, 2024, and from websites Western Balcan SAIs

The SAI of Serbia acts as a control and advisory mechanism in the implementation of the 2030 Agenda and SDGs, adhering to guidelines and recommendations from INTOSAI IDI. In its Strategic Plan for the period 2019-2023 (DRI Srbije a, 2019), the SAI of Serbia addressed audit issues related to the strategic framework for sustainable development.

Between 2019 and 2023, the SAI of Serbia conducted 17 performance audits on topics related to SDGs in the social, economic, and agricultural spheres, focusing on water protection and availability, air quality, waste management, social protection, healthcare, cultural heritage protection, and public services (DRI Srbije c, 2019, 2020, 2021, 2022, 2023). The themes for performance audits were determined based on risk assessments and covered all social areas, from social protection and education to environmental and economic areas. In this way, the SAI of Serbia not only controlled but also supported significant changes in the

operations of public fund users. This support was achieved by adequately responding to the challenges faced by citizens, stakeholder expectations, and emerging risks in a changing environment. Notably, the SAI of Serbia conducted performance audits addressing SDG-related issues, tackling key topics crucial for achieving them.

A particularly important performance audit was conducted on the SDgs: Readiness of the Republic of Serbia for the implementation of 2030 Agenda, covering the period 2015–2022. The audit applied a whole-of-government, results-oriented approach, focusing on the public structures and mechanisms established to achieve 2030 Agenda. More detailed investigations were conducted at the Ministry of Foreign Affairs, the Ministry of European Integration, the Republic Secretariat for Public Policies, and the Republic Statistical Office. Table 4 presents the audit objectives for assessing Serbia's readiness to implement Agenda 2030 and the conclusions reached.

Table 4: Audit objectives and conclusions on Serbia's readiness for 2030 Agenda

Audit Objectives for Serbia's Readiness for Implementing 2030 Agenda 2030	Audit Conclusions
1. Assessment of preparatory processes for the implementation of Agenda 2030 in Serbia	1. For effective implementation of the 2030 Agenda, it is necessary for the relevant authorities to adopt a Development Plan of the Republic of Serbia, ensuring that it is reflected as an overarching document in development planning and public policy documents and consistently linked to SDGs in all aspects of 2030 Agenda.
2. | Analysis of the current state and effectiveness of established mechanisms for implementing and coordinating the process of implemetation of 2030 Agenda	2. Serbia has established an institutional framework for implementing 2030 Agenda involving numerous development partners. However, since 2020, there has been a lack of continuous coordination of activities between state authorities and other stakeholders, which must be reactivated.
3. Analysis of the effectiveness of the established system for monitoring and reporting on progress in achieving SDGs	3. The adoption of a National Road Map for Statistics, national indicators for monitoring SDGs, and regular inclusive reporting to the UN will ensure the implementation and tracking of 2030 Agenda achievements in line with Serbia's specificities.

Source: The table was prepared by the authors according to data from the website of SAI of Serbia (DRI Srbije d, 2023)

In 2023, the SAI of Serbia joined the INTOSAI IDI project "Audit of Equal Futures for All" (DRI b, 2023). The project aims to facilitate the transformation of a group of SAI auditors into change agents who will develop an Equal Futures Audit (EFA) Strategy and lead such audits. The DRI's Strategic Plan for 2024–2028 foresees the further development of other types of audits related to achieving SDGs in accordance with ISAM guidelines (DRI Srbije b, 2023).

In 2024, the SAI of Serbia initiated several performance audits in the areas of managing solar and wind energy potential in electricity production, managing agricultural land quality, planning green infrastructure in cities, and fire protection prevention in Serbia (DRI Srbije e, 2024). The SAI of Serbia is also engaged in cooperative audits related to SDGs. In May 2024, a joint report was produced: "Readiness for the implementation of the SDGs by 2030" - SAI of Serbia and SAO North Macedonia (DRI Srbije f, 2024).

5. Conclusion

The assessment and monitoring of progress and government readiness to implement 2030 Agenda and SDGs are becoming increasingly significant as UN member states face numerous challenges in this area. Therefore, at the SDGs Summit during the 78th session of the UN General Assembly in 2023, a Political Declaration was adopted (UN e, 2023) to accelerate action on 2030 Agenda and its SDGs towards peace, prosperity, environmental protection, and progress for all. The 2024 SDGs Report (UN b, 2024) shows that halfway to the 2030 deadline, current progress falls far short of what is required to meet the SDGs. Numerous global challenges (the impacts of the climate crisis, the war in Ukraine, the conflict in the Gaza Strip, a weak global economy, and the lingering effects of the COVID-19 pandemic) have revealed weaknesses and hindered progress toward achieving the SDGs. Tangible progress has been made in some areas (reducing global child mortality, preventing HIV infections, access to energy and mobile broadband). Some areas require urgent action for sustainable development (climate change, peace and security, inequalities among and within countries). Without massive investment and scaled-up action, with special support expected from science, achieving the SDGs will be impossible.

In this process, SAIs play a specal role, supported by international professional organizations. SAIs, thanks to their independence, are called upon to contribute to both the control and improvement of preparations for implementing and achieving progress in realizing SDGs, as well as ensuring transparency in the actions of executive and legislative authorities. Audits conducted by SAIs thus far have focused on: a) assessing government preparedness for SDGs implementation (evaluating how governments prepared and established institutional frameworks and mechanisms for achieving SDGs; supporting governments in establishing national indicators and ensuring valid data for measuring SDGs implementation progress; supporting governments in raising societal awareness of the importance of SDGs); and b) analyzing and providing assurances in the realization of SDGs by highlighting shortcomings and offering recommendations for their elimination (prioritizing topics related to environmental protection, climate change, the circular economy, and water and food security, with a tendency to expand areas of interest).

In the upcoming period, SAIs will face numerous challenges related to conducting new types of performance audits connected with SDGs, developing standards and methodologies for these types of audits, training personnel to respond to multitasking, increased cooperation intensity and support among SAIs in this field, and collaboration with stakeholders.

It is important to emphasize that the research in this paper has limitations since it is focused on reviewing and classifying new types of audits related to SDGs within the global framework and among EUROSAI members.

Future research directions may explore new challenges faced by SAIs in the process of achieving the 2030 Agenda, which may be related to specific types of performance audits of SDGs, focused on educating audit personnel, or methodologies used by auditors in performance audits of SDGs.

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RAZVOJ NOVIH VRSTA DRŽAVNE REVIZIJE U KONTEKSTU OSTVARIVANJA CILJEVA ODRŽIVOG RAZVOJA IZ AGENDE 2030

Apstrakt: *Usvajanjem Agende 2030 UN 2015. godine, članice UN su se obavezale na implementaciju 17 ciljeva održivog razvoja (COR) i ujedno mobilisane brojne međunarodne i nacionalne organizacije i institucije da u tome pomognu vladama zemalja članica UN. 170 zemalja članica UN otpočelo sa procesom implementacije COR. U ovom procesu implementacije COR na globalnom nivou Vrhovne revizorske institucije (VRI) su prepoznate kao nezavisni kontrolni i savetodavni mehanizam nacionalnih vlada. Takođe, Međunarodna organizacija VRI (INTOSAI), koja okuplja VRI širom sveta, je uključena u ovaj proces aktivnostima na izradi smernica za VRI u obavljanju posebnih vrsta revizije svrsishodnosti (revizija svrsishocnosti priprema za implementaciju Agende 2030 i revizija svrsishodnosti ostvarivanja napretka u COR). VRI u 73 zemalja članica UN, u 7 regiona (AFROSAI-E, ASOSAI, CAROSAI, CREFIAF, EUROSAI, OLACEFS, PASAI), su izvršile reviziju svrsishodnosti pripreme za implementaciju Agedne 2030, a većina njih otpočele sa razvojem posebnih vrsta revizije svrsishodnosti ostvarivanja COR. Istaživanje je pokazalo da proces implementacije Agende 2030, pri kraju isteka roka, nije dao željene rezultate i da je neophodna transformacija na putu ka održivom razvoju u globalnim okvirima. VRI su se u ovaj proces uključile kao kontrolni i savetodavni mehanizam nacionalnih vlada sprovođenjem novih vrsta revizije svrsishodnosti povezanih sa COR. Razvoj revizija svrsishodnosti povezanih sa COR je uslovljen stepenom implementacije Agende 2030 na nacionalnom nivou članica UN. Komparativna analiza VRI u zemljama Zapadnog Balkana (Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, North Macedonia, Serbia) je pokazala da se one nalaze na sličnom nivou razvoja novih vrsta reviyija svrsishodnosti. Većina njih je izvršila evaluaciju spremnosti za implementaciju Agende 2030 i ujedno otpočela sa revizijama svrsishodnosti povezanih sa COR, najčešće u oblasti revizije životne sredine, sa tendencijom praćenja smernica međunarodnih profesionalnih organizacija u daljem razvoju novih vrsta revizija svrsishodnosti.*

Ključne reči: *Agenda 2030, COR, Vrhovne revizorske institucije, revizija svrsishodnosti.*

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BIODIVERSITY CONSERVATION POLICIES IN SERBIA AND THE EUROPEAN UNION: A COMPARATIVE ANALYSIS OF REGULATORY FRAMEWORKS AND IMPLEMENTATION CHALLENGES[1]

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Abstract: In a time when the planet is facing increasing ecological challenges, climate change, and the endangerment of certain species, it is essential to pay more attention to biodiversity conservation. This issue needs to be considered both locally and globally. The goal of this paper is to highlight the basic theoretical concepts and characteristics of biodiversity, as well as the importance of regulation in this area. The central part of the paper will be dedicated to analyzing the regulatory framework of Serbia and the National Program for Environmental Protection. In this way, an overview of the legislative state in our country is provided, pointing to the possibility and necessity of progress for biodiversity conservation.

Keywords: biodiversity, environmental protection, National Environmental Protection Program of Serbia, legislation

1. Introduction

Planet Earth and all life on it are threatened by the impact of climate change and excessive pollution. Today, this issue is one of the most significant, requiring a systemic response within institutions, rather than individual initiatives and actions. It is not only climate change that has affected biodiversity. There are other factors as well, such as the growth of the human population, increased consumption (Rands et

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al., 2010), and the lack of awareness that the world is in trouble if the human species is driven solely by economic motives.

Biodiversity, understood as the diversity of genes, species, and ecosystems that make up life on Earth, is much more than a concept related to nature. This category should be viewed as a social and legal phenomenon. In order to preserve biodiversity, it is essential to have organized action aimed at enacting regulations in this field. It has long been known that a regulatory framework is more effective than the gradual spread of awareness about the need to preserve biodiversity. It is necessary that, alongside actions focused on biodiversity education, there are national laws and international conventions that will encourage individuals to adapt their behavior to the current state of the planet.

There are several key moments that represent turning points in the regulation of biodiversity. These moments have raised awareness and alerted the international expert community to take action in order to prevent a natural disaster. The first of these moments was the adoption of the Global Biodiversity Assessment in 1995. After that, the Millennium Ecosystem Assessment was created in 2005. This led to an increase in the activities of countries working together on the common mission of humanity, which is the preservation of biodiversity. In line with this, the first intergovernmental global assessment was created in 2019, carried out by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Díaz & Malhi, 2022:32).

After the adoption of conventions at the international level, countries began developing national biodiversity strategies and the accompanying action plans, which specify concrete measures for the preservation of plant and animal species and ecosystems. In addition to developed countries, which were leaders in regulatory efforts in this field, developing countries also recognized the seriousness of the situation. Despite all these efforts, biodiversity continues to decline, which remains one of humanity's greatest concerns. Therefore, both local and global initiatives are necessary at the same time to achieve the desired effect and halt biodiversity loss. Aware of the economic consequences and motivations, policymakers must find a balance and design rules in such a way that they do not disrupt the economic incentives of business entities.

2. Biodiversity as a Legal Phenomenon

2.1. The Concept of Biodiversity

The concept of biodiversity has not always captured the attention of scientists. Efforts to define this term began to emerge more significantly in the 1980s (Díaz & Malhi, 2022:33). E. O. Wilson was the first to use the term biodiversity in the literature in 1988 (Colwell, 2009:257). The concept of biodiversity as we know it today was first officially used at the United Nations Conference on Environment and Development – the Rio Earth Summit. This summit, held in 1992, resulted in significant legal documents – the Rio Declaration, the United Nations Framework

Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), and the Declaration on the Principles of Forest Management.[2]

CBD Convention entered into force in 1993. According to Article 2 of the CBD, biological diversity is defined as the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems, as well as the ecological complexes they are part of. This encompasses diversity within species, between species, and of ecosystems. The convention offers definitions to ensure that policymakers and legal authorities can take appropriate actions. It clarifies the concept of biological resources, stating that they include genetic resources, organisms or parts of them, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity. The term ecosystem is defined as a dynamic, complex system of plant, animal, and microorganism communities, along with their non-living environment, interacting as a functional unit.

One group of authors distinguishes alpha, beta, and gamma biodiversity. Specifically, they view biodiversity as a modification of ecosystems and their components within habitats, between habitats, and at the landscape scale (Heydari, 2020: 27).

Biodiversity can be viewed through the lens of evolutionary and ecological criteria (Colwell, 2009: 257). The first component of biodiversity refers to the diversity of species in terms of number and characteristics. It is crucial to focus on this component in order to create measures for the preservation of those species that are most different from one another (Vellend et al., 2011: 194). On the other hand, the ecological criterion implies that each organism has its ecological function within the ecosystem, and the evolutionary traits of species are not considered relevant (Dussault, 2019: 310).

It seems that perhaps the most important breakdown of biodiversity is into genetic diversity, species diversity, and ecosystem diversity (Heydari, 2020: 27). Genetic diversity refers to the existence and origin of different genes found in living organisms. The emergence and disappearance of certain genes occur under the influence of evolution and the adaptation of species to new living conditions (Ellegren & Galtier, 2016: 1). Species diversity refers to the number of different species that exist (Tuomisto, 2013: 4). Ecosystem diversity is the diversity of distinct biological communities or ecosystems, defined by the mix of species, their physical characteristics, and the ecological processes at play. This represents the highest level of biodiversity.[3]

2.2. The Global Legal Framework for Biodiversity Conservation – An Overview of International Conventions

The most significant source of international law is the CBD (Convention on Biological Diversity). This convention was signed on June 5, 1992, in Rio de Janeiro

[2] See: https://www.un.org/en/conferences/environment/rio1992, accessed: 5.12.2024.
[3] https://www.oxfordreference.com/display/10.1093/oi/authority.20110803095741564, accessed: 5.12.2024.

and entered into force on December 29, 1993. The convention has three main goals. The first goal is the protection and preservation of the variety of life on Earth. The second goal is the responsible and balanced utilization of Earth's biological resources. This means using species, ecosystems, and genetic materials in a way that meets human needs while ensuring that these resources remain available for future generations. It involves practices that minimize environmental impact, conserve ecosystems, and maintain the health of species, allowing for their continued regeneration and survival. Sustainable use seeks to harmonize economic development with the preservation of nature's diversity. The third goal refers to the fair and just distribution of benefits gained from the use of genetic resources. This involves ensuring that all parties involved in the use of biological materials—such as plants, animals, or microorganisms—receive a fair share of the benefits. This includes sharing knowledge, technology, and profits derived from these resources with the communities and countries that provide them. It aims to promote fairness and prevent exploitation, ensuring that those who contribute genetic resources are properly recognized and compensated.

The text of the Convention, in addition to the preamble, contains 42 articles and 3 annexes. The introductory articles present the goals, terms that will be used, measures for the conservation of biodiversity, and sustainable resource use. The following sections outline measures for education and raising awareness in this field, as well as actions to neutralize harmful effects on biodiversity, the importance of information exchange, and technical and scientific cooperation, the role and use of biotechnology, and ways to access funding sources. Finally, there are articles addressing the relationship of this Convention with other international agreements and its protocols. Annex I is dedicated to the issue of monitoring, Annex II contains the rules for arbitration, and Annex III outlines the procedures for implementing conciliation.

In addition to the CBD Convention, two protocols are also of great importance: the Cartagena Protocol and the Nagoya Protocol.

The Cartagena Protocol on Biosafety to the Convention on Biological Diversity is a global treaty designed to ensure the safe management, transportation, and use of living modified organisms created through modern biotechnology. The protocol addresses potential risks these organisms may pose to biodiversity and human health. It was adopted on January 29, 2000, and came into force on September 11, 2003. This protocol is an additional agreement to the CBD Convention.

The Nagoya Protocol is also an additional agreement to the CBD Convention. The Nagoya Protocol was adopted on October 29, 2010, in Nagoya, Japan, and came into effect on October 12, 2014, following the deposit of the fiftieth ratification instrument. Its goal is to ensure the fair and equitable distribution of benefits derived from the use of genetic resources, ultimately supporting the conservation and sustainable use of biodiversity. The aim of this protocol is to provide clearer legal certainty and transparency in this area. It emphasizes that there should be setting more predictable terms for accessing genetic resources and ensuring that benefits are shared when genetic resources are transferred out of the country that provided them.

In Japan, in 2010, the revised Strategic Plan for Biodiversity, including the Aichi Biodiversity Targets, for the 2011-2020 period was adopted. This plan offered a comprehensive framework for biodiversity, not just for biodiversity-related conventions, but also for the entire United Nations system and all other stakeholders involved in biodiversity management and policy development. The parties agreed to adapt this global framework into updated national biodiversity strategies and action plans within two years.

The Aichi Targets are goals that are divided into five groups: A, B, C, D, E.

Strategic goal A implies addressing the root causes of biodiversity loss by integrating biodiversity considerations into government policies and societal practices. Within this goal, four specific targets are defined. By 2020, people will be aware of the importance of biodiversity and how they can contribute to its conservation and sustainable use. Additionally, biodiversity values will be incorporated into national and local development and poverty reduction strategies, as well as national accounting and reporting systems. Harmful incentives, such as subsidies that negatively impact biodiversity, will be eliminated, reformed, or phased out, while positive incentives for biodiversity conservation will be introduced, in line with the Convention and international obligations, considering national socio-economic conditions. Lastly, governments, businesses, and stakeholders will have implemented plans to ensure sustainable production and consumption, keeping the use of natural resources within safe ecological limits.

Strategic goal B aims to lessen the direct pressures on biodiversity and encourage its sustainable use. Strategic Goal B includes six specific targets. By 2020, the aim is to drastically reduce the loss, degradation, and fragmentation of natural habitats, including forests, with a target of at least a 50% decrease and, where possible, bringing it close to zero. Moreover, all fish, invertebrate populations, and aquatic plants should be managed and harvested sustainably, ensuring that overfishing is avoided, recovery plans are in place for depleted species, and no significant harm is caused to threatened species or vulnerable ecosystems. Fisheries should operate within safe ecological limits. By 2020, agricultural, aquaculture, and forestry practices must be sustainably managed to protect biodiversity. Pollution, particularly from excess nutrients, should be reduced to levels that do not negatively affect ecosystems or biodiversity. Invasive species and their pathways must be identified, controlled, and prioritized, with effective measures to prevent their spread. By 2015, human pressures on coral reefs and other ecosystems affected by climate change or ocean acidification should be minimized to preserve their integrity and function.

Strategic goal C is focused on improving the status of biodiversity by protecting ecosystems, species, and genetic diversity. Strategic goal C includes three sub-goals. By 2020, the objective is to safeguard at least 17% of terrestrial and inland water areas, and 10% of coastal and marine areas, particularly those critical for biodiversity and ecosystem services, through well-managed, ecologically representative, and connected protected areas and other effective conservation measures, integrated into larger landscapes and seascapes. Efforts will ensure that the extinction of known threatened species is prevented, and the conservation status of species, especially those most at risk, will be improved and maintained. The genetic diversity of

cultivated plants, farmed and domesticated animals, their wild relatives, and other species of socio-economic and cultural importance will be preserved, with strategies implemented to prevent genetic erosion and protect their diversity.

Strategic goal D aims to increase the benefits that biodiversity and ecosystem services provide to everyone. This goal also includes three sub-goals. By 2020, ecosystems that provide vital services, such as water-related functions, and support health, livelihoods, and well-being, will be restored and safeguarded, with special consideration given to the needs of women, indigenous and local communities, and vulnerable populations. The resilience of ecosystems and the contribution of biodiversity to carbon storage will be enhanced through conservation and restoration initiatives, including the restoration of at least 15% of degraded ecosystems, which will support climate change mitigation, adaptation, and efforts to combat desertification. By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits will be fully operational and implemented, in accordance with national legislation.

Strategic goal E aims to improve implementation by promoting participatory planning, managing knowledge, and building capacity. The achievement of this goal is planned through four specific targets. By 2015, all Parties should have developed, adopted, and begun implementing an updated, effective, and participatory national biodiversity strategy and action plan. By 2020, the traditional knowledge, innovations, and practices of indigenous and local communities regarding biodiversity conservation and sustainable use, along with their customary use of biological resources, must be respected in line with national laws and international obligations. These practices should be fully integrated into the Convention's implementation, with the active participation of these communities at all relevant levels. Improvements should be made in knowledge, science, and technology related to biodiversity—its value, functioning, status, trends, and the effects of its loss—and this knowledge should be widely shared, transferred, and applied. There should be a substantial increase in the mobilization of financial resources for the successful implementation of the Strategic Plan for Biodiversity 2011-2020, in accordance with the Strategy for Resource Mobilization, based on the resource needs assessments provided by the Parties.

As a framework and legally binding agreement, the CBD sets out broad provisions that necessitate action at the national level to be effectively implemented. A key requirement is the creation of National Biodiversity Strategies and Action Plans (NBSAPs), which must be integrated into relevant sectors and programs. These plans serve as a primary tool for carrying out the Convention's objectives at the national level (Chandra & Idrisova, 2011: 3295).

2.3. The Concept of Environmental Protection in Serbian Legislation and the Role of Institutions

The protection of nature is governed by the Nature Protection Law, along with other related legal and subordinate acts that address nature and natural resources, either directly or indirectly. In line with global goals and developments, our country has adopted laws and subordinate acts in this area. The adoption of the Nature Protection

Law, which regulates the conservation of nature, biological, geological, and landscape diversity, has been crucial in this area. In addition to the laws, various subordinate acts also play an important role in shaping the legal framework. As the country aligns its environmental and nature protection laws with those of the European Union, European and global standards are increasingly being integrated. Furthermore, the enhancement and harmonization of nature protection are supported by the implementation of international conventions that our country has signed.

In addition to developing national regulations for environmental management, our country has signed numerous international conventions important for biodiversity conservation. These include: The Regulation on the Ratification of the Revised Text of the International Convention for the Protection of Plants, The Law on the Ratification of the International Convention for the Protection of Birds, The Regulation on the Ratification of the Convention on Wetlands of International Importance, Especially as Habitats for Waterfowl, The Law on the Confirmation of the Convention on Biological Diversity, The Law on the Confirmation of the Convention on Cooperation for the Protection and Sustainable Use of the Danube River, The Law on the Confirmation of the Convention on the Conservation of Migratory Species of Wild Animals, The Law on the Confirmation of the Convention on the Conservation of European Wild Flora and Fauna and Natural Habitats, The Law on the Confirmation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, The Law on the Ratification of the Convention Concerning the Protection of the World Cultural and Natural Heritage, The Law on the Confirmation of the Convention on Access to Information, Public Participation in Decision-Making, and Access to Justice in Environmental Matters.[4]

As for institutional support on this matter, biodiversity conservation falls under the jurisdiction of the Ministry of Environmental Protection. The Ministry performs the following tasks.[5] The Ministry is tasked with managing various areas of environmental protection, such as developing and implementing protection systems, overseeing national parks, and conducting inspections. It applies scientific research to environmental issues, ensures public participation and access to environmental information, and is responsible for safeguarding nature, air, water, and the ozone layer.

There are also other competencies of the ministry that are of great importance for environmental protection. The Ministry also tackles climate change, cross-border pollution, and water conservation. It sets environmental standards in spatial planning and construction, manages responses to chemical accidents, noise, and radiation, and regulates chemicals and biocidal products. Additionally, it handles waste management (excluding radioactive waste), enforces international agreements, and approves the transboundary movement of waste and protected species. The Ministry also supports EU-funded and other development aid projects.

The next chapter will present a detailed analysis of the relevant regulations of our country. Also, the National Environmental Protection Program and the Draft of The First Action Plan will be analyzed.

[4] See: https://zzps.rs/medunarodne-konvencije/, accessed: 14.12.2024.
[5] See: https://www.ekologija.gov.rs/organizacija/nadleznost, accessed: 14.12.2024.

3. Legal Framework for Biodiversity Conservation in Serbia

3.1. Analysis of Relevant Laws and Regulation

The Republic of Serbia has equally joined the circle of countries that influence the implementation of measures and the protection of biodiversity through their regulations. The beginning of inclusion in the European, but geographically broader level of entities (and countries) that understood the seriousness of the need to determine legal boundaries in the implementation of the protection of basic human rights, for Serbia, is the beginning of this century. The adoption of the Law on Environmental Protection in 2004 (*Sl. glasnik RS", br. 135/2004, 36/2009, 36/2009 – other law, 72/2009 – other law, 43/2011 - decision US, 14/2016, 76/2018, 95/2018 – other law and 95/2018 – other law),* and its constant improvement with additions and changes, as well as the Law on Nature Protection in 2019 started Serbia's path towards harmonization of regulations, primarily with European legal sources.

What do these two very important pieces of legislation bring?

The focus of the Law on Environmental Protection is defining an integral system of environmental protection. This system includes ensuring the realization of the human right to life and development in a healthy environment. Another task of the Law is to ensure a balanced relationship between economic development and the environment in the country. The environmental protection system itself puts sustainable management, preservation of natural balance, as well as prevention and control of all forms of environmental pollution in the foreground.

The priority of this work is biodiversity and the goal is to present the legal definition of this term. However, biodiversity is part of the environmental system, which consists of '*a set of natural and created values whose complex interrelationships make up the environment, that is, the space and conditions for life*' (Article 3 of the Law). On the other hand, biodiversity, i.e. biological diversity, is defined as *'diversity of organisms within a species, between species and between ecosystems'* (Article 3 of the Law).

Biological diversity additional could be definited as 'the set of diversity of genes, species and ecosystems at the local, national, regional and global level', based on the aforementioned Law on Environmental Protection.

A few years later, since 2009, the Republic of Serbia regulates the nature protection. The Law on Nature Protection was adopted (*Published in the Službeni glasnik RS, Nos. 36/09 of 15 May 2009, 88/10 of 23 November 2010, 91/10 of 3 December 2010 (Corrigendum), 14/16 of 22 February 2016 and 95/18 of 8 December 2018 (other law))*. Among other things, Article 2 of this Law defines protection, conservation and improvement of biological (genetic, species and ecosystems), geological and landscape diversity, in other words – biodiversity.

According the Article 14 of the Law on Nature Protection, 'the protection of biological diversity shall be accomplished by carrying out measures for protection and improvement of species, their populations, natural habitats and ecosystems'. In addition, previous mentioned Law defines the way of protection ecosystem, as well

as the details about conserving biological diversity. Using the biological, biotechnical and chemical agents would be allowed in compliance with law. That is the way of protecting ecosystem. Article 19 of the Law on Nature Protection defines that in order to conserving biological diversity, biological and biotechnical agents can be used in protected areas.

Environmental protection measures and conditions

According to the Environmental Protection Act, measures and conditions can be divided into:

- Preventive measures,
- Conditions of environmental protection,
- Protection measures against dangerous substances, and
- Programs and plans.

When it comes to environmental protection conditions, they are preceded by **preventive measures**.

In addition, **the conditions** themselves can be said that the Law on Environmental Protection precisely determines them. In the first place are unquestionably the requirements related to the quality of the environment, as well as the requirements regarding emissions.

Quality requirements for products, processes and services are also defined. However, the defined requirements cannot be realized without an adequate environmental protection management system.

Protection measures against hazardous materials include the movement of materials and protection against possible accidents.

Plans and programs refer to various types of legal acts that support the implementation of the Law on Environmental Protection, with mandatory IT support.

Economic instruments

Having mind to the Law on Environmental Protection (Part VI), economic instruments refer to the provision of financing for the said protection. There are different types of economic instruments: compensation for the use of natural values, compensation for environmental pollution, funds provided from the national budget or international funds, economic incentive measures.

Monitoring of the implementation of economic instruments is a mandatory element of the implementation of the Law.

Finally, when it comes to ***responsibility for environmental pollution***, the Law on Environmental Protection defines key participants who are responsible for pollution, their obligations, responsibility for possible damage, as well as compensation for it.

3.2. National Environmental Protection Program and Draft of the First Action Plan

The 2030 Agenda emphasizes five key elements: people, progress, planet, partnership and peace, which are included within 17 goals and 169 sub-goals of sustainable development and include all three dimensions of sustainable development: economic growth, social inclusion and environmental protection environment. (Serbia and Agenda 2030, November 2022)

By adopting the Strategy of Sustainable Urban Development until 2030, with the Action Plan 2021-2022. year, the Republic of Serbia transferred the new Urban Agenda of the United Nations to the national level.

Biodiversity represents the totality of genes, species and ecosystems. As ***National Environmental Protection Program*** highlights, the biodiversity introduces value of a certain territory is the first and most important a step in its preservation, protection and improvement. The most common method of assessment biodiversity is the determination of the number of species per unit of area determined territories. Contemporary assessments of the biodiversity of certain territories, as well as the selection of species and habitats for protection must be based on fundamentals research and knowledge of taxonomy, biogeography and ecology. Condition ecosystem is a key indicator of anthropogenic and natural influences process, as well as the effects of climate change, and their monitoring includes long-term monitoring of a set of ecological parameters. (National Environmental Protection Program, part 4.3)

The great biological diversity in the Republic of Serbia is conditional biogeographic position, openness of the territory to other regions in environment, as well as the historical processes of florogenesis and faunogenesis in the last few hundred thousand years.

The greatest pressure on biodiversity and geodiversity is exerted by excessive and uncontrolled exploitation of natural resources that have a limited capacity. The negative impacts of various human factors are particularly significant activities on forest ecosystems as well as other sensitive habitats. Problems related to biological diversity in the Republic of Serbia have arisen are due to institutional, financial, economic and other shortcomings. Very important fact is that no there is a National Strategy and Action Plan for biodiversity protection, as well as National strategy for sustainable use of natural resources and goods.

However, the National Environmental Protection Program was an attempt to solve the management of protected areas, as well as the protection of biodiversity. Also, negative impacts of economic activities should be taken into account on the overall state of biodiversity, habitats of natural rarities and endangered species and landscapes in protected natural assets, as well as in the entire Republic of Serbia. (National Environmental Protection Program, part 4.3.3)

The protection of nature and biodiversity can only be demonstrated by:

- Improving the monitoring of biodiversity components, endangered species, ecosystems and protected areas;

- Establishing monitoring of sustainable use natural resources (hunting, fishing, forestry);
- By establishing biomonitoring of certain aquatic ecosystem
- Establishing a national information system and databases data in protected areas;
- Identification and mapping of habitats.

The ***Action plan*** for the implementation of the Green Agenda for the Western Balkans is also binding for the Republic of Serbia. This document contains activities to combat climate change, reduce emissions of pollutants, transform the energy and transport sectors, and develop a circular economy. One of the focuses is on area III - Reduction of air, water and soil pollution in the Western Balkans.

The contribution to the realization of this goal is, among other things, interventions aimed at harmonizing with international requirements in the field of air and water protection, establishing a system for air quality monitoring, including accreditation of air quality monitoring networks, modernizing the infrastructure for water monitoring and building the necessary infrastructure for wastewater treatment.

In addition, it is necessary to highlight that the key documents for achieving the goals of the document *Access to adequate, safe and affordable housing and basic services are the Strategy of Sustainable Urban Development of the Republic of Serbia until 2030 with the Action Plan for the Implementation of the Strategy of Sustainable Urban Development until 2030, for the period 2021-2022. year.*

The Republic of Serbia has an obligation to implement measures in the field of climate change and pollution prevention, energy development, mobility and circular economy, as well as biodiversity development, sustainable agriculture and food production.

Within area V Biodiversity, the countries of the Western Balkans will define the framework for biodiversity after 2020 and develop long-term strategies to stop the loss of biodiversity, protect and restore ecosystems and rich biodiversity. (https://ec.europa.eu/neighbourhood-enlargement/system/files/2020-10/green_agenda_for_the_western_balkans_en.pdf)

4. Challenges and Perspectives in the Implementation of Legislation at the European Union Level

At the level of the European Union, there is a Biodiversity Strategy for the period up to 2030. This strategy supports the core ideas of the European Green Deal. It advocates for halting the degradation of nature and ecosystems.

The goal of the Strategy is to address climate change and reduce harmful effects on the climate, as well as protect wildlife and combat illegal trade in them. The strategy first presents the necessity for action in this area, followed by protecting and restoring nature in the European Union, and a new governance framework. Additionally, the Strategy addresses issues of investment and the sustainability of

such a governance framework, through the analysis of international cooperation, trade policies of member states, and available resources for engagement.

The Nature Restoration Law is a central element and support of the EU Biodiversity Strategy. It outlines obligations that will contribute to the conservation of natural resources and the entire living world. The provisions of the law focus on the protection of marine and terrestrial habitats and species, as well as on controlling climate change. The Law outlines specific biodiversity targets in several ecosystems (Regulation EU 2024/1991):

- Habitats (Wetlands, Forests, Grasslands, etc.): The aim is to restore and improve biodiversity in these areas on a large scale, enhancing habitats and increasing species populations.
- Forests: Targets include increasing deadwood, supporting diverse-aged forests, improving forest connections, boosting the number of common forest birds, and increasing organic carbon in forest soils.
- Pollinators: By 2030, the goal is to halt the decline of pollinators and promote population growth, with a system for regular monitoring of pollinator trends.
- Agriculture: The goal is to increase populations of grassland butterflies and farmland birds, improve soil carbon in croplands, enhance agricultural land diversity, and restore peatlands used for farming.
- Rivers: The regulation aims to remove barriers to river flow, aiming to restore 25,000 km of rivers to their natural state by 2030.
- Urban Areas: The regulation seeks to ensure no loss of green spaces and tree cover in urban areas by 2030, with steady growth in these areas starting then.
- Marine Environments: The focus is on restoring marine habitats like seagrass and sediment bottoms to help combat climate change, as well as protecting habitats for species like dolphins, sharks, and seabirds.

EU countries are expected to submit national restoration plans to the Commission within two years of the Regulation coming into force (i.e., by mid-2026), demonstrating how they will achieve the set targets. They will also be required to monitor their progress and report regularly. The European Environment Agency will prepare regular technical reports on progress toward the targets. The Commission, in turn, will report to the European Parliament and the Council on the implementation of the Nature Restoration Law.

At present, the EU lacks a unified framework to guide the implementation of biodiversity commitments at the national, European, or international levels. To address this issue, the Commission plans to create a new governance framework for biodiversity in Europe. This will help outline the commitments and provide a clear plan for their execution. The strategy advocates for the establishment of a new framework for biodiversity governance and its regulation.

As part of the new framework, the Commission will implement a system for monitoring and evaluation. This will include setting clear indicators, conducting regular progress assessments, and taking corrective measures when needed. This is expected to lead to an increase in awareness and accountability among the stakeholders. The new governance framework will guarantee joint responsibility and collective ownership among all key actors in fulfilling the EU's biodiversity obligations. It will promote the strengthening of administrative capacities, transparency, stakeholder engagement, and participatory management across different levels.

5. Conclusion

The European Parliament, the Council of the European Union, and the European Commission play a key role in developing and implementing strategies, regulations, and action plans related to biodiversity conservation. The importance of successful implementation of EU biodiversity legislation is reflected in achieving one of the Union's core objectives, which is environmental protection. Differences in legal traditions and systems among member states can make alignment with EU legislation more challenging. Each member state has different procedures and capacities for implementation. Therefore, key EU institutions must advocate for and act towards creating clear and precise rules to facilitate the implementation of the regulatory framework by member states. Political factors or disagreements between national authorities and EU institutions can slow down implementation. Sometimes there are institutional issues, such as insufficient coordination between different levels of government within a particular country. Many member states face problems related to the administrative capacities needed for the proper implementation of legislation. This includes a lack of trained personnel and resources at the national level. The economy of different member states can impact their ability to implement legislation, especially when significant investments in infrastructure or changes in industrial practices are required. Issues with monitoring and enforcement of legislation, including the lack of effective mechanisms for penalties and exemptions, can lead to misalignment between national biodiversity conservation strategies and the EU-level strategy.

In order to achieve visible results from these policies and actions, it is necessary to develop better mechanisms for cooperation between the EU and its member states. This includes strengthening dialogue and joint platforms for exchanging experiences. Increasing administrative capacities in member states through training, technical assistance, and financial support for environmental and ecosystem conservation projects is also essential. The EU could invest in developing better capacities for implementing biodiversity legislation at the national level. In this way, more flexible approaches to implementing legislation could be created, allowing for adaptation to the specificities of individual member states, while preserving the fundamental principles and objectives of EU legislation. The use of digital tools and platforms to improve monitoring and reporting on the implementation of legislation can contribute to faster and more efficient application. And perhaps most importantly, it is essential to raise public awareness and involve all relevant

stakeholders (national authorities, civil society, the private sector) in the process of implementing legislation to increase transparency and support. Examples of successful implementation of EU legislation and national programs in certain member states can serve as models for other countries. However, it is crucial to conduct a detailed analysis of the challenges in implementing specific legislative acts, such as regulations on environmental protection, ecosystems, flora, and fauna. This approach provides a thorough analysis of the problems and opportunities in each country and allows for a balanced view of how the past, present, and future can shape progress in this area.

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POLITIKE OČUVANJA BIODIVERZITETA U SRBIJI I EVROPSKOJ UNIJI: KOMPARATIVNA ANALIZA REGULATORNIH OKVIRA I IZAZOVA U IMPLEMENTACIJI

Apstrakt: U vremenu kada se planeta suočava sa sve većim ekološkim izazovima, klimatskim promenama i ugrožavanjem određenih vrsta, neophodno je posvetiti veću pažnju očuvanju biodiverziteta. Ovo pitanje potrebno je razmatrati kako na lokalnom, tako i na globalnom nivou. Cilj ovog rada je da istakne osnovne teorijske pojmove i karakteristike biodiverziteta, kao i značaj regulative u ovoj oblasti. Centralni deo rada biće posvećen analizi regulatornog okvira Srbije i Nacionalnog programa zaštite životne sredine. Na taj način pruža se pregled zakonodavnog stanja u našoj zemlji, ukazujući na mogućnosti i potrebu za napretkom u oblasti očuvanja biodiverziteta.

Ključne reči: biodiverzitet, zaštita životne sredine, Nacionalni program zaštite životne sredine Srbije, zakonodavstvo.

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REGENERATIVE ECONOMY THROUGH THE PRISM OF MONTENEGRO - CHALLENGES AND LIMITATIONS

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***Abstract*:** Environmental challenges, which have taken on global proportions in the past decades, have become a powerful catalyst for changes in the approach to the sustainability of economic systems. Evident and often irreversible damages caused to the planet by the existing methods of action require the urgent adoption of new models that enable the regeneration of ecosystems and the restoration of natural resources to the closest possible original state. In this context, the regenerative economy is emerging as a strategic response to increasingly pronounced environmental problems. Countries with more developed environmental awareness have recognized the importance of this concept, introducing it through concrete policies and practices that balance economic development and nature conservation. Although Montenegro was formally declared an ecological state in 1991, the principles of the regenerative economy have not yet been fully recognized or implemented. Nevertheless, the geographical position, exceptional natural beauty and significant tourist and agricultural potential provide Montenegro with a unique opportunity to become a leader in the Western Balkans in the development of regenerative practices. However, transition processes, political instability and economic uncertainties continue to slow progress towards a more environmentally conscious society. Regenerative approaches, such as sustainable tourism, regenerative agriculture, efficient waste management and the development of renewable energy sources, are key mechanisms by which Montenegro can achieve

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the goals of a regenerative economy. Despite challenges, the goal of this paper is to identify limitations through the analysis of the current situation and offer concrete recommendations for the improvement and implementation of regenerative principles, in order to direct Montenegro towards a more sustainable and prosperous future.

Keywords: environmental challenges, sustainable development, regenerative economy, transition, Montenegro.

1. Introduction

The concept of regenerative economy, although present for quite some time, has not been widely utilized in public discourse, as it is often viewed through the lens of sustainable development and circular economy. The concept of regenerative economy, which is broader than that of the circular economy, is far more proactive. It is based on a holistic approach, aiming not only to achieve sustainability principles but also to promote healing, restoration of ecosystems, and the economy as a whole. Fundamentally, the term "regeneration" refers to the process of renewal, or returning to the original state of what has been damaged or depleted. In a modern context, the term "regenerative" is frequently used as a prefix in various fields, particularly in relation to nature and the state of the planet.

The urgency of implementing regenerative processes is becoming increasingly apparent, given the irrational exploitation of scarce resources, primarily natural ones. Traditional models of economic management have resulted in significant impoverishment and degradation of the planet, making profound regeneration essential. The principles of regenerative economy are directed towards establishing sustainable development, fostering a humane approach, and achieving long-term prosperity. Specifically, this concept is based on numerous key principles, including innovative approaches to the use of renewable energy sources, improving recycling systems, fostering collaboration among competitors instead of rivalry, and promoting a harmonious and sustainable way of life. The pursuit of regeneration encompasses not only ecological but also social aspects, contributing integrally to the revitalization of economic and natural systems with the goal of preserving the planet for future generations. These principles provide a foundation for building a regenerative model that transcends the framework of sustainability, focusing on creating a positive impact and restoring resources.

Unfortunately, many economies, especially those that have undergone or are currently experiencing intense political and economic turbulence, have failed to develop the capacity, motivation, or necessary awareness of the strategic importance of implementing the concept of a regenerative economy. Montenegro serves as an example of this, as despite its significant natural and geographical potential, the country has not sufficiently seized the opportunity to establish and promote this progressive model of economic development.

In 1991, Montenegro declaratively acquired the status of an ecological state, a pioneering step in recognizing the importance of sustainable development at an institutional level. However, despite this status, the lack of systemic implementation

and strategic measures has resulted in the concept of an ecological state remaining largely nominal, with little to show in terms of concrete results towards regenerative practices and sustainable economic prosperity.

On the other hand, Montenegro's aspiration to join the European community, with the implicit obligation to meet the requirements of Chapter 27 – Environment and Climate Change, the most demanding and last opened chapter, highlights its serious commitment to achieving the goals outlined in the UN Agenda 2030. This ambition is further confirmed by the adoption of the National Strategy for Sustainable Development until 2030[2], which formalizes Montenegro's dedication to integrating sustainable and regenerative principles into its development policies and practices.

In light of the above, the primary goal of this paper is to assess Montenegro's achievements as an ecological state through the lens of regenerative economy principles, identifying the limitations and potentials for its further development. Conceptually, the topic will be structured into three key thematic chapters, in addition to the introduction and conclusion. The first chapter will analyze, through a review of relevant literature, the conceptual definition, significance, and achievements of the regenerative economy, offering a comparative overview of experiences from other countries based on available research. The second chapter will focus on an analysis of Montenegro's achievements in the field of regenerative economy, while the third chapter will address key constraints and propose recommendations for improving existing practices.

It is worth emphasizing that no prior research on this topic has been conducted in Montenegro, which underscores the originality and innovative approach of this paper. Simultaneously, the aim of this paper is to draw academic attention to the importance of the topic of regenerative economy and to encourage broader discussion on its application. Examining this concept from the perspective of Montenegro's economy represents a pioneering step that will serve as a foundation for future, deeper, and more comprehensive research.

2. Literature review

Sustainable development (Ehrenfeld & Hoffmann, 2013; United Nations, 1987), circular economy (Bonciu, 2014; Kuah & Wang, 2020), and regenerative economy are key topics in contemporary scientific debate, significantly influencing not only academic circles but also companies, governments, investors, and civil society (Järvenpää et al., 2023). While the circular economy has become a central concept in political and economic discussions, its definition remains insufficiently precise, often subject to varying interpretations (Ghisellini et al., 2016; Kalmykova et al., 2018; Laurenti et al., 2018; Reike et al., 2018).

Research (Järvenpää et al., 2023) analyzing 55 papers (38 of which were examined in detail) highlights the lack of a clear distinction between circular and regenerative economies. Authors frequently reference the definition by the Ellen

[2] See more: https://www.gov.me/dokumenta/67dc487e-097d-41d2-8fd5-7827a19a1f5a

MacArthur Foundation (EMF, 2013), which describes the circular economy as "an industrial economy that is restorative or regenerative by intention and design." Furthermore, regeneration is recognized as the third key principle of the circular economy, referring to contributing to nature or creating space for nature.

However, progress in implementing these concepts remains unsatisfactory, as evidenced by data from the Circularity Gap Reporting Initiative (CGRI, 2022). According to their report, only 8.6% of the global population operates in line with circular principles. Additionally, between the Paris Agreement (2015) and the Glasgow meeting (2021), 70% more raw materials were extracted than the Earth can safely regenerate. These figures underscore the need to accelerate the implementation of circular and regenerative principles in practice to address growing ecological and economic challenges.

What is evident is the lack of consensus among authors regarding both the conceptual and terminological definition of regenerative economy. Many equate "restoration" with "regeneration," conflating these terms with sustainability, business, and economy. According to authors (Morseletto, 2020; Merriam-Webster, 2024), restoration involves "returning something to its original good condition," whereas regeneration refers to "enhancing that condition, making it better than it was." Based on these differences, Morseletto (2020) introduces two additional conceptual levels: the first is "restorative sustainability," aimed at restoring social and ecological systems to a healthy state. The second level is the "regenerative scenario," which enables social and ecological systems to continue developing and evolving. In this context, it is clear that a regenerative system does not adhere to the "delaying problems for later" approach, which is often a characteristic of contemporary political economy (Jain, Y., 2021).

There is broad consensus among researchers that regenerative economy represents a deeper and more comprehensive concept compared to sustainability, significantly expanding the principles of circular economy. Its exceptional value lies in its holistic approach, which not only encompasses biological and technical cycles but also places particular emphasis on improving human well-being (Hahn & Tampe, 2021; Robinson & Cole, 2015). This approach integrates nature, society, and economy into a unified, sustainable system, enabling the advancement of socio-ecological systems through evolution and integration rather than merely mitigating the negative impacts of human activities.

The regenerative economy, as reflected in a review of relevant literature, remains in its nascent stage of development. However, its conceptual framework and fundamental ideas provide clear guidance for shaping a more sustainable and equitable future. Core components of the regenerative economy include restoration, reformation, achieving a net positive impact, regeneration through restoration and conservation, systems thinking, and a holistic approach. These elements, combined with transformative changes at social, organizational, and individual levels, represent essential aspects of the regenerative approach (Untera et al., 2024).

Adopting new circular practices that enhance the interconnection of existing ecosystems with renewable energy sources (Kiviranta et al., 2020), promote tourism

sustainability (Schumann, 2020), and support regenerative agriculture are emphasized. A significant aspect of the regenerative economy is addressing global solid waste management issues through recycling and resource recovery. This approach increases resource efficiency and reduces environmental footprints (Kowlesser, 2020). Regenerative economies are defined as those maintaining stable inputs and balanced outputs without depleting resources or disrupting broader social and ecological processes (Brown et al., 2018).

Regenerative agriculture is identified as a critical response to ecosystem degradation caused by global food systems, which emit approximately 25% of anthropogenic greenhouse gases (Poore & Nemecek, 2018). This agricultural model has the potential to restore soil health, enhance resilience, and mitigate ecological damage (Elevitch et al., 2018). It aligns with food security goals within the planet's capacity (Malik & Verme, 2014).

The concept of regenerative tourism is evolving from sustainable tourism and emphasizes leaving destinations in better conditions than found. This paradigm shift promotes long-term renewal of social and natural systems while fostering local community engagement (Duxbury et al., 2021; CBI, 2022). Regenerative tourism supports new economic models focusing on social and ecological benefits alongside financial growth.

Renewable energy (RE) is a cornerstone of the regenerative economy. With global RES use rising significantly from 4.098 TWh in 2010 to 7.627 TWh in 2020 (IEA, 2021), its potential to drive sustainability is evident. Case studies (Qazi et al., 2019) show that public awareness and supportive policies are critical for adoption. For example, public inclusion in decision-making has positively influenced RE development in Japan, while subsidies for fossil fuels have hindered competitiveness in Malaysia. Challenges in the Western Balkans, such as coal dependency and external geopolitical influences, further underline the need for targeted reforms (BIEPAG, 2023).

Despite definitional ambiguities, the regenerative economy is widely recognized as a transformative framework applicable across various industries, including agriculture, energy, tourism, construction, and manufacturing. Its implementation leverages innovative technologies to regenerate resources, minimize waste, and improve ecosystems. Developed countries' initiatives demonstrate the practical applicability of regenerative approaches, providing a roadmap for less developed nations to build resilient and sustainable systems.

The regenerative economy holds promise as a dynamic response to global challenges, offering solutions that combine ecological, social, and economic dimensions for a future of enhanced resilience and sustainability. By operationalizing these principles, societies can move beyond mitigation and toward holistic improvement of the socio-ecological landscape.

3. Montenegro – A review of macroeconomic indicators and environmental aspects

Montenegro, a country of extraordinary natural diversity, encompasses spectacular mountain ranges and a stunning Adriatic coastline. With its favorable geographic position and pleasant climate, it is considered one of the most beautiful areas in Europe. Covering an area of 13.812 km² and home to over 620.000 residents, Montenegro is renowned as a multiethnic and multiconfessional state.

The Montenegrin economy is small and open, heavily reliant on tourism, and highly vulnerable to external shocks. Nevertheless, it has demonstrated a certain resilience in addressing global challenges such as inflationary pressures, supply chain disruptions, and the energy crisis, achieving significant growth in recent years.

The focus of Montenegro's economic policy over the past three years has been on improving citizens' living standards and creating a predictable and supportive investment and business environment. These efforts aim to generate new jobs and accelerate the convergence of income and GDP per capita with the EU average. On its path to joining the European family, Montenegro achieved significant milestones in 2024, including obtaining IBAR status and recently closing three negotiation chapters.

Regarding key macroeconomic indicators, relevant international organizations project that Montenegro's economic growth from 2024 will continue in the coming year, ranging between 3,5% and 4,2%.

After experiencing exceptionally high inflation rates in 2022 and 2023, reaching a record 17,5%, inflation in 2024 showed more positive trends. During the first ten months of 2024, the average inflation rate was 3,6%. Similar trends are expected to continue, with inflation projected to average 2,9% for the period 2025–2027, driven by reduced price pressures at the European level.

The labor market displayed positive trends in 2024, with the unemployment rate reaching a historic low of 11,4% (Statistical Office of Montenegro – MONSTAT, https://www.monstat.org/cg/page.php?id=22&pageid=22) by the end of the second quarter, according to MONSTAT's labor force survey.

On the other hand, industrial production declined by 6,2% in the first eight months of 2024, primarily due to a 21,8% reduction in electricity production. However, the mining and manufacturing sectors showed positive growth of 6,3% and 5,9%, respectively, with an exceptional increase of over 200% in metal product manufacturing.

Despite the challenges, optimism for economic prosperity and stabilization stems from the increase in employment and wages, as well as the key role of foreign investments, which, along with strengthening confidence in the banking sector, additionally strengthen the country's economic foundations.

When it comes to longer-term forecasts, an optimistic approach is also noticeable. Namely, according to the *Government's draft document Economic Reforms Program 2025-2027*, the belief is expressed that it will strive to achieve

sustainable and inclusive economic growth that will improve the quality of life of all citizens. According to the *Forecasts of the European Commission for Montenegro* (European Economic Forecast, Autumn 2024, https://economy-finance.ec.europa.eu/document/download/7173e7c9-3841-4660-8d6a-a80712932f81_en?filename=ip296_en.pdf), economic growth is expected to accelerate in 2025, stimulated by newly adopted measures that should stimulate private consumption and investments. However, this effect is predicted to weaken during 2026. Export growth in the period 2025–2026. it will probably be supported by the continued development of the tourism sector.

According to the *Report on the Climate and Development of the Country - Montenegro*, published by the World Bank, it is pointed out that Montenegro has the opportunity to strengthen its resilience to climate change and encourage sustainable economic growth through carefully planned investments and policies.

The report estimates that $5,7 billion is needed over the next decade to reduce harm and improve resilience, with nature-based solutions and green infrastructure already showing positive effects on public health and the quality of urban space. Montenegro also aims to achieve net zero emissions by 2050, and the private sector is expected to provide more than 70% of the required capital through green bonds and public-private partnerships.

Along with the expansion of renewable energy sources and the decarbonisation of the transport and heating sectors, these measures can open up opportunities for sustainable growth, bringing economic, environmental and social benefits to the country.

Montenegro formally confirmed its commitment to European integration by submitting an application for membership in the European Union at the end of 2008, while negotiations began in mid-2012. One of the most challenging chapters in this process is Chapter 27 - Environment and Climate Change, which, being the last to be opened, is also the most demanding. According to the *Report of the European Commission* from 2024, Montenegro has a certain level of preparedness in this area. It also points to certain achieved progress, but also to the necessary reforms that should be implemented in the coming period, which confirms that Montenegro is facing significant challenges.

Key areas within Chapter 27 include improving waste management and recycling systems, preserving natural resources such as forests and water, and raising energy efficiency to a higher level. These challenges require systematic planning and implementation through strategic documents, the goal of which is the long-term protection of natural resources and sustainable development. However, one of the biggest problems remains the change in the awareness of citizens and society, which requires intensive information campaigns, but also the application of restrictive punitive measures in order to achieve the desired results.

In addition, by adopting the *National Strategy for Sustainable Development until 2030*, Montenegro undertook to fulfill the goals defined by the UN Agenda for Sustainable Development. This strategy further strengthens efforts to achieve sustainable development through integrated approaches to nature conservation,

emission reduction and improvement of quality of life. In support of the above, the fact that the Government's document entitled *Proposal of the National Strategy for Circular Transition until 2030* points out that the National Strategy is the "umbrella development document of Montenegro" which "set the concept of circular economy as a response to challenges in the field of waste management, not only in terms of waste prevention and reduction, but also in the area of innovation from the beginning to the end of the value chain". In addition to the above-mentioned document, the Government of Montenegro adopted a large number of national strategic frameworks, which serve to achieve the above. However, the challenges are complex, the wishes are many, and the time to solve them is getting shorter.

One of the key challenges in the field of sustainable development in Montenegro is unplanned construction, uneven regional development and excessive population concentration in the central part of the country. These problems contribute to the significant disruption of urban biodiversity and the imbalance between urban and rural areas, which affects ecological, social and economic sustainability. Therefore, it is essential to introduce comprehensive measures that will improve spatial planning and support sustainable urban development as an integral part of the green transition of Montenegro.

Tourism, as a strategic branch of development, faces serious infrastructural deficiencies that limit the use of the full potential of the natural and cultural resources of Montenegro. In addition, insufficiently developed capacities in agriculture and animal husbandry further weaken the opportunities for rural development and improvement of economic sustainability, thereby missing the opportunity to strengthen the local economy and promote Montenegro as a destination with authentic natural and agro-tourism offers.

In the context of European integration, Montenegro transposed the provisions of EU Directive 2014/95, which refers to non-financial reporting and encourages sustainable business between companies, through amendments to the Accounting Act in 2016. However, despite the legal framework, the change in traditional corporate awareness towards sustainability remains minimal. New challenges appear with the implementation of EU Directive 2022/6424, which introduces a radical reform of the corporate reporting system, including sustainability reporting standards, mandatory audit of non-financial reports and extension of reporting obligations to a larger number of entities.

Solving these problems requires a multidisciplinary approach, coordination of different sectors and significant education in order to promote the principles of sustainable development in all segments of society. This implies not only technical and legislative changes, but also systematic work on strengthening awareness of the importance of sustainability at the local, national and corporate levels.

From all of the above, the conclusion follows that a linear approach to the economy is still present in Montenegro and that in addition to the existence of formal strategic documents, very little has been done in the field of achieving the goals of sustainable development and realizing the idea of a circular economy. What are the potentials in the field of establishing and developing the concept of regenerative economy will be shown in the next chapter.

4. The concept of regenerative economy in Montenegro - potentials and limitations

As already emphasized, Montenegro has significant potential to position itself as a recognizable leader in the Western Balkans in the development of a sustainable economy, combining the preservation of natural resources with modern approaches to economic growth. However, the available data and achievements so far indicate that Montenegro uses its potential either minimally or not at all. Although the normative framework seems relatively organized, the available data suggest modest progress, which clearly indicates a significant lag in achieving the goals of sustainable development. When it comes to the regenerative economy, that concept, unfortunately, is still not considered in the Montenegrin context.

In support of the above, the fact that according to the document of the Government of Montenegro (Information on the achieved share of energy from renewable sources in the total final energy consumption in Montenegro in 2021 with the Report) it is pointed out that Montenegro has a great potential to use RES, but that the share RES in the total final consumption of energy in Montenegro in 2021 amounted to 39,29%, which is shown in the following table:

Table 1. Total share and sectoral shares in total final consumption (2021-2022)

	2021	**2022**
Sectoral share		
1.1. RES-H&C (%) - heating and cooling	57,61	60,56
1.2. RES-E (%) – electic energy	60,33	63,47
1.3. RES-T (%) - transport	0,80	0,91
Total share RES (%)	**39,29**	**40,09**

Sources: https://www.gov.me/dokumenta/b35e3b31-a553-43d6-b705-9525f1876560?utm ; https://wapi.gov.me/download-preview/287bd733-166c-4870-b49d-5215d160d608?version=1.0

In the aforementioned document, it is emphasized that the adoption of the *National Energy and Climate Plan (NECP)* is expected in the coming period, which will define new sectoral goals for the share of renewable energy sources in the power sector, the heating and cooling sector, as well as the transport sector. This plan will include measures, activities, projects and dynamics to achieve the national goal of a 50% share of energy from renewable sources in the total gross final energy consumption by 2030, with precisely defined sectoral goals. The Government's report for 2022 confirms that Montenegro has increased the share of renewable energy sources (RES) in the total final consumption to 40,09%, which indicates active efforts towards achieving this goal.

The *Report on the State of the Energy Sector of Montenegro* for 2022 highlights the significant energy potential of the country, especially in the field of hydropower, wind power plants and solar resources. Renewable energy sources accounted for

40,7% of gross final consumption, with a clear ambition to reach 50% by 2030. Although coal production still plays a key role in the energy mix, Montenegro is focusing on projects like SE Briska Gora and VE Gvozd in order to increase the share of renewable sources and improve energy efficiency. Along with planned investments and reduction of losses in energy transmission and distribution, Montenegro has set a goal of reducing greenhouse gas emissions by 55% by 2030, which represents a significant step towards sustainable energy development.

Based on the government document *Energy Balance for 2025*, which also contains an accompanying annual analysis of the share of energy from renewable energy sources in total energy production, the total production of electricity in 2023 was 14.554,22 TJ, production from renewable sources was 9.071,50 TJ, which is 62,33% of the total production. In 2024, the expected production is 12.076,20 TJ, of which 7.431,32 TJ or 61,54% of the total production comes from renewable sources. For the year 2025, the total production is planned to be 10.439,90 TJ, of which 8.323,10 TJ or 79,72% of the total production will come from renewable sources.

The total produced coal energy (excluding coal that is transformed into electricity at the Pljevlja Thermal Power Plant) in 2023 was 172,95 TJ, in 2024 it was estimated at 138,15 TJ, while 184,20 TJ is planned for 2025. From the above data, it can be concluded that the ratio of energy produced from renewable sources in the total energy production in 2023 was 75,91%, in 2024 it was estimated at 76,97% and for 2025 it is planned at 88,01 %.

The planned production for 2025 is 2.312 GWh or 80% from renewable energy sources (RES), consisting of hydroelectric power plants, wind power plants and solar power plants, and from thermal power plants 588 GWh or 20% of the total electricity production.

Montenegro has significant potential for the transition to a regenerative economy, especially through the development of regenerative production. However, previous efforts in this field show that this potential is insufficiently used. MONSTAT data, as well as research results, indicate that the share of organic production in the total used agricultural land in 2022 was only 1,6%, which confirms the need for more intensive investments and support for this sector.

Furthermore, the circular economy and waste management are also highlighted as great potentials for promoting the idea of a regenerative economy in Montenegro. However, the achievements so far in Montenegro in this field indicate very poor progress, regardless of the very ambitious goal of recycling 50% of waste by 2030. According to MONSTAT data, only 0,3%, or 1,021 tons, of the total collected 335,000 tons of municipal waste was recycled in 2022 in Montenegro, which is the lowest result in the last four years. These data indicate a significant lag behind the goals stipulated by the Law on Waste Management, which planned the recycling of 22% of the total municipal waste by 2020, as well as the standards of the European Union, which foresees the recycling and composting of at least 55% of municipal waste by 2025. In addition, in 2022, a total of 1,41 million tons of waste was created in Montenegro, of which 20.9% is hazardous waste, which further emphasizes the need to improve the waste management system in the country. The observation of the mentioned problems by municipalities leads to the conclusion that they face

significant challenges, which include a low rate of recycling and inadequate infrastructure. Most of the waste in municipalities ends up in unorganized landfills, while the capacities for separate collection and recycling are minimal.

At the conference "Modern waste management system, the foundation of a sustainable future" (https://komora.me/saopstenja/moderan-sistem-uprajvanja-otpadom-temelj-odrzive-buducnosti) it was pointed out that Montenegro, as an ecological country, must establish an effective system of waste management to preserve the environment and support a tourism-based economy. Also, the importance of transforming everyday practices and establishing an adequate regulatory and institutional framework for sustainable development was emphasized. From all of the above, it is clear that Montenegro has the obligation to fulfill the requirements defined in the negotiation Chapter 27. Initiatives for the regenerative economy include the adoption of policies for the development of the circular economy, improvement of energy efficiency through the use of waste for energy production, and the promotion of sustainable development through EU funds. However, progress in the implementation of these initiatives remains slow, and efficient waste management and the transition to a regenerative economy require greater investment, education and institutional support.

Furthermore, what is generally known is that in all strategic documents of Montenegro, tourism is recognized as a key economic branch, as well as a branch through which it is possible to achieve sustainability goals, achieved balanced regional development, especially through achieving the development and promotion of eco-tourism in the northern region. The above is elaborated in detail within the Tourism Development Strategy of Montenegro 2022-2025, but it also points out that although the north has great potential for the development of ecotourism, cultural and adventure tourism, challenges such as lack of infrastructure and poor accessibility require significant investments and alignment with EU regulations, especially from Chapter 27. The implementation of the strategy depends on the effective implementation of green investments, strengthening of destination management and public-private partnership, with the aim of positioning Montenegro as a recognized sustainable destinations.

The development of a regenerative economy in Montenegro requires a comprehensive integration of innovative policies that promote sustainability in key sectors, including energy, waste management, tourism and agriculture. Key challenges include improving infrastructure, strengthening institutional capacities and aligning with international standards, especially EU regulations. Without strategic planning and adequate implementation, the achievements so far could remain limited, which would slow down the transition to regenerative development.

It is necessary to establish coordination between national and local policies, with a focus on the balanced development of the northern and southern parts of the country. Education of local communities and their active involvement in development initiatives are key to creating sustainable practices. Special attention should be paid to the use of renewable energy sources and the development of ecotourism in northern municipalities, where there are significant natural resources that can be valorized in a sustainable manner.

The inclusion of international funds and public-private partnerships will enable the realization of strategic projects that contribute to economic growth and the preservation of natural resources. The regenerative economy represents an opportunity to reduce environmental risks and increase the economy's resilience to global challenges. Montenegro has the potential to position itself as a regional leader in the application of regenerative models, if priorities and implementation dynamics are clearly defined.

In conclusion, the synergy of public policies, private investments and local initiatives is the key to success in achieving sustainable development that simultaneously improves economic performance and environmental protection. The transition to a regenerative economy is not only a challenge, but also an opportunity for the long-term prosperity of Montenegro.

5. Conclusion

The concept of the regenerative economy, still imprecisely defined and separated from the circular economy, however, is seen as a much broader, more inclusive and proactive approach than the circular economy. Regeneration is a process and as a result of that process sustainable living systems are created. Therefore, the regenerative economy strives to transform various industries (agriculture, energy, construction, tourism, etc.) by applying innovative technologies that will create sustainable systems.

Although Montenegro has had the status of an ecological state for more than 30 years, it has not yet recognized the importance of the principles of regenerative economy, that is, it has not reached the required level of development in this area. Therefore, the goal of this work was to point out the key potentials, as well as the challenges faced by Montenegro on the way to the development of a regenerative economy. The existence of numerous formal strategic documents in Montenegro, however, did not contribute much to achieving the goals of sustainable development and realizing the ideas of circular and regenerative economy. Actualization of this issue at all levels of action must be a priority for Montenegro in the coming period, especially due to the fact that Montenegro is a candidate for EU accession, where Chapter 27 - Environment and climate change is one of the most demanding chapters in that process.

The significant potentials of Montenegro in the transition to a regenerative economy are reflected through: the development of regenerative production, whose potentials are currently underutilized; then sustainable tourism, taking into account the fact that tourism stands out as a key economic branch; establishment of an efficient waste management system.

Regardless of the mentioned potentials, Montenegro faces numerous challenges and limitations on the way to a regenerative economy. This entire process requires: the construction of adequate infrastructure in all industries that are recognized as important for the development of the regenerative economy, more efficient implementation of green investments, coordination of national and local policies, as well as harmonization with international standards. Achieving sustainable

development that simultaneously improves economic performance and preserving the environment should be seen as an opportunity for the long-term progress of Montenegro.

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REGENERATIVNA EKONOMIJA KROZ PRIZMU CRNE GORE – IZAZOVI I OGRANIČENJA

Apstrakt: Ekološki izazovi, koji su tokom poslednjih decenija poprimili globalne razmere, postali su snažan katalizator promena u pristupu održivosti ekonomskih sistema. Očigledne i često nepovratne štete nanesene planeti postojećim metodama delovanja zahtevaju hitno usvajanje novih modela koji omogućavaju regeneraciju ekosistema i vraćanje prirodnih resursa u stanje što bliže izvornom. U tom kontekstu, regenerativna ekonomija se pojavljuje kao strateški odgovor na sve izraženije ekološke probleme. Zemlje sa razvijenijom ekološkom svešću prepoznale su značaj ovog koncepta, uvodeći ga kroz konkretne politike i prakse koje balansiraju ekonomski razvoj i očuvanje prirode. Iako je Crna Gora još 1991. godine formalno proglašena ekološkom državom, principi regenerativne ekonomije još uvek nisu u potpunosti prepoznati niti implementirani. Ipak, geografski položaj, izuzetne prirodne lepote i značajan turistički i poljoprivredni potencijal pružaju Crnoj Gori jedinstvenu priliku da postane lider u razvoju regenerativnih praksi na području Zapadnog Balkana. Međutim, tranzicioni procesi, politička nestabilnost i ekonomske neizvesnosti i dalje usporavaju napredak ka društvu koje je ekološki osvešćeno. Regenerativni pristupi, poput održivog turizma, regenerativne poljoprivrede, efikasnog upravljanja otpadom i razvoja obnovljivih izvora energije, predstavljaju ključne mehanizme pomoću kojih Crna Gora može ostvariti ciljeve regenerativne ekonomije. Uprkos izazovima, cilj ovog rada je da kroz analizu trenutnog stanja identifikuje ograničenja i ponudi konkretne preporuke za unapređenje i implementaciju regenerativnih principa, kako bi se Crna Gora usmerila ka održivijoj i prosperitetnijoj budućnosti.

Ključne reči: ekološki izazovi, održivi razvoj, regenerativna ekonomija, tranzicija, Crna Gora.

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FOSTERING SUSTAINABLE REGIONS IN SERBIA: STRATEGIC APPROACH, AI, AND REGENERATIVE ECONOMICS

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Abstract: This paper explores the interplay among strategic governance, artificial intelligence, and regenerative economics as key pillars for fostering balanced regional development and driving the growth of smart cities in the Republic of Serbia. The first part of the paper examines the challenges and potentials of strategic governance in reducing regional disparities, the second part investigates the role of artificial intelligence and smart technologies in urban development, while the third part introduces the concept of regenerative economics as a model for sustainable development. The paper emphasizes the imperative to harmonize these approaches in establishing a sustainable, inclusive, and economically viable framework for regional development. This framework aims to reduce regional disparities, enhance local, regional, and national competitiveness, and ultimately improve the standard of living for citizens in the Republic of Serbia. Through a multidimensional lens encompassing economic, social, cultural, and environmental aspects, the study highlights the critical need for an integrated strategic approach to regional development, aligning regional aspirations with national objectives and strategies. Furthermore, the paper underscores the role of the government in facilitating and enhancing these processes, with a particular focus on strengthening administrative capacities, fostering innovation, and ensuring transparency in decision-making. The aim of this paper is to contribute to the creation of a theoretical foundation for further theoretical and practical research in the field of regional development.

Keywords: Strategic governance, artificial intelligence, regenerative economics, regional development, Republic of Serbia.

1. Introduction

The Republic of Serbia faces significant challenges in achieving balanced regional development. Differences in infrastructure, economic opportunities, and access to

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basic services between developed and underdeveloped regions hinder the country's overall progress. Simultaneously, the concepts of smart cities and regenerative economics offer innovative pathways to address these inequalities. By integrating strategic governance, artificial intelligence, and the principles of regenerative economics, the Republic of Serbia can establish a sustainable framework for regional development.

This paper examines the roles of these three pillars in fostering regional development. Strategic governance ensures alignment between local aspirations and national goals, artificial intelligence facilitates technological advancement and efficiency, while regenerative economics promotes resource renewal and community resilience. The primary objective of this research is to propose an integrated and contemporary model of regional development that enhances social, economic, and environmental outcomes.

Regional disparities remain a key challenge for societal progress, particularly in countries with pronounced developmental imbalances. The Republic of Serbia, like many other nations, faces this complex issue, where certain regions develop rapidly while others lag, resulting in unequal access to resources, limited socio-economic opportunities, and a lower standard of living.

Addressing regional disparities in the Republic of Serbia requires an analysis of the factors contributing to economic inequality among regions, as well as the strategic alternatives to achieve balanced development. Understanding and addressing these issues is not only an academic but also a practical imperative, as developmental inequality can lead to social tensions, political instability, and long-term economic stagnation.

To address these challenges, one of the key concepts explored in this paper is strategic governance as a tool for achieving balanced regional development. Strategic governance entails a systematic process of planning, directing, and controlling activities undertaken by an organization or state to achieve its long-term goals (Bošković and Manasijević, 2023). In the context of regional development, strategic governance facilitates the allocation of resources, identification of priorities, and coordination of actions to reduce regional disparities and their negative effects.

By analyzing the causes and consequences of regional disparities, as well as the current problems of regional development in the Republic of Serbia, this paper aims to systematically analyze the key factors contributing to economic inequality among regions, including infrastructure deficiencies, insufficient economic diversification, unequal access to education and healthcare, and a lack of investments and support for local initiatives.

Recent advancements in artificial intelligence have brought revolutionary changes to many sectors, particularly urban areas, enabling the development of so-called smart cities. Smart cities represent complex systems where various technological resources and information systems are integrated to optimize public services, improve the quality of life, and enhance resource efficiency. The concept of a smart city relies on advanced technologies such as the Internet of Things, big

data analytics, and artificial intelligence, which enable the collection, processing, and analysis of vast amounts of data in real time. These technologies, combined with intelligent infrastructure solutions, enable data-driven decision-making, which is crucial for improving urban environments (World Economic Forum, 2021).

With urban populations continuing to expand, the demand for efficient and sustainable cities is growing significantly. United Nations projections indicate that over 68% of the global population will reside in urban areas by 2050. This demographic shift necessitates innovative urban management strategies, such as intelligent infrastructure, optimized resource management, and enhanced ecological sustainability. Artificial intelligence is crucial for tackling urban challenges such as congestion, energy efficiency, safety, and waste management. Smart traffic systems allow real-time adjustment of traffic signals to reduce congestion and emissions, while data analytics helps optimize energy consumption.

Despite the numerous benefits of artificial intelligence, challenges such as privacy concerns, security issues, and ethical dilemmas persist. As more data about citizens' behavior and activities is collected and analyzed, concerns about potential violations of privacy and data security grow. Effectively balancing technological progress with robust privacy safeguards remains a critical challenge, especially regarding sensitive citizen data. Algorithms used for monitoring and behavior prediction can provide valuable insights but also raise ethical questions and concerns about potential misuse.

This paper explores the relationship between the principles of regenerative economics, sustainable development, and smart city development through the lens of artificial intelligence. First, the primary areas of AI application in smart cities will be addressed, followed by an analysis of key technological features and challenges in their implementation. Finally, future development perspectives and trends in this field will be discussed, with particular attention to social, economic, and environmental aspects.

The aim of this analysis is not only to contribute to a better understanding of regional development phenomena and the complex challenges of achieving balanced economic development but also to provide concrete proposals for developing strategies and policies for regional development in the Republic of Serbia that will reduce regional disparities. In this sense, the paper is intended for the academic community, policymakers, organizations, institutions, businesses, and civil society to foster the creation of a sustainable and inclusive economic system, at the levels of local communities, districts, and regions, as well as at the national level.

2. Challenges of Regional Development in the Republic of Serbia

An analysis of the current state of regional development in the Republic of Serbia reveals numerous challenges and issues that negatively affect the spatial distribution of economic activity, social inclusion, and infrastructural progress across the country. Key problems in regional development include uneven economic activity,

underdeveloped transportation and institutional infrastructure, social inequality, and population migration. These factors collectively contribute to the creation and widening of regional disparities, necessitating a comprehensive approach to mitigate them.

The lack of adequate transportation and institutional infrastructure in rural areas and smaller towns restricts investment attraction and business development, further exacerbating regional disparities. Moreover, social inequality manifests through limited access to healthcare, education, and social services, especially in rural parts of the country. This situation hinders improvements in living standards and deepens social exclusion.

Population migration from less developed regions to urban centers such as Belgrade, Novi Sad, and Niš creates significant pressure on infrastructure and services in these cities, while rural areas face depopulation and economic stagnation. These trends underline the urgent need for targeted interventions to alleviate urban pressure while revitalizing rural economies. Achieving balanced regional development throughout the Republic of Serbia requires a holistic approach that addresses these interconnected issues.

To overcome these challenges, a unified, comprehensive, and long-term regional development strategy must be adopted. Such a strategy should guide regional policies through targeted measures and instruments aimed at achieving equitable regional development (Manasijević and Petrović, 2023). Strengthening all forms of infrastructure in rural areas and smaller towns is essential to enhance conditions for business and living. Additionally, fostering local entrepreneurship, diversifying economic structures, and spatially dispersing economic activities are critical components of this approach. Investments in education and healthcare in rural areas are also crucial to improve the quality of life and ensure access to fundamental services.

Furthermore, mechanisms must be established to support rural development and attract investments to less developed regions. Enhanced cooperation between local and national authorities is vital to ensure coordination and synergy in implementing regional policies, measures, instruments, and programs. These efforts can lead to significant progress in addressing regional development challenges and creating conditions for prosperity and inclusive growth in all parts of the Republic of Serbia. It is equally important to strengthen the role of civil society, the private sector, and academic institutions in formulating, planning, and implementing development strategies, programs, and projects at the local level. Their involvement ensures greater transparency, accountability, and inclusivity in decision-making, which is essential for successfully addressing regional development challenges. Thus, this analysis highlights the necessity for systemic changes and the formulation of an efficient and comprehensive approach to overcome challenges and achieve balanced regional development. This requires the engagement of all relevant stakeholders in decision-making processes and a commitment to long-term sustainable regional development goals.

The causes and consequences of regional disparities in the Republic of Serbia are a complex topic requiring thorough analysis to understand the factors

contributing to uneven regional development. This issue is crucial for the country's overall development policy, as significant regional disparities can lead to severe social, economic, and political problems. The causes of regional disparities are diverse and include economic, social, geographical, and political factors (Aranđelović and Gligorijević, 2014). For instance, varying economic structures across regions, levels of investment, educational systems, resource availability, geographical location, and political decisions all contribute to uneven regional development. Unequal distribution of resources and inadequate spatial dispersal of transportation and institutional infrastructure frequently result in disparities in employment levels, living standards, and access to basic services such as healthcare and education (Gligorijević et al., 2023).

The consequences of regional disparities are multifaceted. Less developed regions often face higher unemployment rates, poverty, and social exclusion, while more developed regions enjoy greater opportunities for economic prosperity and improved living conditions. Additionally, regional disparities can drive population migration, cause a loss of human resources, and lead to unequal distribution of economic and political power.

Understanding the causes and consequences of regional disparities is essential for developing effective regional policies that reduce these differences and promote more balanced development across all parts of the Republic of Serbia. This requires a holistic approach involving the collaboration of all relevant stakeholders, an analysis of the specific characteristics of each region, and the implementation of targeted tools, measures, and instruments that support long-term sustainable and balanced economic, social, and political development.

In addition to economic and social implications, regional disparities in the Republic of Serbia can have broader political consequences. Unequal distribution of resources and political power among regions can exacerbate political polarization and dissatisfaction among citizens. Such inequalities may undermine democratic processes and institutions, complicating efforts to establish an inclusive political system that represents the interests of all citizens (Bruszt and Palestini, 2016).

Addressing regional disparities requires the development of a long-term strategy to tackle deeply rooted issues. This strategy should promote balanced economic development through targeted investments in less developed regions, strengthening local infrastructure, and supporting entrepreneurship. Improving educational systems to ensure access to high-quality education and professional training in every region is also crucial. Reducing regional disparities demands inclusive policies that consider the specific needs and characteristics of each region, as well as the active inclusion of local communities in decision-making processes. Transparency and accountability in public resource management are equally essential to prevent corruption and misuse of power.

Through these efforts, significant progress can be made in reducing regional disparities in the Republic of Serbia, ultimately creating a fairer and more sustainable society. However, achieving the goal of balanced regional development requires continued engagement and investments at all levels. Local and regional cooperation,

as well as international support, play a vital role in the process of reducing regional disparities.

The exchange of experiences, technologies, and resources between regions, along with support from international organizations and partners, can greatly enhance the efficiency and success of policies aimed at balanced regional development. Additionally, civic activism and participation in decision-making processes related to regional development should not be overlooked.

Active involvement of citizens, local communities, and non-governmental organizations, in collaboration with the state, is crucial for identifying priorities and ensuring efficiency and transparency in managing limited resources. Achieving the goals of balanced regional development in the Republic of Serbia requires long-term participation and efforts from all relevant stakeholders, continuous monitoring of results, and adaptability to changes in economic, environmental, social, and political contexts.

3. Strategic Approach to Regional Development in the Republic of Serbia

Strategic governance represents a crucial tool applied in various contexts, including regional development management. The fundamental principles and methods of strategic governance can play an essential role in shaping and implementing policies, programs, and projects aimed at achieving balanced regional development.

The concept of strategic governance involves a systematic process of planning, leading, and overseeing activities undertaken by an organization, institution, or state to achieve long-term objectives. This process typically consists of several phases: analyzing the current state, formulating strategy, implementing plans, and evaluating results. Key tools and techniques utilized in strategic governance include SWOT analysis (strengths, weaknesses, opportunities, and threats), PESTLE analysis (political, economic, social, technological, legal, and environmental factors), competitive analysis, and the establishment of SMART goals (specific, measurable, achievable, relevant, and time-bound) (Pouw and De Bruijne, 2015).

Identifying critical success factors in the implementation of regional development strategies involves analyzing economic, social, political, and environmental factors affecting the development of a specific region. Leadership and the participation of key stakeholders are vital for the success of regional development strategies. Methodological approaches to strategic governance in regional development vary depending on the specific characteristics of the region and the objectives to be achieved. Quantitative approaches focus on analyzing data related to economic indicators, demographic trends, and social processes to identify key challenges and opportunities. In contrast, qualitative approaches emphasize understanding the context, decision-making processes, and the influence of social factors on regional development. Interdisciplinary approaches, which combine elements of economics, sociology, political science, geography, and other disciplines, are increasingly essential for addressing the complex factors influencing regional development.

Integrating sustainable development into strategic governance for regional development is critical for achieving balanced growth. Sustainable development entails balancing economic, social, and environmental objectives, making it imperative for regional strategies to promote the long-term sustainability of resources, environmental protection, and improvements in citizens' quality of life. Key principles of sustainable development that can be incorporated into regional strategies include conserving natural resources and biodiversity, advancing social equity and inclusion, supporting local economies and communities, promoting energy efficiency and renewable energy, and enhancing resilience to climate change. These principles are essential for achieving long-term sustainability and ensuring better living conditions for current and future generations.

Challenges in integrating sustainable development into strategic governance for regional development include insufficient resources, a lack of awareness about sustainability's importance, resistance to change, and inadequate coordination among stakeholders (Manasijević, 2024). Overcoming these challenges requires a holistic approach, collaboration among all relevant interest groups, and institutional capacity for implementing sustainable policies and measures.

Future perspectives on strategic governance in the context of dynamic global socio-economic changes emphasize the need for continuous adaptation and innovation at local, regional, national, and international levels. Introducing new technologies, strengthening the capacities of local institutions, promoting inclusive and participatory decision-making processes, and enhancing international cooperation are key elements in regional development strategies for individual economies.

The theoretical and methodological foundations of strategic governance in regional development provide the basis for understanding the complexity and importance of planning processes and implementing effective measures and instruments in regional policies. The integration of sustainable development into these strategies is becoming increasingly significant in addressing global challenges such as climate change, economic inequality, and social instability. A comprehensive approach and continuous dialogue with all stakeholders can create sustainable and prosperous communities that facilitate equitable economic development processes.

Despite progress in some regions, significant regional disparities persist in the Republic of Serbia, impeding the efficient functioning of the country's economy. Developing a comprehensive and inclusive regional development strategy is crucial to addressing these challenges. Such a strategy should aim to balance disparities among regions and enhance their competitiveness nationally and internationally. Currently, the lack of such a strategy represents a major obstacle to effective development management and fully utilizing regional potential.

Creating a clear regional development strategy requires the involvement of all relevant stakeholders, including governments at all levels, local authorities, the private sector, non-governmental organizations, academia, and citizens. This inclusive approach facilitates identifying key problems and priorities within each region and developing tailored solutions that meet specific needs and characteristics.

One of the main priorities of a regional development strategy should be investments in infrastructure in less developed regions, particularly in rural and underdeveloped areas. This includes constructing and modernizing roads, railways, water supply systems, energy infrastructure, institutional facilities, and telecommunications. Such improvements create a foundation for attracting investments, fostering business development, and improving living standards. Additionally, supporting local entrepreneurship and small and medium-sized enterprises in rural and less developed urban areas is crucial for boosting economic activity and creating new jobs. Measures such as providing financial support, training, mentorship, and incentives for starting businesses, alongside promoting local products and services in broader markets, are essential.

Investments in education, healthcare, and social protection in less developed regions are vital for improving the quality of life and reducing socio-economic inequalities. This includes building and equipping schools, hospitals, and other healthcare facilities and ensuring access to high-quality education and adequate healthcare services for all citizens, regardless of geographic or social status.

Beyond infrastructure investments, improving governance and administration at the local level is essential for effectively implementing development programs and projects. Strengthening local government capacities, enhancing transparency and accountability in public resource management, and promoting participatory decision-making processes are key to achieving these objectives (Uvalić and Bartlett, 2021).

Achieving long-term sustainable regional development goals requires commitment and coherence in regional policies across all levels of government. Continuous monitoring and evaluation of results, adapting strategies to environmental changes, and aligning projects and programs to achieve synergistic effects are crucial elements. Private sector involvement is particularly important in advancing regional development, as businesses play a significant role in job creation, innovation, and economic growth. Ensuring a favorable business environment and offering incentives to attract investments in less developed regions are vital. These measures may include tax benefits, employment subsidies, and support for establishing business incubators and science and technology parks.

Aligning regional policies with sustainability goals is equally critical. Promoting energy efficiency, developing renewable energy sources, conserving biodiversity, and safeguarding natural resources should remain priorities. Supporting rural tourism, agro-tourism, and the protection of geographically indicated products can enhance regional development, particularly in underdeveloped rural areas (Gligorijević and Manasijević, 2023). These initiatives contribute to diversifying economic structures, creating jobs, and preserving cultural heritage and natural values.

Developing tailored training programs to meet local labor market demands and equipping citizens with skills for emerging technologies is equally vital. Collaboration between educational institutions, businesses, and local governments is essential for identifying priority sectors and fostering workforce readiness. Regional cooperation and synergy among different areas within the Republic of Serbia can

further strengthen resource utilization and create new opportunities. This can be achieved through regional projects, joint training programs, and sharing best practices across various sectors.

Continuous monitoring and evaluation of development strategies are essential for identifying successes, challenges, and opportunities for improvement. Such efforts enable flexible adjustments to strategies and better outcomes in reducing regional disparities. Promoting innovation, digitization, and modern regional development models can be key drivers for economic growth and competitiveness across all regions. Developing digital infrastructure, supporting technology startups, and enhancing digital skills are crucial for creating new business opportunities and improving productivity in less developed regions (Manasijević et al., 2019).

Finally, implementing regional development strategies involves allocating resources, defining budgets, identifying funding sources, and distributing resources according to established priorities (Miljanović et al., 2010). Institutional mechanisms and structures for coordinating and managing implementation processes are equally important. Establishing specialized agencies or strengthening existing institutions at local and national levels can enhance efficiency.

Building partnerships between the public, private, and civil sectors, as well as academic institutions and international organizations, is critical for overcoming challenges. Limited financial resources, fragmented decision-making, and political resistance are significant barriers to successful implementation. Strengthening partnerships, fostering transparency, and encouraging political will are necessary to address these challenges and maximize opportunities for regional development. By focusing efforts on sustainable and inclusive strategies, the Republic of Serbia can significantly reduce regional disparities and create a more equitable, resilient, and prosperous society.

4. AI and urban inovations: path to smart regional development in Serbia

The application of artificial intelligence (AI) has become a cornerstone in improving urban environments, offering a wide range of solutions that enhance efficiency, sustainability, and safety. One of the most critical areas of AI application is traffic management. Advanced algorithms analyze and predict traffic flows, reduce congestion, and optimize traffic signal operations. For example, Singapore employs predictive models and sensors to adjust traffic signals in real time, significantly reducing congestion and air pollution. Similarly, Barcelona integrates sensor data into smart management systems to improve traffic flow and reduce carbon emissions (World Economic Forum, 2021). These examples illustrate how AI can transform traffic infrastructure, making it more adaptive to urban needs and improving overall mobility.

Energy efficiency is another key domain where AI plays a transformative role. Integrated smart grid systems allow for better monitoring and management of energy consumption, optimizing the use of renewable resources. AI analyzes energy usage

patterns and predicts demand, improving efficiency and minimizing waste. Studies reveal that AI application in the energy sector reduces operational costs and greenhouse gas emissions by utilizing smart grids to align energy distribution with real-time user demands (IEEE Xplore, 2022). These systems not only enable more sustainable energy use but also decrease reliance on fossil fuels, supporting the transition to cleaner energy solutions.

In the security sector, AI provides advanced tools for identifying and analyzing potential threats in urban areas. Through video surveillance data analysis and pattern recognition technologies, security agencies can detect unusual activities and respond promptly. AI-powered systems, employing machine learning algorithms, identify behavioral anomalies, enabling faster incident responses and enhancing public safety. Cities like Barcelona leverage such technologies to increase security in public spaces while ensuring high levels of privacy through data encryption and anonymization.

While AI offers significant benefits, its implementation in Serbia faces challenges similar to those encountered globally. These include managing vast amounts of data from various sources, such as sensors, cameras, and smart devices. Real-time data analysis requires complex algorithms and scalable infrastructure, posing significant financial and technological demands (Cugurullo, 2020). Moreover, integrating AI with legacy systems in many cities is challenging due to incompatibilities between new technologies and outdated infrastructures.

Ethical issues, particularly those related to privacy and data security, are becoming increasingly relevant as data collection scales up. Developing regulatory frameworks and standards for AI usage in urban environments is crucial to balancing AI's benefits with citizens' rights to privacy and data protection. Addressing these challenges requires ongoing research and development to ensure responsible AI implementation in smart cities and to support sustainable urban growth.

In Serbia, the application of AI in urban and regional development has immense potential. For instance, using AI for traffic management could alleviate congestion in urban centers like Belgrade, Niš, and Novi Sad. Implementing predictive traffic models, similar to those used in London, could reduce delays by up to 20%, directly lowering carbon emissions and improving urban air quality (Kassens-Noor & Hintze, 2020). Such systems would also enhance the efficiency of public transportation, promoting greater mobility and reducing reliance on private vehicles.

AI can also play a transformative role in Serbia's energy sector. Cities like Amsterdam have adopted AI-driven systems that integrate weather data and energy needs to optimize consumption during peak hours, achieving cost reductions of approximately 15% annually (Akhtar & Moridpour, 2021). Serbia could replicate this model, particularly in transitioning its energy grid toward renewable sources such as solar and wind power. AI could facilitate this integration by balancing energy supply and demand, thereby reducing dependence on coal and contributing to the country’s climate goals.

In terms of safety, Serbia’s urban areas could benefit from AI-powered surveillance systems, such as those implemented in Tokyo, where facial recognition

technology identifies potential threats in high-traffic zones like metro stations and shopping centers. Such systems have proven effective in reducing incidents by approximately 30% (Ullah et al., 2020). For Serbia, integrating these technologies could improve security in public spaces while fostering public trust through strict privacy protocols and transparent data governance.

While the potential of AI is significant, Serbia must address challenges, including upgrading infrastructure and ensuring data scalability. These hurdles are not unique to Serbia but are intensified by limited resources and legacy systems. However, strategic partnerships between the public and private sectors, supported by international donors and development programs, could accelerate the adoption of advanced, AI-integrated systems.

State support is critical for advancing smart city initiatives. The Serbian government could create regulatory frameworks that facilitate AI integration while incentivizing private sector investments in urban infrastructure and technology development. Tax benefits and subsidies for companies engaged in AI-driven projects, such as smart grids, traffic management systems, or urban mobility solutions, could stimulate innovation and attract foreign direct investment.

AI-driven optimization of urban resources can significantly reduce costs, enhance service delivery, and improve quality of life. For example, reducing traffic congestion and air pollution directly contributes to public health improvements, while energy efficiency measures ensure long-term sustainability. Moreover, smart city development can drive economic growth by fostering new industries, creating jobs, and promoting technological advancements.

Looking forward, Serbia could position itself as a regional leader in smart city initiatives by integrating AI into its urban and regional planning strategies. Combining AI with existing efforts to balance regional development could help reduce disparities between urban and rural areas. For example, deploying AI to optimize resource allocation in less developed regions could stimulate local economies, improve public services, and enhance connectivity.

Smart cities offer a pathway to long-term sustainable urban development. By leveraging AI, Serbia can create interconnected systems that enhance mobility, energy efficiency, and public safety. At the same time, these initiatives reduce environmental impact and foster innovation. Through strategic investments and progressive policies, Serbia has the opportunity to transform its urban and regional landscapes, fostering innovation, sustainability, and equitable growth for all citizens.

5. Regenerative economics and regional development in the Republic of Serbia

The regenerative economics is an approach based on the restoration, enhancement, and sustainability of ecosystems, communities, and economic systems through the application of integrated and sustainable practices. This concept goes beyond traditional models that focus on harm reduction, directing attention instead toward the active renewal of natural resources and the creation of value that is continually

replenished. Regenerative economics establishes fundamental principles that can be applied across all aspects of society, particularly in the context of regional development. These principles include sustainable resource use, ecosystem restoration, fostering local economies, and promoting education and community engagement, thereby providing a foundation for long-term sustainability and resilience of economic systems at the regional level (Zero Waste Montenegro, n.d.).

In the context of Serbia's regional development, applying regenerative economics principles could significantly enhance social, economic, and environmental aspects of various regions. Regenerative economics not only emphasizes resource preservation but also their renewal through innovative practices such as regenerative agriculture, ecosystem restoration, local economic initiatives, and educational projects. For Serbia, such initiatives could be transformative, offering tangible benefits like increased agricultural yields and improved resilience to floods and droughts while addressing climate challenges and economic uncertainties (NALED, n.d.).

A key principle of the regenerative economics is the sustainable use of resources, which involves reducing the consumption of natural resources and minimizing waste. In this framework, resources are not treated as inexhaustible but are used with the aim of maximizing efficiency and longevity. Practices such as using renewable energy, recycling, and optimizing water usage are central elements. Moreover, regenerative economics prioritizes optimizing production processes to minimize waste and enhance circularity, ensuring that resources are reused and renewed rather than lost. This principle aligns well with Serbia's efforts to address environmental challenges, particularly in regions like Vojvodina, where agricultural and industrial activities demand sustainable resource management (Zero Waste Montenegro, n.d.; NALED, n.d.).

Another critical aspect is ecosystem restoration, which involves comprehensive strategies to revitalize degraded ecosystems. Practices like regenerative agriculture, reforestation, wetland restoration, and biodiversity protection are key components. Ecosystem restoration helps rebalance nature, improves soil and water quality, reduces carbon emissions, and contributes to global efforts against climate change. On a regional level, these initiatives in Serbia could boost agricultural yields, reduce risks from floods and droughts, and restore vital natural resources that underpin both environmental and economic stability. For instance, reforesting areas near the Morava River could enhance flood resilience while supporting biodiversity (UG "Nešto Više," n.d.).

Encouraging local economies is another cornerstone of the regenerative economics, enabling communities to achieve economic self-sufficiency while reducing reliance on external markets. Regenerative practices promote local entrepreneurship, agriculture, and production, leveraging regional resources and knowledge. Implementing circular economic models in Serbia could ensure that resources and products remain within local communities for extended periods. Sustainable business practices, such as renewable energy adoption and ecological agriculture, can strengthen local economies while creating long-term economic opportunities for regional populations. For example, fostering small-scale solar

energy projects in rural areas could provide both energy independence and economic growth (OSCE, n.d.).

Education and community engagement are vital for successfully implementing a regenerative economics. Education fosters awareness and behavioral change at both individual and collective levels. Community engagement in decision-making processes facilitates the development of sustainable practices tailored to regional needs and characteristics. By equipping citizens with knowledge and tools through educational programs, Serbia can foster a grassroots movement that supports regenerative principles, ensuring collective progress and societal benefits. Educated and engaged communities often serve as examples of successful development rooted in regenerative principles, inspiring broader adoption across the country (UG "Nešto Više," n.d.).

The application of regenerative economics principles could also enhance regional resilience to global economic and climatic challenges. For instance, adopting sustainable agricultural practices in Serbia can reduce dependency on volatile global markets and resource supply uncertainties. Techniques like composting, crop rotation, and the use of biological agents not only restore soil health and improve yields but also reduce environmental impacts. These practices could lead to a more sustainable agricultural sector, ensuring stable and secure food sources while preserving biodiversity and reducing greenhouse gas emissions.

Furthermore, the regenerative economics has the potential to improve quality of life in regional communities through the development of eco-friendly infrastructure. Projects such as the implementation of energy-efficient public buildings in Belgrade or sustainable transport systems in Novi Sad could bring numerous benefits to local communities. These initiatives not only reduce carbon emissions and reliance on fossil fuels but also drive innovation and create new jobs in green technology and sustainable development sectors. Additionally, these projects enhance citizens' health and well-being by reducing air pollution and improving environmental quality.

Successfully implementing regenerative economics models at the regional level in Serbia requires coordinated efforts among various sectors and stakeholders, including local governments, entrepreneurs, non-governmental organizations, and citizens. Without active engagement from all parties, regenerative practices cannot achieve their desired impact. Collaborative efforts enable the creation of strategies tailored to regional characteristics. These consider natural resources, economic potential, and societal needs. For Serbia, this means not only adopting regenerative economics as a theoretical framework but also leveraging it as a practical tool for achieving sustainable development and improving the quality of life for future generations.

Projects such as renewable energy installations in rural areas or urban reforestation programs in cities like Belgrade and Novi Sad could serve as flagship examples of Serbia’s commitment to regenerative principles. Educational programs and workshops promoting sustainable practices in local communities could empower citizens to actively participate in the transition toward a regenerative economics. By aligning regional development strategies with regenerative principles, Serbia has the

opportunity to not only address current environmental and economic challenges but also position itself as a leader in sustainable and resilient development in the Balkans.

6. Conclusion

The study of the interconnection between strategic governance, regenerative economics, and the application of artificial intelligence highlights their potential as pillars for achieving balanced and sustainable regional development in the Republic of Serbia. This work emphasizes the importance of their synergy in addressing the structural challenges Serbia faces, pointing to opportunities for improving social, economic, and environmental performance at both local and national levels. Strategic governance relies on analytical tools and stakeholder coordination. It provides a robust framework for purposeful and targeted action. Its role in aligning local and national priorities is crucial for creating strategic solutions tailored to the specificities of each region while simultaneously enhancing institutional capacities and ensuring transparency in decision-making processes.

The application of artificial intelligence is revolutionizing urban and regional management through the integration of technological solutions that enhance efficiency and sustainability. The concept of smart cities, based on data analytics, the Internet of Things, and predictive models, offers concrete tools for optimizing infrastructure, public services, and resource management. Building upon these advancements, the importance of establishing appropriate regulations becomes evident. These regulations must balance innovation with privacy protection while ensuring public participation in decision-making processes. Such an approach is vital for achieving broader social acceptance and long-term sustainability.

Regenerative economics represents a fundamental shift in the approach to sustainability, moving the focus from harm reduction to the active restoration of resources and ecosystems. Its principles, such as resource circularity, community engagement, and support for local economic initiatives, provide a foundation for transforming regional communities into more resilient and self-sustaining systems. Regenerative agriculture, energy-efficient technologies, and local initiatives for natural resource restoration reduce reliance on global markets and increase regional resilience to economic and environmental challenges. Engaging local communities and educating citizens are essential for turning these principles into tangible improvements in daily life, fostering a shared sense of purpose and progress.

While this study successfully integrates the three mentioned concepts, their implementation requires a multidisciplinary approach, institutional reforms, and continuous collaboration among all relevant stakeholders. Policymakers, the private sector, academia, and civil society share a joint responsibility for designing and implementing development strategies that can translate theoretical frameworks into practical initiatives. Evaluating outcomes through clear success metrics—such as reducing regional disparities, improving infrastructure and quality of life, and strengthening regional economic competitiveness—is equally crucial for sustaining momentum and achieving lasting impact.

In conclusion, integrating strategic governance, regenerative economics, and artificial intelligence offers an innovative development model that can reshape the socio-economic landscape of the Republic of Serbia. This transformation is not merely a strategic imperative but a profound necessity for Serbia. By embracing this integrated model, the nation can redefine its developmental trajectory, transforming future challenges into lasting opportunities for resilience, inclusivity, and prosperity.

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PODSTICANJE ODRŽIVOG RAZVOJA REGIONA U SRBIJI: STRATEGIJSKI PRISTUP, VEŠTAČKA INTELIGENCIJA I REGENERATIVNA EKONOMIJA

Apstrakt: Ovaj rad istražuje međusobnu povezanost strategijskog upravljanja, veštačke inteligencije i regenerativne ekonomije kao ključnih oslonaca za podsticanje ravnomernog regionalnog razvoja i unapređenje pametnih gradova u Republici Srbiji. U prvom delu rada razmatraju se izazovi i mogućnosti strategijskog upravljanja u smanjenju regionalnih razlika. Drugi deo analizira ulogu veštačke inteligencije i pametnih tehnologija u razvoju urbanih sredina, dok treći deo uvodi koncept regenerativne ekonomije kao modela održivog razvoja. Rad naglašava potrebu za usklađivanjem ovih pristupa kako bi se uspostavio održiv, inkluzivan i ekonomski stabilan okvir za regionalni razvoj. Ovaj okvir ima za cilj smanjenje razlika među regionima, jačanje lokalne, regionalne i nacionalne konkurentnosti, kao i unapređenje kvaliteta života građana u Republici Srbiji. Kroz multidimenzionalni pristup, koji obuhvata ekonomske, društvene, kulturne i ekološke aspekte, studija ističe važnost integrisanog strategijskog pristupa regionalnom razvoju koji usklađuje ciljeve regiona sa nacionalnim prioritetima i strategijama. Pored toga, rad naglašava ključnu ulogu države u podršci i unapređenju ovih procesa, sa posebnim fokusom na jačanje administrativnih kapaciteta, podsticanje inovacija i osiguranje transparentnosti u donošenju odluka. Cilj ovog rada je da doprinese kreiranju teorijskog okvira za dalja istraživanja i praktičnu primenu u oblasti regionalnog razvoja.

Ključne reči: Strategijsko upravljanje, veštačka inteligencija, regenerativna ekonomija, regionalni razvoj, pametni gradovi, Republika Srbija.

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