

EDITED BY NATASHA DANILOSKA

THE CIRCULAR ECONOMY IN THE REPUBLIC OF NORTH MACEDONIA

Concepts, Institutions, and Business Models



COLLECTED RESEARCH PAPERS

Ss. Cyril and Methodius University in Skopje
Institute of Economics – Skopje



REPUBLIC OF NORTH MACEDONIA
SS. CYRIL AND METHODIUS UNIVERSITY IN SKOPJE
INSTITUTE OF ECONOMICS - SKOPJE



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Edited by
Natasha Daniloska

Skopje, 2026

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Preface

This volume brings together a set of peer-reviewed papers produced within the research project *Transition towards a Circular Economy in the Republic of North Macedonia: Opportunities and Challenges* (acronym: CERM), conducted at the Institute of Economics-Skopje, Ss. Cyril and Methodius University in Skopje, with funding from the University's integrative research funds.

The project was conceived against the backdrop of a broader shift in economic thinking, one in which the circular economy has emerged as an alternative to the resource-intensive linear model of production and consumption that has long driven global economic growth. The sections that follow set out that broader context in full; for the present purposes, it is sufficient to note that the project took the promise of this alternative model, and the question of what it would take to implement it in North Macedonia specifically, as its starting point.

It was within this wider context that the project set out to examine the opportunities and challenges of transitioning toward a circular economy in the Republic of North Macedonia, as an alternative to the dominant linear approach to production and consumption and a more sustainable model. Over twelve-month duration of the project, a research team led by Prof. Natasha Daniloska and Prof. Diana Boshkovska, together with colleagues from the Institute of Economics-Skopje spanning economics, accounting, management, and business studies, pursued three interconnected research objectives: clarifying the conceptual and theoretical foundations of the circular economy; identifying the institutional framework and priority sectors for circular transition in North Macedonia; and developing an approach to designing circular business models, with particular attention to small and medium-sized enterprises.

These efforts resulted in a body of scientific work published in international journals and presented at scientific and professional conferences. Taken individually, these papers appeared in different outlets and reached different audiences; brought together in a single edition, they form a coherent account of the project's research trajectory, from the conceptual foundations of the circular economy, through an analysis of the institutional and sectoral framework, to the development of practical approaches to circular business models. Compiling them into a single publication was, from the outset, part of the project's own dissemination strategy: to increase the accessibility of the results and support their practical use beyond the confines of individual journal issues and conference proceedings.

The purpose of this publication, then, is to make these results more accessible to researchers, policymakers, business practitioners, and students by presenting them not as isolated contributions but as parts of a connected research effort. The volume is organized in two parts. Part One sets out the background, aims, and methodological approach of the project, concluding with an overview of the individual contributions, situating each paper within the aims and internal logic of the project. Part Two reproduces the papers themselves, in full, in the form in which they were originally published.

Part One: Prolegomena

Context, Aims, and Findings of the Research Project

Background and Rationale

Over recent decades, global economic development has largely followed the linear model of production and consumption, based on the intensive exploitation of natural resources, short product life cycles, and the continuous generation of waste. While this model has contributed to economic growth and industrial development, it has simultaneously generated significant ecological, economic, and social pressures that, under current conditions, increasingly constrain the prospects for sustainable development. The depletion of resources, climate change, pollution, and the rising costs of waste management call for a reconsideration of existing economic paradigms and a search for alternative models capable of ensuring long-term economic, ecological, and social sustainability.

Within this context, the circular economy has established itself as a concept and development model offering a systemic response to the limitations of the linear economy. It rests on the principles of more efficient and more responsible resource use, the extension of product life cycles, the minimization of waste generation, and the retention of the value of materials and energy within the economic cycle for as long as possible. The circular economy is not merely an environmental concept, but an integrated economic and social approach with the potential to stimulate innovation, create new economic opportunities, and strengthen economic resilience, while also supporting the goals of sustainable development and climate neutrality.

It is within this broader context that the project *Transition towards a Circular Economy in the Republic of North Macedonia: Opportunities and Challenges* focused on analyzing the opportunities and challenges of the transition to a circular economy in the Republic of North Macedonia, as an alternative and more sustainable economic model to the dominant linear approach to production and consumption. The research was based on the premise that the linear economic model, based on the extraction, transformation, and disposal of resources, creates serious structural constraints on long-term economic development, particularly under conditions of growing demand for raw materials and energy. The intensive exploitation of natural resources, the limited potential for their renewal, and the accumulation of substantial quantities of waste result in mounting pressures on the environment, the degradation of ecosystems, and rising costs of waste management and pollution control. Beyond its ecological implications, this model also generates significant economic and social consequences, manifested in reduced resource efficiency, increased dependence on imported raw materials and energy sources, and heightened vulnerability of the economy to external shocks and price fluctuations. In this context, the linear approach constrains the competitiveness of businesses and diminishes their capacity to adapt to contemporary market and regulatory requirements related to sustainability.

For the purposes of this research, the concept of the circular economy was examined within a broader analytical and practical context, taking into account its theoretical foundations, the institutional and regulatory conditions for its application, and the possibilities for its

operationalization within a specific national economic context. Particular attention was devoted to understanding the circular economy as a process of transition, that is, a process that entails coordinated change across multiple levels, from policies and institutions, through sectoral structures, to business practices and models of production and consumption. This approach made it possible to analyze the concept not only as a normative framework but also as an applicable model with tangible implications for the economy of the Republic of North Macedonia. This conceptual positioning also shaped the analytical approach and the overall structure of the research.

A successful transition to a circular economy entails coordinated change in patterns of production and consumption that cannot be achieved through the actions of individual actors alone. In essence, it is a process that requires active engagement and cooperation among public institutions, the business sector, and civil society. The state plays a key role in creating an appropriate regulatory and strategic framework, while businesses are the primary agents of practical implementation, through innovation, product redesign, and the adaptation of business models. At the same time, civil society and consumers play significant roles in transforming consumption habits and in generating demand for more sustainable products and services.

The way the circular economy develops is also shaped by broader ecological and economic trends, which are particularly evident in the Republic of North Macedonia. National environmental indicators point to continued pressure on natural resources, high dependence on fossil fuels, and a limited level of material productivity. Despite a moderate decline in domestic material consumption during certain periods, resource productivity remains relatively low, underlining the need for more efficient resource management and the introduction of circular approaches. In addition, the substantial share of waste disposed of in landfills and the limited recycling rate represent structural weaknesses that constrain the sustainability of the existing economic model.

Within this research, the circular economy is positioned as a structural transformation of the economic model, rather than a series of isolated environmental measures or technical interventions. It is understood as a regenerative model aimed at decoupling economic growth from the excessive exploitation of natural resources, through minimizing waste, maximizing resource efficiency, and retaining the value of materials, products, and energy within the economic cycle for as long as possible. On this conceptual basis, the analysis identifies three core principles of the circular economy: eliminating waste and pollution at the design stage, circulating products and materials at their highest possible value, and regenerating natural systems. These principles must be integrated into national development policies and business practices. They have not only an environmental dimension but also a direct bearing on economic efficiency, innovation potential, and long-term competitiveness.

A further dimension of the analysis concerns the institutional and policy context of the circular economy. The circular economy cannot develop spontaneously or purely through market forces; it requires clearly defined public policies, regulatory mechanisms, and strategic support instruments. International experience and European frameworks such as the European Union's Circular Economy Action Plan indicate that the state plays a key role in creating the preconditions for circular transition, through waste management legislation, ecodesign

requirements, extended producer responsibility and economic instruments and public procurement policies that stimulate sustainable solutions.

The circular economy is also closely linked to the wider goals of sustainable development and climate policy. An analysis of environmental trends in the Republic of North Macedonia, particularly with respect to greenhouse gas emissions, the structure of the energy sector, and waste management, shows that the circular economy provides a necessary complementary framework for meeting national and international climate commitments. The high share of fossil fuels in the energy mix, low recycling rates, and the continued dominance of landfilling underline the need for structural change in patterns of production and consumption, which can be addressed in an integrated manner through the circular economy.

In economic terms, the circular economy holds considerable potential for the creation of new forms of economic value. Through more efficient use of resources, the development of new markets for secondary raw materials, the introduction of innovative business models and services, and the encouragement of digitalization and new technological solutions, the circular economy can contribute to economic diversification, increased productivity, and greater resilience of the economy to external shocks. These findings are particularly relevant for small and medium-sized enterprises, which, given adequate institutional support, can become key drivers of circular innovation.

Aims and Scope of the Research Project

The general aim of the project was to offer a systematic, analytically grounded contribution to the debate on transitioning toward a circular economy in the Republic of North Macedonia. Rather than treating the circular economy as a self-evident policy goal, the research sought to examine the conditions, opportunities, and constraints involved in applying circular principles within the specific national context, weaving together its conceptual, institutional, and economic dimensions into a single coherent analytical account. The resulting body of work was conceived as more than an academic exercise: it is intended to serve both as groundwork for further research and as a resource for shaping policy and practice in support of sustainable economic development.

The scope of the research was defined accordingly. Situated within the social sciences, and specifically within economics and business, the project examined the circular economy as an economic and institutional phenomenon rather than a primarily technical or environmental one, with a focus on the Republic of North Macedonia as its national context. Its thematic scope centered on four interconnected areas: the conceptual foundations of the circular economy, the institutional framework governing its adoption, its relationship to sustainable development, and the business models through which it can be put into practice.

This general aim was translated into three specific, interlocking objectives, each building on the one before: clarifying the conceptual foundations of the circular economy, mapping the institutional landscape and priority sectors for its adoption in North Macedonia, and developing an approach to circular business models capable of putting these ideas into practice.

The starting point of the research was conceptual. Before the circular economy could be examined in a national context, its theoretical foundations, defining features, and differences from the conventional linear model needed to be established with some precision. This involved reviewing substantial body of scientific and professional literature, covering the range of definitions, theoretical approaches, and conceptual frameworks found both in academic scholarship and in the policy documents of international organizations, with particular emphasis given to the economic and interdisciplinary dimensions of the concept. The literature was read critically rather than catalogued, the aim being to identify both the common ground across different approaches to the circular economy and the genuine points of disagreement between them. The research moved to a direct comparison of the circular and linear models: how each treats resources, manages waste, accommodates innovation, and affects economic and environmental outcomes over the long run. This, in turn, led to an examination of the relationship between the circular economy and the wider agenda of sustainable development, and specifically how circular principles help reconcile economic, environmental, and social objectives while limiting environmental harm. The conceptual groundwork concluded with an assessment of the benefits the circular economy can plausibly deliver: greater resource efficiency, reduced environmental impact, a stronger push toward innovation, and improved economic resilience. Together, these steps established the conceptual footing on which the rest of the research would build.

With that foundation in place, the second objective turned outward, from concept to context: which institutional framework and which economic sectors in North Macedonia are best positioned for a circular transition? Answering this first required a close examination of the country's existing institutional landscape: its national policies, strategic documents, and legislation, together with the initiatives and measures already in place that relate, directly or indirectly, to the circular economy, resource management, and sustainable development. The analysis paid close attention to which institutions hold which responsibilities, how well they coordinate with one another, and where the institutional gaps lie, including fragmented policies, limited capacity, and weak horizontal and vertical coordination. Building on this institutional mapping, the research then identified the sectors best positioned to lead a circular transition, weighing the country's economic structure, sector-by-sector resource intensity, waste generation, and the practical scope for introducing circular practices, alongside national conditions such as resource availability, the existing industrial base, the regulatory environment, and capacity for innovation. The result was a grounded account of where, institutionally and sectorally, a circular transition in North Macedonia has the best prospects of taking hold, thereby providing the necessary bridge to the project's third objective: circular business models.

The final objective addressed a simple but consequential question: how are circular principles put into practice at the level of the firm? This was, in a sense, the objective on which the entire project turned, since a conceptual and institutional framework only matters insofar as it can be translated into concrete business models and practices. The stakes were considerable. Moving from a linear to a circular business model is not a matter of incremental adjustment; it requires new approaches to resource use, redesigned products and processes, and new forms of collaboration among businesses and other stakeholders. The research approached this question

first through a systematic review of the literature on circular business models, taking stock of the conceptual frameworks, typologies, and methodological approaches used to analyse them, as well as how they have been applied across sectors and national contexts, with close attention to what distinguishes circular from conventional linear business models: value creation through longer product life cycles, the reuse and recycling of resources, redesigned production processes, and different relationships with consumers. The research then turned to the practical question of transition itself, tracing the key phases through which a business moves from a linear to a circular model, with this transition treated as a gradual process unfolding across organizational, technological, and market dimensions. This included mapping the phases of preparation, adaptation, and implementation, and the conditions a business needs to have in place, internally and externally, for that transition to succeed. With this, the research came full circle, connecting the conceptual and institutional analysis that preceded it to its practical expression in business practice.

The project was conducted out over twelve months, during which these three objectives, and the work undertaken to pursue them, unfolded as a single, continuous line of inquiry.

Methodological Approach

The research combined several complementary methods, each suited to the nature of the objective it addressed: a systematic review of the scientific literature for the conceptual and circular-business-model dimensions of the project, qualitative analysis of institutional and policy documents for the assessment of the national framework, and a criteria-based approach to the identification of priority economic sectors.

The literature-based components of the research, spanning both the conceptual foundations of the circular economy and the later work on circular business models, were conducted using the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). PRISMA was chosen precisely because the literature on the circular economy, and on circular business models in particular, tends to be fragmented and terminologically inconsistent: different authors frequently use similar concepts under different names, or, conversely, apply the same term to different practices. Working within a PRISMA framework made it possible to define a clear and transparent process for selecting, filtering, and analyzing relevant sources, from the initial identification of relevant literature through to its analytical synthesis and interpretation, and to do so in a way that could be consistently traced and, in principle, replicated.

The analysis of the institutional and regulatory framework relied on a qualitative review of national policies, strategic documents, and legislation relevant to the circular economy, resource management, and sustainable development, undertaken to establish the responsibilities assigned to different institutions and how effectively they coordinate with one another.

The identification of priority sectors for circular transition followed a methodological framework grounded in the national roadmap for the transition to a circular economy, developed with the support of the OECD. Within this framework, priority sectors are identified

by combining quantitative indicators with qualitative analysis, with the results assessed against four criteria: economic importance, relevance to public policy, potential for the application of circular strategies, and potential for decarbonization. This combination of criteria was chosen to ensure that the resulting priorities reflected not only the scale of a sector's resource use but also its alignment with existing public policy and its practical readiness for circular intervention.

Finally, in developing a typology of circular business models, the research adopted a dual analytical approach, examining these models simultaneously from the standpoint of their underlying strategic logic, that is, why a given business model qualifies as circular - and from the standpoint of how that logic materializes through concrete organizational, technological, and market solutions. This dual approach was adopted because the dominant approaches in the existing literature tend to treat circular business models either through isolated strategic logics or through descriptions of isolated operational practices, an emphasis that, while analytically useful, proved insufficient on its own to capture the full complexity of circular business models and their transformative role within the economic system.

Beyond this shared methodological core, the individual contributions collected in this volume draw on a broader range of methods suited to their specific research questions, including semi-structured interviews, comparative case analysis, econometric modeling, and AI-based analytical approaches. These are introduced individually in the overview that follows and presented in full in the papers themselves.

Summary of Findings and Concluding Remarks

The results generated over the course of the project did not emerge as a set of isolated findings. They emerged from a cumulative process in which conceptual analysis, institutional assessment, and the study of practical implementation were woven into a single analytical framework, capable of offering a systematic synthesis of what the national context requires for a genuine transition to a circular economy, rather than a scattering of disconnected observations.

Read together, the results of the first objective did more than clarify a concept. They positioned the circular economy as a systemic framework for economic transformation, distinct from any collection of isolated environmental practices or waste-focused measures and traced what that framework implies in practice. A successful transition, the research found, is not something any single actor can bring about. It depends on coordinated change across production and consumption alike, with the state responsible for the regulatory and strategic framework, businesses for translating that framework into innovation, redesigned products, and adapted business models, and civil society and consumers for the demand-side transformation, the changing habits and preferences that give circular products and services a market in the first place.

The national context also shapes how the circular economy can realistically develop in North Macedonia. National environmental indicators point to sustained pressure on natural resources, heavy reliance on fossil fuels, and material productivity that remains low even where domestic

material consumption has declined somewhat during certain periods. A significant share of waste is still disposed of in landfills, and recycling rates remain limited. These are not peripheral details; they are structural weaknesses that constrain how far the existing economic model can go on its own terms, and they sharpen the case for circular alternatives rather than merely illustrating it.

Taken further, the analysis identified three principles that recur across the literature and that the research treats as foundational: eliminating waste and pollution at the design stage, keeping products and materials in circulation at their highest possible value, and regenerating natural systems rather than merely seeking to limit damage to them. What matters about these principles, the research insists, is that their relevance is not confined to the environmental dimension of the ledger. They bear directly on economic efficiency, on the space available for innovation, and on how competitive an economy remains over the long run, which is precisely why the circular economy cannot be developed through market forces alone. It requires public policy, regulatory instruments, and strategic direction, a conclusion reinforced by international experience and by European frameworks such as the EU's Circular Economy Action Plan, where the state's role ranges from waste legislation and ecodesign requirements to extended producer responsibility and procurement policies that promote sustainable choices.

The same logic extends to climate policy. North Macedonia's emissions profile, its energy structure, and its waste management practices point in one direction: the circular economy is not merely an adjacent concern to climate commitments but a necessary complement to them. A high share of fossil fuels in the energy mix, low recycling rates, and continued dependence on landfilling are, in effect, the same structural problem viewed from different angles, one that circular approaches are well positioned to address in an integrated way rather than piecemeal. And there is an economic rationale for pursuing this path: more efficient resource use, new markets for secondary raw materials, new business models and services, and a greater adoption of digitalization all point toward diversification, productivity gains, and greater resilience to external shocks, gains that matter disproportionately for small and medium-sized enterprises once the institutional support they need is in place.

Taken together, these findings did more than address the questions associated with the first objective. They set the analytical terms for everything that followed, establishing the actors, principles, and preconditions against which the institutional and sectoral analysis, and later, the business model analysis, could be measured.

The second objective turned that conceptual groundwork toward the concrete question of institutions and sectors. What it found, in short, is a landscape of partial pieces rather than a coherent whole: individual initiatives and regulatory elements relevant to the circular economy do exist in North Macedonia, but they remain fragmented and insufficiently coordinated within any unifying strategic vision.

Identifying which sectors might anchor a more coordinated approach drew on the methodology underpinning the national roadmap for circular transition, developed with OECD support, which combines quantitative indicators with qualitative judgment to weigh a sector's economic structure against public policy and against its practical readiness for circular intervention. That roadmap had already flagged four sectors on these grounds: construction, biomass and food,

textiles, and mining and metallurgy, prioritized according to four criteria, namely economic importance, policy relevance, potential for circular strategies, and potential for decarbonization. This research retained that framework in full but extended it. Further analysis of sectoral dynamics and sustainable consumption patterns identified a fifth candidate not present in the original roadmap: the cultural and creative industries, included on the strength of its role in shaping social values, innovative practices, and the broader acceptance of circular solutions, and on the sector's capacity to connect across sectors in ways more conventional industries cannot.

Each of the five sectors that emerged from this analysis carries a distinct profile, examined below in terms of its economic and environmental significance, its institutional and regulatory conditions, and the specific opportunities and constraints affecting circular adoption.

Construction stands out first, both for what it consumes and for what it discards: a substantial share of primary raw materials and intensive energy use, as well as large volumes of construction and demolition waste. The circular opportunities here are correspondingly concrete, from selective deconstruction and the reuse and recycling of building materials to ecodesign principles that simply extend the service life of buildings, interventions that retain material value inside the economic cycle rather than sending it to landfills. Secondary raw materials and industrial by-products likewise have a natural home in construction, strengthening industrial symbiosis across sectors, with public procurement representing an especially effective lever for generating demand once sustainability and circularity criteria are incorporated into public infrastructure projects. What holds the sector back is not a lack of opportunity but a lack of infrastructure: separate waste collection remains underdeveloped, recycling capacity is limited, and regulation and market mechanisms are not well aligned, meaning that construction's circular potential will only be realized in regulatory reform, economic incentives, and a functioning market for secondary construction materials moving together rather than separately.

The biomass and food sector, encompassing the broader agri-food chain, earns its place on the list for reasons that go beyond resource use: its weight in the national economy, its significance for rural development and food security, and the scale of loss and waste that accumulates across production, processing, distribution, and consumption. Much of what is currently discarded as waste, agricultural and food residues chief among it, is in fact underused rather than genuinely without value. Bioeconomy solutions, biogas, biofuels, biofertilizers, and renewable materials among them, offer a route to converting those biological resources into products with economic value, thereby diversifying income for farms and processors in the process rather than simply reducing what they throw away. The sector's circular potential also reaches into energy: using biomass for energy and heat production connects the agri-food chain to the energy transition and to decarbonization, while closing material and energy loops locally, with benefits for rural development and territorial cohesion that extend well beyond the farm gate. The obstacles are familiar ones: weak coordination among stakeholders, limited access to financing for circular technologies, and low awareness of what bioeconomy solutions can actually do, obstacles that point to the need for agricultural, energy, and waste policy to move as one rather than in parallel.

Textiles present something of a paradox: a modest share of GDP paired with an disproportionately large environmental footprint, driven by resource-and chemical-intensive production and the sheer volume of textile waste generated. Its export orientation and its place in European value chains make it particularly exposed to shifts in regulation and market expectations. The circular opportunities center on extending product life, durable design, reparability, and reuse, as well as building the collection, sorting, and recycling systems that are currently lacking for textile waste alongside the use of more sustainable materials, a higher share of recycled fibers, and cleaner production processes generally, all of which align with the direction of European policy. For Macedonian producers, this is less an environmental consideration than a competitiveness issue: as ecodesign requirements and extended producer responsibility obligations become more stringent and supply chain transparency requirements increase across European markets, the circular economy becomes a strategic opportunity for adaptation as much as an environmental one. The constraints, meanwhile, are structural: underdeveloped collection and recycling infrastructure, limited investment in technological modernization, and uneven readiness among businesses to embrace new models, constraints that only a coordinated mix of regulation, financing, and innovation support is likely to overcome.

Mining and metallurgy combine high resource intensity with a considerable environmental footprint yet also offer some of the clearest opportunities for industrial symbiosis anywhere in the economy. The sector supplies raw materials to a large part of the wider industrial economy while generating mine tailings and metallurgical by-products that remain, for the most part, unrecovered. Better management of this waste represents an obvious opportunity: tailings and by-products can serve as secondary raw materials for other industrial processes, including construction and infrastructure among them, turning what one sector discards into what another sector needs and reducing the pressure to extract new primary materials. Aligning the sector with European environmental standards on waste, emissions, and the rehabilitation of degraded land, doubles as both a regulatory obligation and a modernization opportunity, one that can improve resource efficiency and environmental performance while strengthening the sector's economic sustainability. What stands in the way is largely technological and financial: limited capacity for processing and reusing waste, high upfront investment costs, and weak coordination between institutions and industry, obstacles that call for a long-term strategic vision rather than piecemeal fixes.

The cultural and creative industries are the outlier on this list, and deliberately so. They were not identified by the national roadmap, and they are not resource-intensive in the way the other four sectors are. Their relevance lies elsewhere, in their capacity to shape social values, consumption habits, and public perception of what sustainable production and consumption actually look like. The use of recycled, renewable, and bio-based materials in design, art, fashion, and performance offers one direction contribution; the adaptive reuse of heritage buildings and disused industrial spaces offers another, linking spatial regeneration, cultural development, and local economic activity without drawing on new resources. But their most distinctive contribution may be communicative rather than material: cultural and media practices can translate the abstractions of circularity into narratives to which people actually respond to, shaping how both consumers and businesses behave in ways that a policy document

rarely can on its own. Formal economic analysis tends to undervalue this sector, but the research treats its contribution as substantial rather than symbolic, positioning it as a horizontal sector capable of generating synergies with the other four and of helping a circular transition gain broader social acceptance, something none of the other sectors is as well placed to do.

Beyond the sector-by-sector picture, the second objective also yielded a set of policy recommendations that follow directly from it. Circular principles, the research insists, cannot be implemented through isolated or sector-specific measures; they need to be integrating into existing national strategies for economic development, environment, energy, and industrial policy, with waste legislation in particular needing to be aligned so that waste management functions as part of economic planning rather than as its final, disconnected stage. Economic instruments are as important here as regulation: tax relief, dedicated financing, and investment support for circular technologies and business models help businesses overcome the initial barriers to adoption, while green public procurement stands out as perhaps the single most effective tool for generating demand, particularly in sectors such as construction, infrastructure, and public services, where government spending already carries weight. Infrastructure investment in sorting, recycling, and material reuse, is a further precondition that cuts across every sector examined here, and its current inadequacy is a horizontal constraint rather than a sector-specific one, calling for coordinated, long-term planning at both the national and regional level.

If there is a single thread running through the sectoral findings, it is that the circular economy gains real economic traction only where sectors connect to one another. Mining and metallurgy by-products finding their way into construction, biomass and organic waste turning into energy and bio-based products, textiles opening new markets for secondary materials, and the cultural and creative industries carrying the message across all of them: these are not incidental overlaps but mechanisms through which fragmented, ad hoc interventions can develop into a more coherent national strategy. It is through this kind of coordination, the research concludes, that the economic, environmental, and social benefits of circular transition are maximized, and that the transition itself becomes something durable rather than provisional.

The third objective shifted the focus from sectors to firms, and specifically to the question of how circular principles actually reach the level of the business model. Here too the research resists a narrower reading of the transition: regulation and technology can enable circular practices, but they cannot substitute for a change in how businesses create, deliver, and retain value, which is why business models occupy the central position they do in this project, as the hinge connecting the conceptual framework of the circular economy to its real economic application.

Establishing that framework meant confronting a literature that is, by most accounts, highly fragmented, terminologically inconsistent, with different authors attaching different labels to similar ideas, or the same label to quite different practices. Rather than adding another universal classification to an already extensive body of classifications, the research set out to identify and organize the dominant types already present in the scholarship, using the PRISMA methodology to keep the selection, analysis, and synthesis of sources transparent and methodologically consistent from the initial search through to the final interpretation.

What emerged from that review is a claim worth stating plainly: circular business models, in current practice, do not constitute a scattering of isolated eco-innovations. They have become systemic, conceptually coherent approaches to doing business that reshape how resources are managed, how products are designed and brought to market, and how value is created, with circularity built into the underlying business logic rather than bolted on. That is a more demanding claim than it might first appear, since it implies structural change in organizational arrangements, market relationships, and value chain interactions, not merely better technology or marginally more efficient resource use.

It is precisely this conceptual reach and internal diversity that expose the limits of how the literature usually handles circular business models, treating them either through isolated strategic logics or through descriptions of isolated operational practices, useful as far as it goes, but not sufficient to capture the full complexity of what these models are or what they do. The research's response was to develop a dual analytical approach, one lens focused on strategic logic and a second on how that logic plays out operationally, allowing both questions, why a model counts as circular and how it works in practice, to be answered at once rather than traded off against each other.

The strategic-focus typology takes the first of these questions directly: why does a given business model qualify as circular, and what is its primary strategic intent with respect to resources, products, and markets? Four types answer that question in different ways. Design-oriented models build circularity in from the earliest stages of product development by emphasizing durability, repairability, and recyclability, treating design not as a peripheral technical concern but as the primary lever for preventing waste and optimizing material flows throughout a product's life cycle. Use-oriented models take a different route, shifting emphasis from ownership to access, creating value through rental, sharing, subscription, or product-as-a-service arrangements that get more use out of what already exists rather than selling more of what is new. Models built around recovery and closed material loops take a third route, treating waste and discarded products as inputs rather than endpoints, reintroducing them back into new production in order to retain material value inside the economic system for as long as possible. Because circular transformation in practice rarely follows a single logic, a fourth, hybrid category captures the business models that combine several of these strategies at once, a reminder that firms tend to arrive at circularity by more than one path simultaneously.

Where the strategic typology asks why, the operational typology asks how, examining circular business models through their internal architecture and the actual mechanics by which circular principles get translated into organizational and business decisions. It, too, yields four types: product-oriented models, which retain a conventional product focus while incorporating secondary raw materials, redesigning for durability, and remanufacturing; service-oriented models, which move value creation from ownership toward service provision through rental, sharing, maintenance, and upgrading; resource-oriented models, focused on the efficient management of material and energy flows through recycling and industrial symbiosis; and design-innovation models, which put innovation in design itself at the center of circular transformation, building in disassembly, modularity, and adaptability from the outset. Together, these four types trace how circularity shows up in a business's value proposition,

revenue model, customer relationships, and supply chain, the operational detail that the strategic typology, by design, leaves out.

Combined, the two typologies do something neither could do alone: they bridge the divide, common enough in the literature, between theory-driven classification and purely descriptive empirical accounts, letting strategic logic and operational practice inform each other rather than sitting in separate chapters. The result treats circular business models as what they actually are: dynamic and multidimensional, with strategic goals, organizational choices, and day-to-day operational practice all shaping one another rather than one simply dictating the others. That framing turns out to matter especially for small and medium-sized enterprises, where limited resources, institutional constraints, and market uncertainty make the strategic-operational distinction genuinely useful rather than merely academic, helping identify where circular transformation might begin and where the real barriers are likely to show up.

None of these changes the fact that adoption remains genuinely difficult. Underdeveloped regulatory frameworks, high upfront costs for redesigning processes and technology, organizational resistance to change, and rising demands on digital, logistical, and infrastructural readiness are the obstacles that recur across the research, and they confirm something the sectoral findings already suggested: circular business models cannot be willed into existence company by company. They require coordinated action across several levels at once, public policy advancing in step with dedicated financing mechanisms and stronger institutional capacity, not any one of these substituting for the others.

Strategically, businesses appear to reach circularity along a spectrum rather than a single track, from incremental adjustments layered onto existing linear operations to deeper, transformative models that redesign the value chain itself and open up new forms of cooperation among businesses that would otherwise operate independently, including industrial symbiosis, shared resource use, and circular business ecosystems. Small and medium-sized enterprises sit at an interesting point on that spectrum: constrained in resources, certainly, but often more innovative and more flexible than their size would suggest and well positioned to become genuine carriers of circular innovation once institutional support, financing, and a market that actually rewards circular solutions are in place.

Taken together, the third objective's findings do what the first two set out to make possible: they connect theoretical insights into circularity with the organizational, market, and institutional realities businesses actually face, creating a basis for further empirical research and for policy and support programs aimed more precisely at where change is most likely to occur. In that sense, the third objective closes the circle the project set out to draw, an integrated view of the circular economy as concept, as an institutional framework, and as an applicable economic model with a genuine contribution to sustainable, resilient development, in North Macedonia and in the wider region alike.

Read as a whole, the project's results track closely with what it set out to achieve. The first objective delivered a comprehensive conceptual account of the circular economy, distinguishing it clearly from the linear model and positioning it as a systemic, regenerative form of economic transformation. The second built a well-evidenced picture of the policies, institutions, initiatives, and constraints that define the national context, extending the expected

minimum of four priority sectors to five once the cultural and creative industries were brought into view. The third produced a systematized, typological account of how circular business models actually work, connecting the phases and logic of the transition from linear to circular practice together in a structured account of change that is gradual without being incidental. None of these results stands alone. Together they form a single analytical arc, one that treats the circular economy not as an environmental afterthought but as a systemic development paradigm requiring public policy and business practice to move in step, and one whose findings, already disseminated through publication in international journals and presentation at scientific and professional conferences, are gathered here into a connected account for the first time.

Overview of the Contributions

The papers that make up this collection are the project's most concrete outcome: results generated over the course of the research and subsequently tested and confirmed through publication and presentation at scientific and professional venues. Each represents a specific research activity carried out within the project. What follows is a brief overview of each paper, outlining its content and situating it within the project's aims and objectives. The full papers themselves are reproduced in Part Two.

The overviews below are grouped into three clusters, corresponding to the project's three research objectives, followed by a closing overview offering empirical, economy-wide validation of the project's central thesis. The first cluster addresses the conceptual foundations of the circular economy; the second, the institutional framework and priority sectors for circular transition in North Macedonia; and the third, circular business models, moving from the volume's foundational typology through a theoretical extension of the business-model debate to a series of sector-specific empirical cases. This organization lets the papers be read, as far as possible, as a connected account rather than a list of separate publications, echoing the structure already established earlier in Part One.

Papers related to the first research objective: the conceptual framework of the circular economy

Advancing the Circular Economy in the Republic of North Macedonia: Principles, Policies, and Strategic Actions

Authors: Natasha Daniloska, Diana Boshkovska

Economic Development, Journal of the Institute of Economics, Skopje, Year 27, No. 1-2 (2025)

Original scientific paper

This paper lays the conceptual and analytical groundwork for the volume as a whole. It positions the circular economy as a structural transformation of the economic system rather than a set of environmental adjustments, tracing the theoretical principles behind that transformation and their evolution within contemporary economic thought, before turning to the role public policy plays in supporting it. Its review of relevant European policy identifies specific gaps and barriers in the national policy landscape and argues for coordinated strategic action rather than isolated measures. Within the project, this paper functions as the introductory

and conceptual pillar, examining the basic logic of the circular economy and establishing the theoretical coordinates the rest of the volume builds on.

The Evolving Landscape of ESG Ratings: A Critical Examination of Their Role in Promoting Sustainability

Authors: Biljana Angelova, Vladimir Petkovski, Irina Piperkova, Ivana Angelova

Economic Development, Journal of the Institute of Economics, Skopje, Year 27, No. 1-2 (2025)

Original scientific paper, peer-reviewed

This paper takes a critical look at the development and significance of Environmental, Social, and Governance (ESG) ratings as an instrument for encouraging sustainable practice in business. Synthesizing a wide range of academic research on ESG indicators and ratings, it assesses their role in shaping corporate sustainability strategy, their influence on firm value and investment decisions, and their potential to support the principles of the circular economy, while pointing to significant inconsistencies across rating approaches and to the social dimension of ESG in particular, which remains less developed conceptually than its environmental and governance counterparts. Within the project, this paper helps clarify the wider institutional and market frameworks through which the circular economy connects with contemporary instruments of corporate sustainability, extending the conceptual groundwork laid by the previous paper into the territory to market-based sustainability instruments.

Papers related to the second research objective: institutional framework and priority sectors

Priority Sectors for the Macedonian Transition to a Circular Economy: Strategic Pathways for Sustainable Transformation

Authors: Diana Boshkovska, Natasha Daniloska

Economic Development, Journal of the Institute of Economics, Skopje, Year 27, No. 3 (2025)

Original scientific paper

Identifying which sectors should lead the transition is the task this paper takes up directly, providing the central analytical basis for determining priority sectors for circular transition in North Macedonia. It builds on the methodological framework developed in the national roadmap for the circular economy, prepared with OECD support, extending and analytically adapting that framework to the national economic and institutional context. Combining quantitative indicators of economic and environmental relevance with qualitative analysis of institutional arrangements, public policy, and sectoral specifics, and weighing four criteria — economic importance, policy relevance, potential for circular strategies, and potential for decarbonization—the paper identifies construction, biomass and food, textiles, and mining and metallurgy as priority sectors, in line with the national roadmap, and adds the cultural and creative industries as a fifth sector, based on original analysis of their role in shaping sustainable production and consumption and in fostering social acceptance for circular policy. Within the project, it plays a key role in connecting the conceptual framework to the concrete national context, providing an analytical basis for directing governance, policy, and investment toward the areas of highest transformative potential.

The Use of AI Agents in Green Economy Analysis: The Case of the Macedonian Economy

Authors: Dushko Todevski, Klimentina Poposka, Iskra Stancheva Gigov

Economic Development, Journal of the Institute of Economics, Skopje, Year 28, No. 1 (2026)

Original scientific paper

This paper explores the use of autonomous, AI-based agents as an advanced analytical tool for supporting the transition to a green economy, addressing the structural constraints facing transition economies, particularly fragmented, delayed, and difficult-to-process data on greenhouse gas emissions and climate policy. Using AI agents to process and interpret national emissions time series from 1990 to 2019 across the key sectors of the economy, the paper shows that such systems can autonomously identify critical periods, structural trends, and likely future emissions trajectories, outperforming classical econometric models under conditions of incomplete data, and can provide robust support for evidence-based climate policy and decarbonization strategy. Within the project, this paper extends the institutional and analytical dimension of the second objective, demonstrating how digital and AI-based tools can support the kind of policy monitoring and sectoral analysis on which effective circular and climate governance depends.

Papers related to the third research objective: circular business models

Towards a Circular Economy: A Comprehensive Review of Circular Business Models

Authors: Natasha Daniloska, Tatjana Petkovska Mirchevska, Diana Boshkovska

Proceedings of the 4th International Circular Packaging Conference

Paper in an international peer-reviewed conference proceedings

This paper delivers the project's foundational typological work on circular business models. Built on the PRISMA methodology, it offers a transparent, structured, and methodologically consistent review of the relevant literature, drawing on 42 peer-reviewed publications, and identifies the dominant conceptual directions, theoretical approaches, and practical interpretations of circular business models found in the literature, addressing the fragmentation and terminological inconsistency that otherwise characterize the field. Its particular contribution is the dual analytical approach to typology also described in Part One of this volume: a strategic-focus typology, classifying business models according to the underlying logic through which circularity and value creation are achieved, and an operational typology, examining models through their internal architecture and core business model elements. Within the project, this paper plays a central role in connecting theoretical insight into circularity with concrete organizational and market realities and provides the typological framework against which the case studies that follow can be read.

Green Business Model vs. Business Model Innovation: Conflict or Convergence in Value Creation

Authors: Bojana Krstevska, Vasil Popovski

Economic Development, Journal of the Institute of Economics, Skopje, Year 28, No. 1 (2026)

Original scientific paper

At issue in this paper is the relationship between green business models and business model innovation: are the two approaches in tension, or do they tend to converge and reinforce each

other in the process of value creation? Methodologically, it systematically compares six influential frameworks for business model analysis, examining their respective approaches to value creation, innovation, and the integration of sustainability. Its particular contribution is addressing a conceptual gap in the literature regarding the interaction between green business models and business model innovation, treating them not as opposing approaches but as complementary and mutually reinforcing processes. Within the project, this paper extends the theoretical debate introduced by the previous paper's typology, positioning the circular economy as an evolving outcome of the convergence between green business models and business model innovation.

The Role of Accounting Information Systems in Supporting Circular Economy Goals: A Case Study of Waste Collection and Cost Management in the Republic of North Macedonia

Authors: Neda Petroska-Angelovska, Milena Boshkovska Klisaroski, Tea Josimoska, Natasha Bogdanovska

Economic Development, Journal of the Institute of Economics, Skopje, Year 27, No. 3 (2025)
Original scientific paper

Accounting rarely takes center stage in circular economy research, but this paper places it at the center of the analysis, examining the role of accounting information systems in supporting circular economy goals through a case study of Pakomak DOO Skopje, the first and largest collective operator for packaging waste management in North Macedonia. The paper shows how integrating financial and operational data allows costs to be allocated precisely by activity, waste type, region, and collection channel, while tracking key economic and environmental indicators, and argues that a well-designed accounting information system functions not merely as a financial record-keeping tool but as a strategic support for circular practice. The paper contributes to the project's third research objective by offering a concrete example of how circular principles are operationalized through business and management systems, deepening the analysis of circular business models from the standpoint of organizational architecture.

Reducing Food Waste Through Circular Economy: Evidence from Hospitality Practices

Authors: Sasho Nefovski, Natasha Daniloska, Tatjana Petkovska Mirchevska, Diana Boshkovska

Economic Development, Journal of the Institute of Economics, Skopje, Year 28, No. 1 (2026)
Original scientific paper

Hospitality provides the empirical ground here, with a qualitative case study of the Ibis Skopje City Center examining how circular economy principles translate into food waste management in practice. Drawing on semi-structured interviews, internal data, and a digital waste-tracking platform, it finds that the hotel achieved a 63 percent reduction in food waste between 2018 and 2023, through a combination of operational changes, staff training, and guest engagement, with institutionalized corporate sustainability frameworks shown to play a notable role in making circular practice consistent and measurable. The paper connects directly to the project's third research objective, offering concrete empirical evidence of how circular business models function in service industries and deepening the sectoral analysis of waste generation in hospitality and tourism.

Comparative Analysis of Circular Business Models in Agriculture

Authors: Natasha Daniloska, Diana Boshkovska, Aleksandar Stojanoski

Second International Scientific Agri-Business Conference AgroMak 2026, "Local Resources and Global Challenges: Integrated Approaches to Sustainable Rural Development in the Era of Climate Change"

Paper in international peer-reviewed conference proceedings

Six cases from agriculture, three Macedonian and three international, form the basis of this paper's comparative analysis of circular business models in agriculture. The domestic examples include a biogas operation converting poultry manure into energy and fertilizer, a municipal composting initiative, and an eco-oriented rice producer, set alongside an insect-protein facility in France, an integrated anaerobic digestion and composting plant in the Netherlands, and the Kalundborg industrial symbiosis network in Denmark, with all six examined in terms of technological characteristics, economic viability, environmental effects, and scalability potential. Rather than treating the circular economy as a universal model, the paper argues that circular business models are context-dependent configurations, whose performance depends on the alignment between technological structure, value-creation logic, environmental goals, and operational scale. Its findings show that technological sophistication is neither a precondition nor a guarantee of circular effectiveness: low-technology, locally embedded models can generate meaningful environmental and economic benefits, while highly integrated systems enable broader material throughput but require greater institutional capacity and capital investment, with economic resilience depending more on diversified value creation than on scale alone. The Macedonian composting case is a telling counterpoint: it ceased operating in 2017-2018 not for technical reasons but because of a lack of sustained institutional support, underscoring that technical viability alone does not guarantee continuity. For North Macedonia specifically, the paper concludes that low-technology circular models such as composting and eco-oriented production are the most immediately replicable pathways, and that policy should prioritize structural compatibility over technological ambition. Within the project, this paper closes the cluster of business-model case studies with an explicitly sectoral, comparative lens, reinforcing the project's broader argument that circular transition is a differentiated, context-dependent process rather than the replication of a uniform set of best practices.

Closing contribution

Circular Economy and Sustainable Growth: Evidence from North Macedonia

Authors: Elizabeta Djambaska, Aleksandra Lozanoska, Tea Josimovska

Economic Development, Journal of the Institute of Economics, Skopje, Year 27, No. 3 (2025)

Original scientific paper

This paper closes the volume with an empirical test of the economic effects of circular transition in North Macedonia, connecting back to both the first and third research objectives. It applies an extended Cobb-Douglas production function, incorporating resource productivity, renewable energy use, and CO₂ emissions alongside the conventional growth factors of capital and labor, estimated using an Autoregressive Distributed Lag model for the period 2000-2023.

Its results show a strong, statistically significant positive effect of resource productivity on GDP, with a one percent increase in resource productivity associated with roughly a 0.75 percent increase in GDP, offering clear empirical support for the decoupling of economic growth from rising resource consumption, while also identifying structural weaknesses in the economy linked to inefficient capital allocation and the transitional costs of energy transformation. With its methodological rigor and clear empirical orientation, this paper provides strong quantitative support for the volume's central thesis, that the circular economy is not merely a normative or environmental concept but a real economic model with measurable effects on growth and competitiveness in a transition economy, an appropriate note on which to conclude the volume.

Significance and Application

The results assembled in this volume were never intended to remain within the confines of academic publication. They speak to several audiences at once, each engaging with the material differently. For the academic community at Ss. Cyril and Methodius University and the wider national and international research community, the project's conceptual frameworks, sectoral analyses, and business model typologies offer a foundation for further inquiry, comparative research, and methodological refinement in the study of the circular economy, particularly in transition contexts where the institutional and structural conditions differ markedly from those typically assumed in the Western European literature. Their value also extends to teaching: the concepts, typologies, and analytical frameworks developed here are well suited to integration into undergraduate, graduate, and doctoral coursework, and could in time inform textbooks and teaching materials that give the circular economy a lasting place in the university's curriculum, helping students develop the interdisciplinary competencies and critical-thinking skills increasingly expected in a sustainability-conscious labor market.

The findings carry equal weight for policymakers and public institutions engaged in economic development, environmental protection, energy, and industrial policy. The institutional and regulatory analysis, the identification of priority sectors, and the policy recommendations that follow from them provide a concrete basis for better-informed decisions and improved coordination, both horizontal and vertical, among the institutions responsible for the circular transition, work that speaks directly to North Macedonia's alignment with the Green Agenda for the Western Balkans and the National Smart Specialization Strategy. For the business sector, and particularly for small and medium-sized enterprises navigating new regulatory, market, and technological pressures around sustainability, the volume's systematized account of circular business models, their strategic and operational dimensions, and the opportunities they offer for creating and retaining value can serve as a conceptual reference point for firms considering circular solutions of their own, a role reinforced by the case studies included here, from waste management to hospitality to agriculture, which show what circular practice looks like on the ground rather than only in principle.

Finally, the project's relevance reaches beyond any single professional audience. Understanding the circular economy as a societal process, one that depends on changing habits, values, and everyday behaviour as much as on policy or technology, means that public

awareness matters as much as institutional reform. The cultural and creative industries, examined in this volume as a priority sector in their own right, are as relevant here as anywhere: their capacity to translate circular principles into narratives people actually respond to is central to building the social acceptance on which a circular transition ultimately depends. Taken together, these audiences point to the same conclusion: the results gathered here extend well beyond the boundaries of individual scientific findings, forming an integrated body of knowledge whose relevance runs from the classroom to the policy table to the factory floor, and whose long-term value lies in supporting evidence-based policy and sustainable practice in the Republic of North Macedonia for years to come.

Part Two: Contributions

The ten peer-reviewed papers produced within the project, reproduced in full.

NATASHA DANILOSKA*
DIANA BOSHKOVSKA**

ADVANCING THE CIRCULAR ECONOMY IN THE REPUBLIC OF NORTH MACEDONIA: PRINCIPLES, POLICIES, AND STRATEGIC ACTIONS

Originally published in *Economic Development - Journal of the Institute of Economics, Skopje*, Year 27, No. 1-2 (2025). Original scientific paper. <https://doi.org/10.55302/ED251-2108d>

Abstract: *The circular economy (CE) is gaining momentum as a sustainable model that promotes resource efficiency, waste reduction, and long-term environmental and economic resilience. Republic of North Macedonia (RNM) has made progress in integrating CE principles into its policies, but challenges remain due to fragmented regulations, financial constraints, and limited institutional coordination. This paper¹ explores the core principles of the CE, examines environmental trends shaping its adoption in the Republic of North Macedonia, and evaluates the country's existing institutional framework. Key policy gaps and barriers are identified, and strategic actions are proposed to enhance circular economy implementation. Recommendations include developing a national Circular Economy Action Plan, improving waste management infrastructure, strengthening financial incentives for businesses, and fostering international cooperation. By aligning policies with EU directives and best practices, RNM can accelerate its transition toward a sustainable, low-carbon, and resource-efficient economy.*

Keywords: circular economy, sustainability, waste management, policy framework, Republic of North Macedonia

JEL Classification: Q0, Q56, O44, P28, R11

Introduction

The shift toward a CE represents a fundamental departure from the traditional linear model of production and consumption, which follows a "take-make-dispose" approach. Instead, a CE focuses on minimizing waste, maximizing resource efficiency, and maintaining the value of materials for as long as possible. This approach is gaining recognition worldwide, with initiatives such as the EU Circular Economy Action Plan setting guidelines for integrating circular principles into national economies (European Commission, 2020).

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RNM has taken important steps in adopting CE principles, particularly in waste management and energy efficiency. However, the transition remains slow due to weak policy coordination, limited financial support, and a continued reliance on fossil fuels. The country has committed to reducing greenhouse gas emissions and aligning its environmental policies with EU standards, yet the absence of a dedicated national CE strategy has hindered meaningful progress.

This paper explores the fundamental principles of the CE and the environmental trends shaping its adoption in RNM. It examines the country's current institutional framework, highlighting key policy gaps and implementation barriers. The paper also presents strategic recommendations aimed at improving regulatory enforcement, strengthening institutional collaboration, and fostering financial incentives to support circular business models. By addressing these challenges and leveraging international best practices, RNM can create new economic opportunities while advancing its sustainability goals.

1. Overview of Circular Economy Principles

The CE represents a transformative economic model that seeks to decouple economic growth from resource depletion by promoting sustainable resource management, waste minimization, and long-term resilience (Geissdoerfer et al., 2017). Unlike the traditional linear economic model which follows a "take-make-dispose" approach, the CE is regenerative by design and focuses on maintaining the value of materials, products, and resources for as long as possible (Kirchherr et al., 2018). This approach not only enhances economic efficiency but also contributes to environmental conservation and societal well-being, and at its core, is guided by three fundamental principles (Ellen MacArthur Foundation, 2023):

- **Eliminating Waste and Pollution**-A core circular strategy is designing out waste, enabling companies to reduce pollution, conserve resources, and lower their carbon footprint.
- **Circulating Products and Materials (at Their Highest Value)**-Extending material use through reuse, repair, refurbishment, and recycling preserves value and prevents premature waste.
- **Regenerating Nature**-A sustainable economy restores nature by enhancing biodiversity, soil health, and reducing ecological harm.

The successful transition to a CE requires a multi-stakeholder approach, where governments, businesses, and civil society collaborate to reshape production and consumption systems. To facilitate this shift, several global best practices and policy frameworks have been developed:

- **Policy and Regulatory Support**-Governments play a crucial role in setting legal frameworks that encourage circular practices. Regulations promoting eco-friendly product design, extended producer responsibility (EPR), and sustainable waste management have been implemented across the European Union and OECD member states, setting an example for other regions to follow (European Commission, 2022).
- **Collaborative Supply Chains**-Companies are increasingly forming strategic partnerships to close material loops by designing take-back programs, repair initiatives,

and circular material exchanges. These collaborations help reduce waste and improve supply chain efficiency (Lacy & Rutqvist, 2015).

- **Digitalization and Data Analytics**-Emerging technologies such as blockchain, artificial intelligence, and IoT (Internet of Things) enable better tracking of material flows, product lifecycles, and waste management processes. By leveraging data-driven decision-making, businesses can optimize resource use and design more effective circular models (Kalmykova et al., 2018).
- **Innovative Business Models**-Business are evolving toward service-based approaches, where products are leased, rented, or shared instead of being purchased outright. This shift encourages extended product lifespans, resource efficiency, and waste reduction by promoting durability, upgradability, and reparability. By maintaining responsibility for the product throughout its lifecycle, businesses can enhance customer value, reduce environmental impact, and create more sustainable economic models (Ramdani et al., 2019).
- **International Cooperation**-The transition to a CE requires global collaboration to ensure knowledge-sharing and coordinated policy actions. Initiatives such as the EU Circular Economy Action Plan, OECD Circular Economy Framework, and United Nations Sustainable Development Goals (SDG 12: Responsible Consumption and Production) provide guidelines and incentives for countries to adopt circular principles (Schroeder et al., 2019).

By adopting these principles and drawing insights from global best practices, countries and businesses can shift towards a CE, fostering sustainable economic development, environmental conservation, and societal well-being. Similarly, by integrating the core principles of the CE and aligning with international best practices and policy frameworks, RNM can achieve substantial economic, environmental, and social advantages.

2. Environmental trends shaping the circular economy in the Republic of North Macedonia

As a Non-Annex-I signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement, RNM has committed to reducing GHG emissions to 82% of 1990 levels by 2030. Furthermore, in alignment with the EU's ambition to become climate-neutral by 2050, RNM has endorsed the Green Agenda for the Western Balkans, pledging to achieve carbon neutrality by 2050.

Despite these commitments, RNM still faces significant environmental challenges. According to the Emissions Database for Global Atmospheric Research (EDGAR) 2023 report, RNM's greenhouse gas (GHG) emissions have undergone notable changes over recent decades (Table 1.). In 1990, the country's total GHG emissions were approximately 16.5 million tonnes of CO₂ equivalent (Mt CO₂eq). By 2022, this figure had decreased to around 12.3 Mt CO₂eq, representing a reduction of about 25.5% over the 32-year period. This decline can be attributed to various factors, including economic transitions, shifts in energy production, and the implementation of environmental policies aimed at reducing emissions. However, the energy sector remains the largest contributor to emissions, primarily due to the country's continued reliance on fossil fuels for electricity generation and heating. Efforts to transition towards

renewable energy sources and enhance energy efficiency are crucial for RNM to continue its trajectory towards lower emissions and to meet international climate commitments.

Table 1. Greenhouse Gas (GHG) Emissions Trends in the Republic of North Macedonia (1990-2022)

Year	GHG emissions Mt CO ₂ eq/yr	GHG emissions per capita t CO ₂ eq/cap/yr	GHG emissions per unit of GDP PPP t CO ₂ eq/kUSD/yr	Population
1990	14.469	7.248	0.637	1.995M
2005	12.440	6.038	0.545	2.060M
2015	10.645	5.120	0.340	2.079M
2022	11.184	5.354	0.317	2.089M

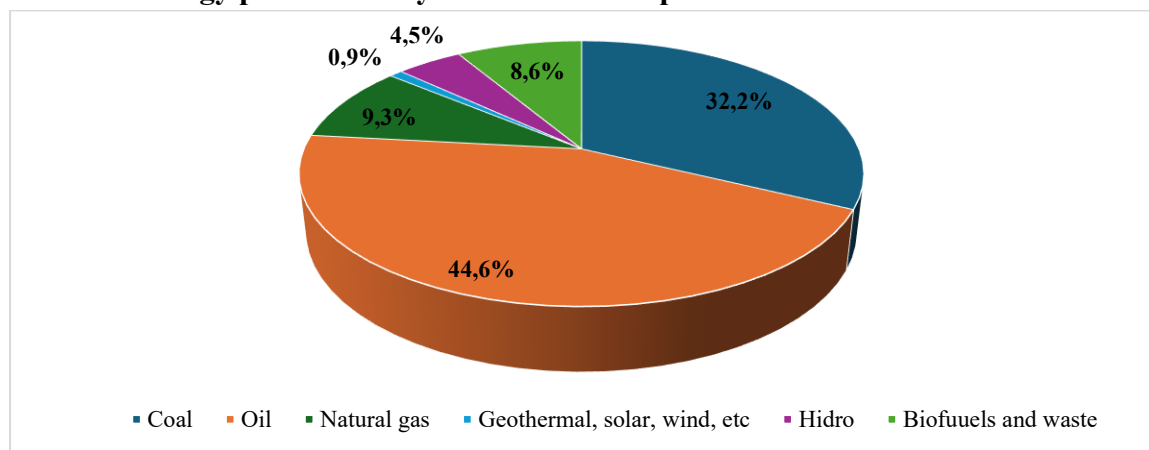
Source: EDGAR-Emissions Database for Global Atmospheric Research (2023); JRC SCIENCE FOR POLICY REPORT-GHG EMISSIONS OF ALL WORLD COUNTRIES, p. 818

CO₂ emissions account for 80% of RNM's total GHG emissions (Ministry of Environment and Physical Planning, 2021). In 2022, energy-related CO₂ emissions reached 8 million tonnes, representing 0.02% of global emissions (IEA, 2023). The sectoral breakdown of CO₂ emissions in 2022 highlights that: (IRENA, 2024)

- Electricity and heat generation accounted for 80% of total emissions, reflecting the country's reliance on fossil fuels.
- Industrial combustion contributed 17%, indicating the need for energy efficiency improvements in manufacturing.
- Transport accounted for 4%, showing that emissions from vehicles remain relatively low but could increase with rising mobility.

The relationship between energy production and GHG emissions is central to understanding RNM's environmental footprint and sustainability challenges. As depicted in Chart 1., over 75% of country's energy production still depends on fossil fuels, particularly oil (44.6%) and coal (32.2%). While the country's GHG emissions have declined over the past three decades due to policy-driven efficiency measures, it still faces significant challenges in decarbonizing its energy mix. Renewable energy sources, such as hydropower (4.5%), biofuels and waste (8.6%), and solar and wind (0.9%), remain underdeveloped despite their potential. The slow adoption of renewable energy highlights the urgent need for policy reforms, increased investment in green energy alternatives, and stronger incentives for sustainable energy production.

Chart 1. Energy production by source in the Republic of North Macedonia in 2022



Source: IEA-International Energy Agency (2025): Energy system of North Macedonia

Decarbonizing the energy sector by increasing renewable energy adoption and enhancing industrial energy efficiency can further strengthen the CE transition. The integration of renewable energy in manufacturing, alongside green infrastructure investments, can help optimize resource use, lower operational costs, and drive innovation in sustainable industries. As RNM aligns with EU climate goals, shifting to renewable energy and reducing reliance on fossil fuels is crucial for cutting emissions and ensuring sustainability. Embracing circular economy principles will further support environmental, economic, and social progress.

While energy production and fossil fuel dependency remain the primary drivers of greenhouse gas (GHG) emissions in RNM, waste management is another critical factor contributing to the country's environmental footprint. Poorly managed municipal, industrial, and hazardous waste not only generates methane (CH₄), a highly potent greenhouse gas, but also poses serious risks to air, water, and soil quality. Despite ongoing efforts to modernize waste collection and recycling systems, more than 80% of municipal waste still ends up in landfills or illegal dumpsites, with recycling rates remaining below 5% (EEA, 2023). According to the State Statistical Office, as seen in Table 2, RNM generated 878.303 tonnes of municipal waste in 2023, equating to 503 kg per capita, a 7,7% increase from 2022. Of this, 621.686 tonnes were collected, with 82% from households and 18% from commercial entities. Notably, 99.8% of collected waste was disposed of in landfills. Of the total amount of generated waste in 2023, 70,8% was collected. By waste type, the highest amount of collected waste was mixed municipal waste, 85.4%, followed by organic waste 6.4%. The lowest amount was rubber waste, 0.2% of the total amount of collected waste.

Table 2. Generated municipal waste in the Republic of North Macedonia and annual amount of collected municipal waste (2014-2023)

Year	Generated municipal waste ¹⁾ (in tonnes)	Collected municipal waste ¹⁾ (in tonnes)
2014	765.156	569.794
2015	786.182	620.328
2016	796.585	160.289
2017	786.881	635.875
2018	854.865	625.386
2019	915.943	632.484
2020	913.033	630.086
2021	896.066	632.087
2022	856.766	605.638
2023	878.303	621.686

¹⁾ Data are estimated based on the number of resident population according to the Estimations of the Population, except for 2021 when the estimation is made according to the Census of Population, Households and Dwellings, 2021

Source: State Statistical Office (2024): Makstat Selection, p. 23

By investing in circular business models, closed-loop recycling systems, and waste-to-energy technologies, RNM can significantly reduce waste-related emissions, extend product lifecycles, and create new economic opportunities. Circular solutions are also necessary to reduce plastic pollution, generated by its untenable use and disposal of (single-use) plastic products, as it comes with several risks for the tourism sector, ecosystem and human health. Moreover, implementing Extended Producer Responsibility (EPR) schemes and encouraging eco-innovation can foster sustainable production and consumption patterns, aligning the country with EU circular economy directives.

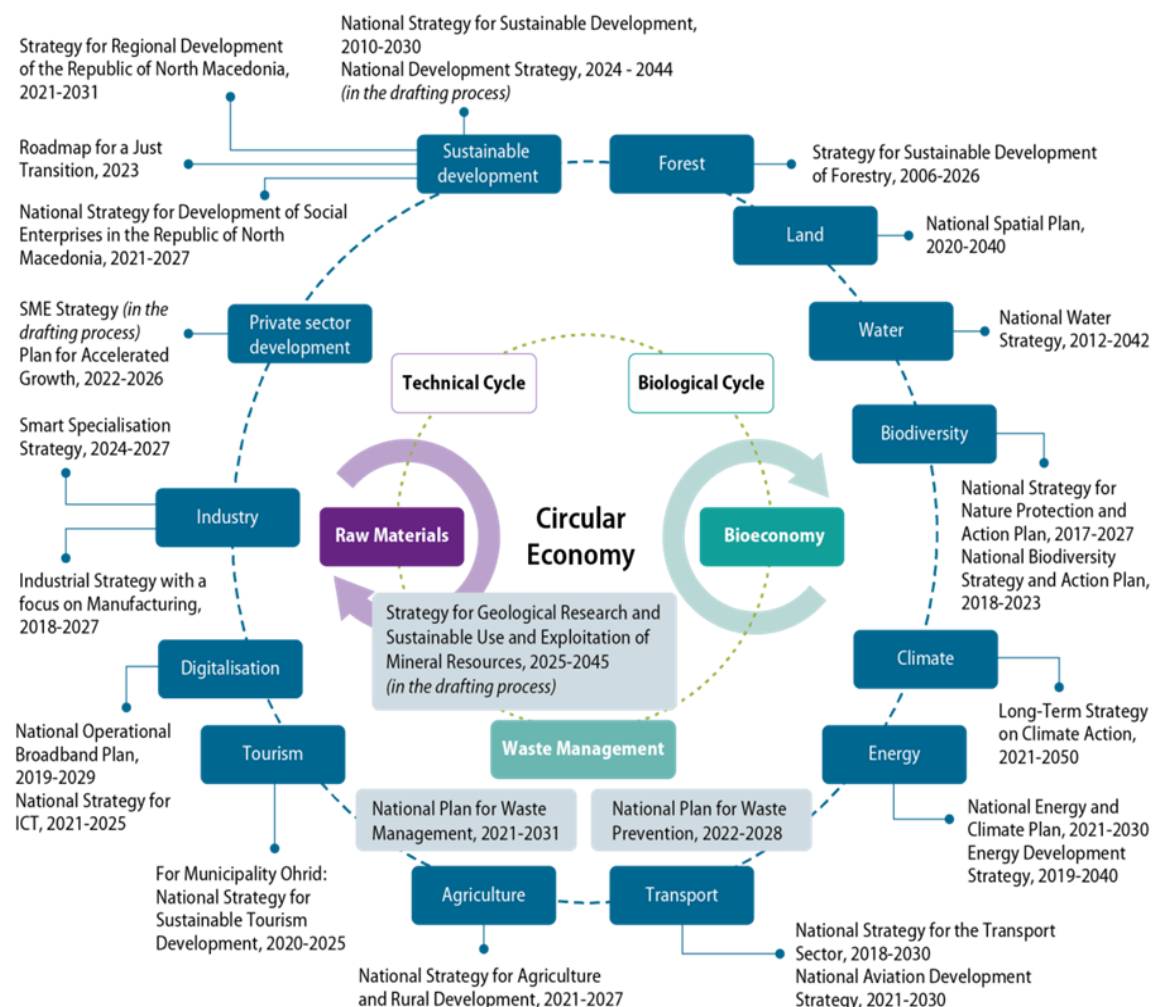
By combining CE initiatives with energy decarbonization strategies, RNM can accelerate its climate commitments, strengthen economic resilience, and establish itself as a leader in sustainable development within the Western Balkans.

3. Institutional Framework for the Circular Economy in the Republic of North Macedonia

The transition to a CE in RNM has been gradually progressing, yet there is no comprehensive policy framework to guide this transformation effectively. Various initiatives and regulations contribute to CE objectives, but these efforts remain fragmented, primarily driven by international organizations, civil society, and academia. The absence of a dedicated CE strategy limits the efficiency of ongoing initiatives and results in gaps in implementation and long-term planning (OECD, 2023).

Figure 1. illustrates the policy framework supporting CE initiatives in RNM, highlighting the institutions involved in policy development and implementation.

Figure 1. Policy Framework for the circular economy in the Republic of North Macedonia



Source: OECD (2023), A Roadmap towards Circular Economy of North Macedonia, p. 40

Several government institutions play a crucial role in shaping CE policies. The Ministry of Economy, the Ministry of Environment and Physical Planning, the Ministry of Finance, the Ministry of Agriculture, Forestry and Water Management, the Ministry of Transport and Communication, and the Ministry of Local Self-Government are among the key entities responsible for policy development and execution. These ministries oversee various aspects of environmental sustainability, waste management, economic development, and infrastructure, all of which are critical for fostering CE principles (European Commission, 2023).

Beyond the central government, other institutions contribute to the promotion of CE. The Agency for Promotion of Entrepreneurship of RNM (APPRM) and the Fund for Innovation and Technological Development play an increasing role in supporting businesses through financial and technical assistance, particularly for enterprises implementing circular business models. Additionally, the State Statistical Office (MAKSTAT) is instrumental in collecting and analysing data that informs decision-making and measures progress in CE initiatives.

Despite the involvement of multiple institutions, the legal and policy framework in RNM does not yet provide a strong foundation for a full-scale transition to a CE. The country lacks an overarching environmental policy that integrates CE principles into national development strategies. However, a step forward was taken with the adoption of the Long-term Strategy on Climate Action in 2021, which includes provisions for fostering circularity in various sectors. While this strategy, alongside several sectoral policies, indirectly supports CE objectives, it lacks a unified and structured approach, resulting in inconsistencies in implementation (World Bank, 2022).

Existing policies related to the CE in RNM can be categorized into two groups. The first includes core policies that directly reference CE principles, such as resource efficiency and waste minimization. The second consists of supporting policies that contribute to sustainability but do not explicitly integrate CE measures. These policies address themes such as waste management, green infrastructure, and climate action. However, weak institutional coordination and the lack of a dedicated regulatory framework hinder the effective implementation of these policies.

RNM needs a clear, integrated CE strategy aligned with EU directives. Consolidating policies, strengthening regulations, enhancing financial incentives, and improving data collection will support circular business transitions. Greater collaboration among government, businesses, and civil society is key to advancing circular initiatives. (EEA, 2023).

The successful transition to a CE in RNM depends on a more cohesive institutional and policy approach. While existing initiatives provide a foundation for progress, significant improvements in policy design and governance mechanisms are necessary to accelerate implementation. Establishing a comprehensive framework that integrates environmental sustainability, economic incentives, and regulatory measures will be crucial for achieving long-term success in CE adoption. By addressing these gaps, RNM can position itself as a regional leader in CE practices and enhance its economic and environmental resilience in alignment with EU sustainability goals.

4. Policy recommendations and strategic actions for the circular economy in the Republic of North Macedonia

RNM is making progress toward a CE, but the transition remains slow due to fragmented policies, financial constraints, and a lack of coordination among key institutions (OECD, 2023). While various initiatives have been introduced, a more structured and integrated approach is needed to drive meaningful change.

One of the biggest challenges is the lack of a dedicated national strategy for the CE. To move forward, RNM should develop a Circular Economy Action Plan that sets clear targets for waste reduction, recycling, and resource efficiency. This plan should not only introduce regulations but also provide practical guidelines for industries to adopt circular practices. (World Bank, 2022). Strengthening regulations related to waste prevention and extended producer responsibility will also help enforce CE measures.

Institutional coordination is essential for better governance and policy implementation. Establishing a National Circular Economy Coordination Body could improve cooperation between government ministries, municipalities, and businesses. Local governments need more

funding and technical support to enhance waste management, while stronger public-private partnerships could encourage investment in circular initiatives. A Circular Economy Advisory Board, with experts from government, business, and academia, could provide policy guidance and monitor progress to ensure long-term success (European Commission, 2023).

Financial constraints remain a major barrier, particularly for small and medium-sized enterprises looking to adopt circular business models (ICT, 2021). The government should create a Circular Economy Investment Fund to offer grants and low-interest loans for businesses implementing sustainable practices. Tax incentives for companies adopting eco-friendly production methods, along with eco-taxation policies discouraging wasteful practices, would further encourage investment in sustainability (Järvinen & Sinervo, 2020). Also, expanding access to EU funding would provide much-needed financial support for large-scale projects.

RNM still relies heavily on landfilling, and to reduce this, investment in waste management infrastructure is needed. Improving waste collection and sorting systems, expanding recycling programs, and implementing waste-to-energy solutions could help manage waste more effectively while also generating renewable energy. Municipalities should introduce mandatory waste separation programs, making it easier for businesses and households to recycle effectively (European Commission, 2023). Expanding producer responsibility programs, where manufacturers take back and recycle their own products, would also support waste reduction efforts.

Encouraging businesses to adopt circular models is another key priority. Providing financial incentives, research grants, and startup funding could help companies develop new solutions for waste reduction and sustainable production. Promoting leasing and sharing business models, as well as fostering industrial symbiosis where industries exchange and reuse materials instead of discarding them, would contribute to more efficient resource use (Zero Waste Scotland, 2020).

Raising public awareness and consumer engagement is key to successful CE policies. Educational system should integrate CE education, and national campaigns can promote recycling, responsible purchasing, and repair initiatives. Also, a national ecolabeling system would help consumers choose sustainable products (EEA, 2023).

In order to obtain implementable strategies and effective regulations, a National Circular Economy Monitoring System is essential. This will help to track progress, analysing waste and recycling data, and identifying areas for improvement (World Bank, 2023). Additionally, businesses should report sustainability efforts to ensure transparency and accountability (European Commission, 2023).

Finally, international cooperation is another important element in accelerating CE efforts. RNM should strengthen its ties with EU institutions, the OECD, and UN programs to leverage their expertise and financial support. Participating in regional partnerships with neighbouring countries could help exchange best practices and improve CE implementation (UNDP, 2023). Aligning with the EU Green Deal and European CE directives would also open up new opportunities for investment and innovation in sustainable industries.

Conclusion

The transition towards a CE in RNM brings both challenges and opportunities. This transition is not only a response to pressing environmental concerns but also a chance to foster economic growth. As part of its EU integration efforts, the country is aligning its policies with European sustainability frameworks, including the EU Green Deal and the Circular Economy Action Plan.

While some progress has been made, gaps in policy enforcement, financial support, and institutional coordination continue to slow the country's efforts. Developing a national Circular Economy Action Plan with clear targets for waste reduction, resource efficiency, and sustainable industry practices will be essential to moving forward. Strengthening financial incentives, improving waste management infrastructure, and fostering collaboration between public and private sectors will also play a crucial role in advancing CE initiatives.

Raising public awareness and encouraging consumer participation is equally important. Education programs, national awareness campaigns, and clear ecolabeling systems can help businesses and individuals embrace more sustainable consumption practices. Additionally, improving data collection and monitoring mechanisms will allow policymakers to refine strategies and track progress effectively.

International cooperation remains a key driver of CE progress. Aligning policies with EU standards, participating in regional sustainability initiatives, and securing financial and technical support from global institutions will help RNM accelerate its transition toward a resource-efficient and low-carbon economy. Implementing these strategic actions will not only enhance environmental sustainability but also strengthen economic resilience and improve overall quality of life, positioning RNM as a leader in CE development within the Western Balkans.

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THE EVOLVING LANDSCAPE OF ESG RATINGS: A CRITICAL EXAMINATION OF THEIR ROLE IN PROMOTING SUSTAINABILITY

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Abstract: *Environmental, Social, and Governance (ESG) metrics have become increasingly influential in shaping corporate sustainability strategies, influencing firm valuation, and guiding investor decisions. This paper synthesizes insights from a range of academic studies focusing on ESG indicators, ratings, and their impact on performance, aiming to provide a comprehensive analysis of the role of ESG frameworks in fostering corporate sustainability and promoting a circular economy.² By examining the theoretical underpinnings and empirical evidence, this work underscores the potential of robust ESG practices to drive corporate sustainability, societal progress, and the advancement of circular economy principles. The study specifically investigates the impact of the social pillar of ESG practices on organizational sustainability through a systematic literature review. While the analysis reveals a growing investor interest in ESG, often driven by financial value, it also identifies a disproportionate focus on the environmental and governance pillars, with the social dimension, particularly concerning diversity and inclusion, receiving less attention. Significant gaps and a lack of academic consensus on the impact of ESG practices highlight the need for further research to enhance understanding and facilitate more effective implementation of ESG frameworks for improved organizational sustainability.*

Key words: ESG rating, circular economy, sustainability

JEL classification: Q010

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Introduction:

Recent global events, including natural disasters and the COVID-19 pandemic, have underscored a societal shift towards values and principles centered on sustainability. This shift is reflected in investment patterns and management practices within organizations that increasingly recognize sustainability as an intrinsic and essential business value, permeating all aspects of their operations. ESG frameworks play a crucial role in shaping organizational interactions with society, promoting respect for human rights and driving the strategic development of products, services, and solutions that benefit employees, consumers, and society at large.³

ESG principles are closely aligned with the UN's 17 Sustainable Development Goals (SDGs), reflecting practices for sustainable development that generate value within organizations.⁴ The SDGs, however, transcend organizational boundaries, representing global commitments from diverse actors, including governments, civil society, and businesses. ESG adoption is becoming fundamental as stakeholders, including collaborators, customers, and investors, prioritize engagement with companies that demonstrate a commitment not only to profit maximization but also to the sustainability and development of both their organizations and the planet.⁵ Despite the acknowledged importance of social issues, research indicates that the social pillar of ESG often receives less attention in corporate strategy, frequently limited to inclusion and diversity programs.⁶ This is a critical oversight, as human capital represents the true wealth of organizations, driving performance and profitability. Without a focus on people, the very existence of consumers, organizations, and even a viable environment is called into question.

This disparity in research focus across ESG pillars is a significant concern, with studies disproportionately concentrating on environmental, financial, and governance practices, while the social dimension, despite its crucial role, remains comparatively under-explored.⁷ The increasing urgency of environmental degradation, social inequality, and corporate governance failures has catalysed the adoption of ESG frameworks by businesses and investors. Since its inception in the early 2000s, ESG has evolved into a multifaceted metric that influences firm operations, stakeholder decisions, and investment outcomes. Developing a comprehensive set of indicators that accurately capture the full spectrum of sustainability efforts, balancing environmental, social, and governance concerns, presents a significant challenge. This limitation further complicates the use of such indicators as motivational tools for achieving sustainability goals. While extensive literature exists examining the significance of ESG ratings in various contexts, questions persist regarding their applicability and relevance across all business activities. This study, through a comprehensive literature review, aims to clarify the role of ESG ratings in promoting responsible corporate behaviour and their implications

³ <https://www.ibm.com/think/topics/esg-frameworks>

⁴ <https://globalwellnessinstitute.org/global-wellness-institute-blog/2024/09/13/supporting-un-17-sustainable-development-goals-sdgs-initiative-trends-for-2024/>

⁵ <https://www.undp.org/sdg-accelerator/business-and-sdgs>

⁶ <https://transformacy.co.uk/articles/why-the-social-and-governance-in-esg-are-just-as-important-as-the-environment#:~:text=Despite%20the%20importance%20of%20the,attention%20than%20the%20E%20pillar.>

⁷ Ribeiro do Amaral, Melissa & Willerding, Inara & Lapolli, Édis. (2023). ESG and sustainability: the impact of the pillar social: ESG e sustentabilidade: o impacto do pilar social. *Concilium*. 23. 186-199. 10.53660/CLM-1643-23J43.

across different sectors. Ultimately, the paper seeks to provide insights into how companies can better integrate ESG considerations into their operational strategies, thereby enhancing their contributions to sustainable development and societal well-being.⁸

As the importance of human rights in the workplace gains prominence, companies are compelled to evaluate workforce rights and the social impact of their operations on local communities and nations.⁹ Effectively managing both social responsibility and sustainable business practices has become a cornerstone of corporate governance. Divergence in ESG ratings is primarily attributable to variations in the metrics and data employed by different rating agencies, with measurement divergence being the key contributing factor. This disagreement extends beyond mere definitions and reflects fundamental differences in data assessment methodologies. This divergence highlights the critical need for careful consideration of the validity of data and metrics used by researchers and firms relying on ESG ratings. To mitigate the impact of rating divergence, companies should proactively engage with rating agencies to establish appropriate metrics, ensure data transparency and accessibility, and strive for greater transparency in rating methodologies.¹⁰

1. Theoretical Framework of ESG Indicators and Ratings

The Earth faces unprecedented climate and social challenges, with scientific evidence on climate change becoming increasingly alarming¹¹. As the recognition grows that these challenges originate from the industrial era, there is a growing demand to transform the capitalist system to acknowledge and address these critical issues. Academics, managers, and investors require a framework for evaluating businesses across diverse criteria and classifying them as socially responsible. The process of evaluating climate and social issues is complex. The measurement from each of the environmental, social, and governance pillars is aggregated into ESG scores, providing a single metric that represents organizational performance on the underlying issues. Scholars have adopted ESG scores as a tool for measuring sustainability or evaluating a business's consideration of ESG factors.¹²

Private commercial firms, serving portfolio managers and other investors, utilize both tangible and intangible data to construct ESG scores, generating data that meets investor needs. Organizations undergoing ESG scoring or updates employ self-reporting metrics, which are then audited by independent firms. The growing popularity of ESG scores stems from the expectation that responsible businesses will thrive in the future, based on the historical performance of responsible investment strategies. These scores also provide a mechanism for differentiating between responsible and irresponsible businesses, highlighting those that are

⁸ Li, Duruo. (2025). The Impact of ESG Ratings on Corporate Social Responsibility Across Regions and Industries. *Advances in Economics, Management and Political Sciences*. 151. 161-167. 10.54254/2754-1169/2024.19421.

⁹ <https://www.ilo.org/resource/other/ilo-helpdesk-business-and-labour-dimension-human-rights-due-diligence>

¹⁰ <https://www.iriscarbon.com/key-findings-from-a-study-on-the-divergence-of-esg-ratings/>

¹¹ <https://science.nasa.gov/climate-change/evidence/#:~:text=There%20is%20unequivocal%20evidence%20that,activity%20is%20the%20principal%20cause.>

¹² Clément, Alexandre, Élisabeth Robinot, and Léo Trespeuch. 2022. "Improving ESG Scores with Sustainability Concepts" *Sustainability* 14, no. 20: 13154. <https://doi.org/10.3390/su142013154>

actively addressing ESG challenges. Primarily, ESG scores represent a reduction in long-term investment risk by mitigating the potential negative impacts of global warming and other environmental or social issues on profitability.¹³

In recent decades, ESG has garnered significant attention from researchers, governments, and the corporate sector globally, following guidelines from international organizations like the United Nations.¹⁴ The social pillar of ESG, however, has received less attention in scientific and policy literature compared to the environmental and governance pillars. This disparity is attributed to an approach that prioritizes reconciling environmental and economic concerns. Fundamental concepts in sustainability, ESG performance, and disclosure relate to how companies manage their environmental, governance, and social obligations towards stakeholders. It is important to recognize that these concepts are distinct from one another.¹⁵

Another challenge lies in the nature of ESG data. The environmental, social, and governance dimensions are inherently different. While environmental data tend to be more quantitative and standardized, social and governance data are often qualitative and rooted in social sciences, varying across nations and cultures. The increasing investor focus on financial value has further fuelled the growing interest in ESG data. Organizations are motivated to improve ESG performance when they are financially rewarded, as evidenced by the significant positive correlation between ESG and corporate profitability.¹⁶

ESG ratings assess the sustainability profile of a company or financial instrument by analysing its societal and environmental impact, as well as its exposure to sustainability-related risks. These ratings play an increasingly important role in shaping capital markets and building investor confidence in sustainable investment products.¹⁷ New regulations aim to enhance the reliability and comparability of ESG ratings by improving the transparency and integrity of rating providers' operations and addressing potential conflicts of interest.

ESG ratings are a type of score assigned to a company by rating agencies, evaluating performance across three key areas: Environmental (impact on the environment), Social (treatment of employees, suppliers, and communities), and Governance (management structure, leadership, and board diversity). ESG ratings offer investors a simplified way to incorporate sustainability factors into investment decisions. Traditional financial metrics do not always capture long-term risks and opportunities related to environmental and social issues. ESG ratings help bridge this gap. While ESG ratings are a relatively new concept, and

¹³ Ibidem

¹⁴[https://scc-ccn.ca/resources/news/international-guidance-launched-support-organizations-navigating-esg-challenges#:~:text=With%20ESG%20regulations%20reportedly%20having,Directive%20\(CSRD\)%2C%20the%20UK's](https://scc-ccn.ca/resources/news/international-guidance-launched-support-organizations-navigating-esg-challenges#:~:text=With%20ESG%20regulations%20reportedly%20having,Directive%20(CSRD)%2C%20the%20UK's)

¹⁵ Ribeiro do Amaral, Melissa & Willerding, Inara & Lapolli, Édís. (2023). ESG and sustainability: the impact of the pillar social: ESG e sustentabilidade: o impacto do pilar social. Concilium. 23. 186-199. 10.53660/CLM-1643-23J43.

¹⁶ Li Qingwen, Tang Waifan, Li Zhaobin, "ESG systems and financial performance in industries with significant environmental impact: a comprehensive analysis", *Frontiers in Sustainability*, Vol 5, 2024, <https://www.frontiersin.org/journals/sustainability/articles/10.3389/frsus.2024.1454822> DOI=10.3389/frsus.2024.1454822;

¹⁷<https://plana.earth/academy/esg-rating#:~:text=and%20ethical%20practices,-,A%20clear%20definition%20of%20ESG%20rating,and%20governance%20risks%20and%20opportunities.>

challenges remain, such as the lack of standardized reporting practices, their importance in sustainable investing is expected to grow.¹⁸

Under new regulations, EU-based ESG rating providers must be authorized and supervised by the European Securities and Markets Authority (ESMA). They are required to meet transparency standards, particularly regarding methodologies and information sources. Non-EU providers must have their ratings endorsed by an EU-authorized provider, meet specific recognition criteria, or be included in the EU registry of ESG rating providers through an equivalence decision. To prevent conflicts of interest, regulations mandate a clear separation of business functions and activities.¹⁹

As sustainable investing gains momentum, ESG ratings are becoming increasingly important for investors and issuers, attracting attention from global media. ESG risk ratings are the most common, measuring entities' exposure to and management of ESG risks. Examples include ratings from MSCI, Sustainalytics, S&P, and FTSE Russell. ESG impact ratings, conversely, measure entities' impact on ESG factors.²⁰ The distinction between risk and impact ratings can be subtle, as they often utilize comparable methodologies and similar metrics. ESG ratings can be backward-looking or forward-looking, depending on their objectives. Most ESG ratings cover corporate issuers, while some providers also rate local governments or countries.²¹

A credit rating is an opinion on the creditworthiness of an entity or instrument based on a ranking system of rating categories. It measures creditworthiness derived from summarizing and expressing data, based solely on a pre-established statistical system or model. In the ESG context, no such distinction exists between ratings and scores, and current ESG data limitations necessitate some form of qualitative input for both. Unlike credit ratings, which focus solely on financial risk, ESG rating systems capture non-financial aspects of corporate performance.²²

Early ESG frameworks primarily focused on environmental factors, but growing awareness of social justice and governance issues expanded their scope. The shift from voluntary reporting to regulatory compliance marks a significant milestone in the evolution of ESG metrics, reflecting increasing societal expectations of corporate responsibility. Today, ESG indicators are pivotal in shaping not just investment decisions but also regulatory policies globally. The diverse range of ratings, rankings, and agencies contributes to the complexity and sometimes obscurity of ESG ratings. Report fatigue and a lack of transparency are two significant concerns. However, ESG ratings are beneficial for responsible investment and attract investors seeking sustainable perspectives. In well-functioning markets, portfolios with high ESG ratings tend to exhibit lower risk compared to non-ESG investments, although their reduced volatility

¹⁸ <https://www.pwc.com/gx/en/news-room/press-releases/2022/awm-revolution-2022-report.html>

¹⁹ <https://www.esma.europa.eu/it/informazioni-sullesma>

²⁰ <https://asuene.com/us/blog/ftse-russell-esg-rating-a-comprehensive-guide-to-sustainable-investment#:~:text=FTSE%20Russell%2C%20a%20subsidiary%20of,based%20on%20their%20sustainability%20and>

²¹ <https://inrate.com/blogs/esg-risk-ratings-vs-esg-impact-ratings/#:~:text=In%20contrast%2C%20ESG%20impact%20ratings,outcomes%2C%20regardless%20of%20the%20financial>

²² Ribeiro do Amaral, Melissa & Willerding, Inara & Lapolli, Édis. (2023). ESG and sustainability: the impact of the pillar social: ESG e sustentabilidade: o impacto do pilar social. Concilium. 23. 186-199. 10.53660/CLM-1643-23J43.

often results in lower returns. Increased awareness among users about the flaws in ESG ratings and rankings, coupled with companies sharing data on the resources consumed by this industry, could exert greater pressure on ESG initiatives to become more transparent and credible, potentially leading to standardized questionnaires and collaborative efforts. Ratings play a crucial role by establishing minimum standards and promoting best practices.

2. The Relationship and Impact of ESG on Sustainability

Sustainability is a broad term with multiple definitions. The theory of the three pillars of sustainability – environmental, social, and economic – is a commonly used framework in the literature.²³ This theory posits that sustainability is achieved through equilibrium among these three pillars. ESG metrics are employed to assess an organization's sustainability, and sustainability or ESG reports serve as powerful tools for disclosing information about environmental, social, and corporate governance practices. Several initiatives are underway to integrate sustainability goals into corporate reports, reflecting the need to monitor organizational impact and track progress toward sustainability targets. A company's profitability alone does not guarantee its long-term commercial sustainability, which can be significantly influenced by environmental and social scandals. Governments play a vital role in encouraging companies to meaningfully engage in ESG practices, shifting the perception of ESG from a mere sustainable label at an additional cost to an informational tool that promotes long-term sustainable development and continuous improvement in corporate profitability.²⁴

Unlike credit ratings, which focus solely on financial risk, ESG rating systems capture non-financial aspects of corporate performance. Early ESG frameworks primarily focused on environmental factors, but growing awareness of social justice and governance issues expanded their scope. The shift from voluntary reporting to regulatory compliance marks a significant milestone in the evolution of ESG metrics, reflecting increasing societal expectations of corporate responsibility. Today, ESG indicators are pivotal in shaping not just investment decisions but also regulatory policies globally. The diverse range of ratings, rankings, and agencies contributes to the complexity and sometimes obscurity of ESG ratings. Report fatigue and a lack of transparency are two significant concerns.²⁵ However, ESG ratings are beneficial for responsible investment and attract investors seeking sustainable perspectives. In well-functioning markets, portfolios with high ESG ratings tend to exhibit lower risk compared to non-ESG investments, although their reduced volatility often results in lower returns.²⁶ Increased awareness among users about the flaws in ESG ratings and rankings, coupled with companies sharing data on the resources consumed by this industry, could exert greater pressure on ESG initiatives to become more transparent and credible, potentially leading to standardized questionnaires and collaborative efforts. Ratings play a crucial role by establishing minimum standards and promoting best practices.

²³ <https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf>

²⁴ <https://www.globalreporting.org/>

²⁵ Passas, Ioannis. (2024). The Evolution of ESG: From CSR to ESG 2.0. Encyclopedia. 4. 1711-1720. 10.3390/encyclopedia4040112.

²⁶ Short, J. A., & Ndlovu, G. (2025). Environmental, social, and governance (ESG) scores and portfolio performance: evidence from South Africa. Journal of Applied Economics, 28(1). <https://doi.org/10.1080/15140326.2025.2464507>

Resource sustainability focuses on the impact of a process, considering its effects on the environment, natural resources, and society. Accurate measurement of sustainability can be challenging due to its complex nature and the combination of multiple elements. Sustainability measurements provide a quantitative assessment of a company's actions to protect its natural and social environment and are becoming increasingly widespread, enhancing usability and facilitating comparisons between companies. Different agencies produce ESG scores using varying methodologies. The most widely used ESG scores often originate from prominent financial analysts who also produce well-known stock indexes. Most of these agencies prioritize risk reduction for investors while providing valuable insights into businesses.

As early as 2011, when academic interest in ESG scores was emerging, researchers began questioning how these scores actually measured sustainability.²⁷ Studies have attempted to assess whether ESG rating agencies adequately consider sustainability issues. Unfortunately, while some effort is evident, these agencies do not always sufficiently recognize sustainability issues in the composition of their ESG scores. This highlights the need for developing a new measurement framework that adheres to ESG principles but aligns more closely with the objective of measuring the true level of sustainability within organizations.

A key challenge is that true sustainability is achieved over the long term. The problem lies in the inherent short-term focus of many aspects of management. The underlying notion of time in sustainability is essential when considering organizational sustainability. A long-term perspective is fundamental for breaking the short-termism cycle of merely appearing sustainable and achieving genuine, lasting sustainability.²⁸ Natural resources are finite, and ecosystems have limited capacities to absorb contaminants. Therefore, sustainability is possible only within these limited parameters. A robust sustainability measurement must consider the planet's limited capacity to produce resources and recycle by-products. This is perhaps the most critical reason why current ESG scores often fail to accurately measure sustainability. One way to globally evaluate resource sustainability is by assessing the global impact of pollution from human activities and natural resource extraction on a planetary scale.

The ecological footprint measure of resource sustainability is particularly compelling because it combines the planet's renewal rate with the impact of human consumption on the capital stock of natural resources. The flow-based sustainability measurement suggests that the net national product should incorporate natural resource stock in its calculation. The methodology for assessing the sustainability aspect of a score should make it difficult for those relying on traditional production methods involving the exploitation of scarce and non-renewable natural resources to achieve top scores.²⁹

Sustainability is not simply about performing actions that appear sustainable in the present. A sustainability measurement that considers temporality would be influenced by an organization's

²⁷ Clément, Alexandre, Élisabeth Robinot, and Léo Trespeuch. 2022. "Improving ESG Scores with Sustainability Concepts" *Sustainability* 14, no. 20: 13154. <https://doi.org/10.3390/su142013154>

²⁸ Haessler, Philipp. (2020). Strategic Decisions between Short-Term Profit and Sustainability. *Administrative Sciences*.

²⁹ <https://www.footprintnetwork.org/our-work/ecological-footprint/>

capacity to fulfil its goals and promises. This is closely linked to the concept of resource sustainability, which takes into account available natural resources and the environment's limits to absorb CO₂ emissions or filter water, for example. In contrast to current evaluations, temporality would explicitly moderate the impact of an organization's future ambitions for environmental or social improvement based on its demonstrated capacity to fulfil past goals and objectives.³⁰

Climate change is another leading global concern. Governments worldwide are seeking universal agreement and collaboration to maintain global temperature levels below 2°C above pre-industrial levels, ideally not exceeding 1.5°C. The target of determining this average global temperature and keeping it below 2°C is now established in policymakers' frameworks. The United Nations Framework Convention on Climate Change and subsequent conferences, including the one in Copenhagen, have been intensively working on this critical issue.³¹

Achieving the goal of limiting global temperature rise requires a shift to net-zero emissions by 2050, focusing on the reduction of greenhouse gas emissions. Efforts to address the global warming crisis have primarily concentrated on energy efficiency through a transition to renewable energy sources. However, this shift can only address approximately 55% of emissions originating from the energy sector. The remaining 45% stems from food production, manufacturing, garment production, and other everyday materials.³²

The current "take-make-waste" approach of the linear economy generates significant greenhouse gas emissions, is resource-intensive and heavily extractive, and exacerbates the climate crisis. The current climate crisis may require a fundamental transformation of current trends by shifting from the linear model of production and consumption to a circular economy model. The impacts of the climate crisis place an immense burden on environmental boundaries, including biodiversity loss. Indeed, with the worsening climate crisis, over a million species of plants and animals face the threat of extinction. Global GDP is heavily dependent on nature and the ecosystem services it provides. The current linear economy model highlights the complexity of the challenges facing future generations. Actions are urgently needed to address the increasing demand for raw materials that negatively impact nature and ecosystems. The circular economy (CE) has emerged as an alternative approach to the linear economy, transforming the way products are designed, produced, and consumed.

The CE offers a holistic model for addressing environmental degradation, overconsumption of natural resources, and waste generation. It fulfils the needs for tackling the climate change crisis by reducing GHG emissions across all economic sectors through actions that require emission reduction across value chains, maintaining energy in products, and sequestering soil carbon and the products we use. The circular economy is an economic system designed to

³⁰ Galpin, Timothy & Whittington, J. & Bell, Greg. (2015). Is your sustainability strategy sustainable? Creating a culture of sustainability. *Corporate Governance: The international journal of business in society*. 15. 1-17. 10.1108/CG-01-2013-0004.

³¹ <https://unfccc.int/>

³² <https://www.ipcc.ch/sr15/>

minimize waste and maximize resource utilization by extending the lifecycle of materials through recycling, reuse, refurbishment, and regenerative practices. Unlike the traditional "linear economy," the CE emphasizes closing the resource loop and reducing dependency on virgin materials.

The relationship between ESG performance and green innovation is reciprocal. High ESG scores can promote R&D investment in environmentally friendly technologies, leading to reduced resource dependency and enhanced operational efficiency. Strong governance structures amplify these benefits by ensuring effective resource allocation and strategic decision-making.

The environmental pillar of ESG directly aligns with CE goals by reducing resource extraction, minimizing waste, and lowering greenhouse gas emissions. Circular practices such as recycling and reuse can lower carbon footprints, aligning with ESG objectives to mitigate climate risks. CE's regenerative principles ensure the protection of natural ecosystems, resonating with ESG's focus on sustainable environmental management. The social pillar of ESG also finds strong connections with the CE. CE promotes labour-intensive processes like recycling and remanufacturing, creating employment opportunities, particularly in local economies.³³ Circular business models often involve local partnerships and community-based resource management, fostering stronger social ties and inclusivity. Reducing waste and pollution in a CE contributes to better public health, which aligns with the social responsibilities outlined in ESG. Finally, the governance pillar of ESG is reinforced by CE principles. Implementing circular practices often requires transparent supply chains and clear reporting mechanisms, strengthening governance. Many governments encourage CE through policy and regulation, and organizations adopting CE practices demonstrate compliance with governance norms. Companies embracing circularity often showcase forward-thinking leadership, aligning with ESG's emphasis on ethical business practices.

Research indicates that Asia and America exhibit higher ESG risks compared to European companies, which generally demonstrate lower ESG risk profiles.³⁴ At the industry level, sectors like transportation infrastructure and media, often considered low ESG risk, show significant differences from other sectors. The European Union has been a leader in implementing strict ESG regulations that influence investment activities, carbon markets, accountability, and disclosure, resulting in a sustainable global impact and paving the way for the "Brussels Effect"³⁵. Examples of such EU regulations include the Electronic Equipment Directive and the General Data Protection Regulation. Asia and South America have greater exposure to energy-intensive industries, placing them in a high-risk category. Additionally, the

³³ Shaheera Banu Z, V. Imala, "Integration of ESG principles: An initiative for transformation from Linear Economy to Circular Economy", *Theoretical and Applied Economics* Volume XXXI (2024), No. 2(639), Summer, pp. 183-196

³⁴ Pillai, Rekha & Islam, Md. Aminul & Sreejith, S. & Al-Malkawi, Husam-Aldin. (2024). Comparative analysis of environmental, social and governance (ESG) ratings: do sectors and regions differ?. *Journal of Management and Governance*. 1-41. 10.1007/s10997-023-09692-7.

³⁵ Alamillos, Rocío & de Mariz, Frederic. (2022). How Can European Regulation on ESG Impact Business Globally?. *Journal of Risk and Financial Management*. 15. 291. 10.3390/jrfm15070291.

USA is perceived to have minimal ESG disclosure requirements and limited demand from institutional investors, highlighting the absence of a strong stewardship code that would require institutional investors to incorporate ESG factors into their decision-making. This regulatory leniency may encourage companies to pursue unsustainable practices. Industries sensitive to ESG issues often relate to environment-related topics, including sustainable supply chains and environmental risks, which are mainly linked to sectors such as Energy, Utilities, and Materials, all of which have a substantial environmental footprint.

Conclusion

The integration of ESG and CE represents a paradigm shift in sustainability studies, challenging traditional approaches to economics and business strategy. In conclusion, ESG and the circular economy are mutually reinforcing frameworks that together drive systemic transformation toward sustainability. While ESG provides the evaluative lens, CE offers a practical roadmap for achieving long-term environmental, social, and economic resilience.

ESG ratings are vital tools for assessing firm performance, shaping investment decisions, and ensuring that companies adhere to sustainable and socially responsible practices. However, the impact of these ratings is not uniform across industries or regions, and their effectiveness varies based on factors such as climate risk management, corporate governance, and environmental practices. ESG ratings, while crucial in offering insights into corporate sustainability, reveal a divergence in how risks are assessed. Additionally, the regional context plays a crucial role in determining the significance of ESG ratings.

ESG scores, as they are currently constructed, function more as a risk score and are not designed to fully consider resource sustainability or an organization's overall impact on the world. ESG scores are best suited for evaluating the probability of an organization's future existence while mitigating investment risks that could arise from ESG-related issues. Nevertheless, scholars continue to utilize ESG scores to compare the sustainability of organizations against each other, often alongside other metrics, to make assumptions about the sustainability they represent. There are characteristics of sustainability theories that could be used to update ESG methodologies and more accurately reflect sustainability practices in their evaluations.

In conclusion, while ESG ratings are essential for evaluating firm performance and guiding investment decisions, their application is complex and varies significantly across industries and regions. By addressing discrepancies in rating methodologies and considering regional and industry-specific risk profiles, ESG ratings can become more robust tools for promoting sustainable business practices globally. Further research is needed to refine ESG metrics, particularly within the social dimension, and to develop more holistic frameworks that truly capture the long-term sustainability performance of organizations. This includes exploring the interplay between ESG and CE principles, as well as considering the temporal aspects of sustainability and the limitations of current measurement approaches. By addressing these

challenges, ESG frameworks can more effectively contribute to a future where business practices are aligned with the long-term health of the planet and its inhabitants.

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PRIORITY SECTORS FOR THE MACEDONIAN TRANSITION TO A CIRCULAR ECONOMY: STRATEGIC PATHWAYS FOR SUSTAINABLE TRANSFORMATION

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Abstract: *The circular economy (CE) offers a comprehensive framework for decoupling economic growth from resource use and environmental degradation. For the Republic of North Macedonia (RNM), transitioning to a CE is both an environmental necessity and an economic opportunity, aligned with the country's EU accession commitments and the Green Agenda for the Western Balkans. This paper¹ identifies five priority sectors with the greatest potential for transformation: construction; biomass and food; textiles; mining and metallurgy; and cultural and creative industries. The first four were identified in the OECD's Circular Economy Roadmap for North Macedonia based on four key criteria-economic importance, policy relevance, circularity potential, and decarbonisation potential, while the fifth sector, cultural and creative industries, is introduced here as an emerging priority following further analysis. Beyond identifying these sectors, the paper outlines strategic implications, explores cross-sectoral synergies, and proposes targeted policy measures to support their transition. By focusing on these sectors and fostering coordinated action, the analysis aims to guide governance, policy design, and investment toward areas where the CE transition can deliver the most significant economic, social, and environmental benefits for the Republic of North Macedonia.*

Keywords: Circular economy, Republic of North Macedonia, sectoral prioritisation; sustainable development; policy recommendations

JEL Classification: Q01, Q56, O13, O44, L52

Introduction

The concept of the CE has emerged globally as a response to the unsustainability of the linear “take-make-dispose” economic model, which has led to overexploitation of natural resources, environmental degradation, and increased climate risks (Ellen MacArthur Foundation, 2017, Kirchherr, Reike and Hekkert, 2017). By promoting resource efficiency, waste prevention, and closed-loop systems, the CE decouples economic growth from intensive resource use, supporting long-term economic resilience. While the CE concept spans the entire

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economy, effective implementation requires targeted prioritisation (Salvatori, Holstein and Böhme, 2019). Focusing on sectors with the highest potential for transformation enables policymakers to direct resources, design relevant policy interventions, and mobilise stakeholders where the impact will be greatest. International experience shows that strategic sectoral prioritisation is a common feature of successful CE national roadmaps, allowing for more efficient investment allocation and stronger policy coherence (OECD, 2024). In RNM, the prioritisation of sectors has been informed in large part by the OECD's Circular Economy Roadmap for North Macedonia, which identified four priority sectors-construction; biomass and food; textiles; and mining and metallurgy, using four key criteria: economic importance, policy relevance, circularity potential, and decarbonisation potential (OECD, 2024). Building on these findings, this paper adds cultural and creative industries as a fifth priority sector, reflecting its emerging role in promoting sustainable production and consumption patterns and influencing consumer behaviour. Alongside sectoral identification, the paper examines strategic implications, explores cross-sectoral synergies, and proposes targeted policy recommendations for CE transition in the country.

1. METHODOLOGY FOR SECTOR PRIORITISATION

The identification of priority sectors for RNM's transition to a CE builds on the results of the OECD's Circular Economy Roadmap for North Macedonia (OECD, 2024), which applied a CE diagnostic framework combining quantitative indicators with qualitative policy considerations to ensure sector prioritisation reflects both domestic realities and international best practices. In the OECD roadmap, four sectors: construction; biomass and food; textiles; and mining and metallurgy, were prioritised using four key criteria:

- Economic importance-measured through indicators such as gross value added (GVA), contribution to national GDP, employment levels, and export potential. Sectors with significant economic weight are more likely to deliver substantial CE benefits when targeted for transformation (European Commission, 2020).
- Policy relevance-alignment with existing national development strategies, EU accession requirements, and sector-specific regulatory frameworks. This ensures that CE priorities are embedded in broader economic, industrial, and environmental policies (Salvatori, Holstein and Böhme, 2019).
- Circularity potential-the extent to which sectors can adopt CE strategies such as eco-design, reuse, repair, remanufacturing, recycling, industrial symbiosis, and resource recovery (Ellen MacArthur Foundation, 2015; UNEP, 2019). This includes potential for innovation, substitution of virgin resources, and extension of product lifecycles.
- Decarbonisation potential, the capacity of sectors to reduce greenhouse gas (GHG) emissions through circular interventions, contributing to climate targets under the Paris Agreement and the Green Agenda for the Western Balkans (European Environment Agency, 2022).

This paper retains these four criteria as the analytical foundation but expands the scope by introducing a fifth sector-cultural and creative industries, identified through supplementary

analysis. This addition reflects the sector's growing role in shaping sustainable production and consumption patterns, its capacity to influence societal values, and its potential for integrating circular principles in design, manufacturing, and cultural heritage preservation.

The analysis draws on multiple sources, including national statistics (State Statistical Office of North Macedonia, 2023), EU datasets (Eurostat, 2023), international CE reports (OECD, 2024; Ellen MacArthur Foundation, 2015), and sectoral studies. Quantitative data on resource flows, energy use, and waste generation were combined with qualitative assessments of technological readiness, regulatory feasibility, and market dynamics. Where available, stakeholder perspectives from government agencies, industry representatives, and civil society organisations were incorporated to provide additional insights into sector-specific challenges, investment barriers, and potential synergies.

This combined approach ensures that the identified sectors not only reflect the OECD's evidence-based prioritisation but also integrate emerging opportunities and national strategic considerations, strengthening the overall basis for targeted policy interventions. Additionally, these sectors combine high economic significance with strong potential for circularity and decarbonisation, while also aligning with the country's EU integration commitments and long-term sustainable development objectives.

2. PRIORITY SECTORS FOR MACEDONIAN CIRCULAR ECONOMY TRANSITION

The combined approach in the paper in the process of identifying five priority sectors not only reflect the OECD's evidence-based prioritisation but also integrate emerging opportunities and national strategic considerations, strengthening the overall basis for targeted policy interventions. Additionally, these sectors combine high economic significance with strong potential for circularity and decarbonisation, while also aligning with the country's EU integration commitments and long-term sustainable development objectives.

2.1 Construction Sector

The construction sector is both a major economic driver and a significant contributor to environmental pressures. It generates around 5.5% of national GDP and employs approximately 5% of the workforce, while globally construction and demolition activities account for roughly one-third of total waste. In RNM, construction is closely integrated with the mining and metallurgy sectors, as well as the domestic manufacturing of cement, steel, and other building materials (OECD, 2024). Circular opportunities in this sector are considerable. These include substituting primary resources with secondary raw materials from demolition waste, using locally sourced renewable materials such as sustainably harvested timber (European Commission, 2015), and designing buildings for adaptability, modularity, and ease of disassembly. Expanding selective demolition practices can help recover high-value components like metals, timber, and fixtures for reuse (OECD, 2024). Additionally, establishing functioning markets for recycled aggregates and enforcing quality standards would facilitate wider adoption of secondary products (Nadazdi, Naunovic and Ivanisevic, 2022). Public procurement policies integrating CE criteria, such as mandatory recycled content or

lifecycle assessments, can serve as a powerful catalyst for systemic change. The sector's transformation could also be supported by capacity-building for architects, engineers, and contractors on circular construction techniques. The OECD roadmap highlights construction as a sector with strong regulatory leverage, and building professional capacity among architects, engineers, and contractors in circular techniques is essential to accelerate transformation.

2.2 Biomass and Food Sector

Agriculture, forestry, and food processing remain pillars of Macedonian economy, employing a significant share of the rural population and contributing substantially to exports (OECD, 2024). The country's diverse agro-climatic conditions enable the production of a variety of crops, livestock, and processed food products. However, inefficiencies along the supply chain led to substantial food loss and waste, while biomass residues often remain underutilised.

The CE potential lies in valorising agricultural and food-processing by-products into energy, materials, and soil-improving products. Key measures include reducing post-harvest losses through better storage, refrigeration, and logistics (FAO, 2019), converting organic waste into biogas, biofertilizers, and animal feed, and promoting regenerative agricultural practices such as crop rotation, cover cropping, and agroforestry to restore soil fertility and biodiversity (OECD, 2024). The forestry sector also presents opportunities to utilise wood residues for bio-based products and sustainable energy. Integration with the EU Bioeconomy Strategy could open access to funding and technological innovation (European Commission, 2018). For rural communities, these approaches can diversify income sources, enhance resilience to climate impacts, and reduce reliance on synthetic inputs. The analysis notes that biomass valorisation could also contribute directly to North Macedonian renewable energy targets, linking agricultural modernisation with decarbonisation efforts.

2.3 Textiles Sector

While representing a smaller share of GDP, Macedonian textile industry is a key export-oriented sector, heavily integrated into European fashion supply chains. Its environmental impact, however, is disproportionate to its size due to high water consumption, chemical use, and textile waste generation (Ellen MacArthur Foundation, 2017).

The transition towards circularity in textiles involves multiple strategies. These include designing garments for durability, reparability, and recyclability (European Environment Agency, 2022), scaling up take-back schemes and second-hand markets to extend product lifespans (WRAP, 2020), and investing in fibre-to-fibre recycling technologies capable of processing mixed and blended materials (Textile Exchange, 2021). Eco-labelling and certification (ISO, 2020) can provide consumers with transparency, strengthening trust in sustainable products. The sector's strong export focus makes alignment with EU sustainability regulations, such as the Ecodesign for Sustainable Products Regulation. From 2025 onwards, this Regulation will introduce binding requirements on durability, reparability, and recyclability for textiles placed on the EU market, making early adaptation by Macedonian

producers critical for maintaining access to export markets. Building capacity in sustainable design and manufacturing could enhance competitiveness, open access to niche high-value markets, and reduce environmental burdens. According to the OECD roadmap, capacity-building in sustainable design, production, and supply chain management is critical if Macedonian textile producers are to retain and expand their position in EU markets under tightening environmental standards.

2.4 Mining and Metallurgy Sector

Mining and metallurgy are foundational to the country's industrial economy, producing key inputs for construction, manufacturing, and export (OECD, 2024). Yet, they are resource and energy-intensive, with significant waste streams including tailings, slag, and dust emissions (European Commission, 2020).

Circular strategies in this sector include improving recovery of valuable by-products and secondary raw materials from mining waste (UNEP, 2019), adopting cleaner production technologies to improve resource efficiency (OECD, 2019), and establishing industrial symbiosis networks to exchange waste heat, water, and materials across facilities (Chertow, 2000). Given the sector's importance for export revenues, compliance with EU directives on waste management, industrial emissions, and resource efficiency will be essential. Developing expertise in environmental remediation and post-mining land restoration can also contribute to both ecological recovery and community benefits. In addition, given the EU's focus on securing critical raw materials, aligning domestic mining operations with responsible sourcing standards could enhance strategic relevance and investment attractiveness. The OECD (2024) emphasises that integrating environmental performance metrics into operational planning could help the sector align with EU environmental benchmarks while maintaining competitiveness. Best practices in environmental remediation, such as progressive rehabilitation of mined land, restoration of biodiversity, and water quality protection, can reduce long-term liabilities and improve community relations. Furthermore, given the EU's increasing focus on securing critical raw materials, aligning Macedonian mining outputs with this strategic supply priorities can enhance policy relevance and open new trade opportunities.

2.5 Cultural and Creative Industries

Identified in this paper through additional analysis beyond the OECD roadmap, the cultural and creative industries (CCIs) encompass architecture, design, arts, crafts, publishing, media, and rapidly growing digital creative sectors such as video games and multimedia production. They also include cultural heritage, performing arts, and other creative activities with a strong innovative capacity and close connections to multiple economic value chains (UNESCO, 2021). CCIs are vital to national identity, culture, and values, and their integration into the CE cannot be treated as a "bolt-on" or secondary priority. As Foster (2020) and UNESCO (2021) note, considering environmental sustainability as merely an additional agenda item weakens the holistic approach needed for CE transformation. Instead, culture and sustainability must be addressed together to create systemic change.

In RNM, the potential for CCIs to contribute to the CE is significant. These industries can shape consumer perceptions, inspire sustainable lifestyles, and raise awareness about climate change and resource use. However, they can also be resource-intensive, meaning they must undergo their own transformation to align with environmental and sustainability principles. The most recent available mapping of Macedonian CCIs, dating back to July 2009, found that the most represented sub-sectors were advertising (13.9%), publishing (12.6%), arts and crafts (10.9%), film (9.6%), fine arts (8.3%), contemporary art (7.8%), architecture (7.4%), and software (7%) (Petkovska, 2009). While outdated, these figures provide a baseline for understanding the sector's structure and highlight the need for updated data to guide future policy and investment.

From a CE perspective, CCIs offer multiple opportunities. Using recycled, upcycled, and bio-based materials in creative production incorporating modularity and disassembly into design processes, and embedding repair, reuse, and upcycling in artisan and craft practices (UNESCO, 2021) can significantly reduce resource use. Furthermore, the adaptive reuse of heritage buildings and the restoration of vacant or derelict properties can revitalise neighbourhoods, generate economic value, and contribute to environmental objectives (Foster, 2020). Cultural events, festivals, and media campaigns can serve as vehicles (Diana Boshkovska, Natasha Daniloska: Priority sectors for the Macedonian transition for public engagement, enabling CCIs to bridge the gap between technical CE solutions and societal adoption (European Commission, 2018).

Strategic integration with EU programmes such as Creative Europe, Horizon Europe, and the New European Bauhaus initiative could provide funding and technical support for CE-related creative projects. Cross-sector collaboration between CCIs and industries like construction, textiles, and tourism could generate innovative solutions-such as cultural events in restored heritage buildings, fashion collections from recycled fabrics, or public art installations made from industrial by-products.

Policymakers can amplify these impacts by providing targeted funding for sustainable creative projects, establishing innovation hubs for cross-sector collaboration, and integrating CE criteria into cultural grant programmes. In doing so, Macedonian CCIs can simultaneously advance environmental objectives, strengthen cultural heritage, and foster economic development.

3. POLICY RECOMMENDATIONS, STRATEGIC IMPLICATIONS, AND CROSS-SECTORAL SYNERGIES

The Macedonian transition to a CE requires a coherent policy framework, strong institutional capacity, and sustained engagement from both public and private stakeholders. Embedding CE principles into national strategies and legislation is a critical starting point (Daniloska and Boshkovska, 2025). This means that CE objectives should be integrated into the country's development plans, environmental regulations, and sectoral strategies, ensuring alignment with the EU Circular Economy Action Plan and related legislation, including waste, eco-design, and extended producer responsibility directives. Building on the five prioritised sectors, four from the OECD (2024) and one (cultural and creative industries) identified through this paper's supplementary analysis, policy integration must account for both

established and newly recognised sectoral priorities. Incorporating CE provisions into the Law on Waste Management (Ministry of Environment & Physical Planning of the RNM, 2011), the Industrial Strategy 2018-2027 (Ministry of economy of the RNM, 2018), and sector-specific development plans would provide legal certainty and send clear market signals, thereby encouraging investment in sustainable practices.

Economic incentives will play an important role in accelerating adoption by making circular practices financially viable. Tax reductions or exemptions for companies using secondary raw materials, subsidies or low-interest loans for investments in recycling infrastructure, and mandatory green public procurement (GPP) criteria could stimulate both supply and demand for circular products. In addition, specialised incentives should be tailored to sector-specific needs, such as support for selective demolition and recycled aggregate markets in construction, funding for advanced biomass-to-energy conversion facilities in the agri-food sector, or targeted grants for upcycling and adaptive reuse initiatives in cultural and creative industries. **Public sector leadership in procurement**, particularly in construction and infrastructure projects, can help establish stable markets for recycled materials and resource-efficient solutions.

Infrastructure development is a cornerstone of CE adoption and a prerequisite for scaling sector-specific initiatives. Modernising waste collection, sorting, and recycling facilities would improve recovery rates and material quality. Regional centres for processing construction and demolition waste could help divert large volumes of material from landfills, while investment in composting facilities and anaerobic digestion plants would create value from biomass and food waste. Expanding logistics hubs dedicated to textile reuse and repair could also boost circularity in the apparel sector. For mining and metallurgy, upgrading waste processing infrastructure, creating industrial symbiosis hubs, and improving the recovery of secondary raw materials can maximise the reuse of by-products across multiple industries.

Equally important is the **development of skills and awareness**. The successful shift towards a CE will require a workforce equipped with relevant technical knowledge, design capabilities, and business competencies. Incorporating CE concepts into vocational training and higher education, creating certification programmes for CE-related skills, and running nationwide awareness campaigns can help foster a culture of sustainable production and consumption. In the cultural and creative industries, capacity-building should include training in sustainable design methods, integration of circular thinking into creative curricula, adaptive reuse of heritage buildings, and circular business models for creative entrepreneurs, thereby enabling the sector to influence consumer mindsets across the economy.

Research, development, and innovation will underpin long-term transformation. Dedicated funding streams for innovation in circular design, material recovery technologies, and bio-based product development should be established. Collaboration between universities, research institutes, and the private sector could be incentivised through grants, innovation hubs, and cluster-based partnerships, enabling the creation of new value chains and business opportunities. Where relevant, R&D support should explicitly encourage cross-sector projects such as linking creative design with advanced textile re-cycling technologies, applying digital tools to optimise material flows in construction and metallurgy, or using immersive media from CCIs to visualise and promote circular solutions in other sectors.

Reliable data is equally essential for informed decision-making. Establishing a national CE monitoring framework aligned with Eurostat indicators would provide the necessary evidence base for tracking progress, assessing policy effectiveness, and adjusting measures over time. Transparent and consistent data on material flows, waste generation, and resource productivity would also help attract investors and inform business decisions. Given the lack of recent mapping for the cultural and creative industries, targeted data collection in this sector should be a priority, including its environmental footprint, economic contribution, and capacity to deliver circular solutions.

Maximising the benefits of the CE will also depend on **leveraging cross-sectoral synergies**. For instance, mining and metallurgy can provide by-products such as slag for use as aggregates in the construction sector, reducing the need for virgin materials. Organic waste from agriculture and food processing can be converted into bioenergy for industrial processes, including textiles and metallurgy. The cultural and creative industries can act as an accelerator of these synergies-transforming textile waste into high-quality upcycled products, promoting sustainable consumption patterns through cultural platforms, branding agri-food products with sustainability narratives, and showcasing adaptive reuse in architecture and urban regeneration projects. Similarly, architects and designers in the cultural and creative industries can incorporate reclaimed materials into building projects, showcasing the potential of circular design to enhance both functionality and aesthetics.

Harnessing these synergies will require platforms for cross-sector collaboration, underpinned by supportive policy incentives, active knowledge-sharing networks, and public–private partnerships. With strategic coordination and targeted action, RNM can create a significant and competitive circular economy that delivers long-term environmental, economic, and social benefits.

Conclusion

This paper has identified five priority sectors with the highest potential to accelerate the CE transition: four of these—construction; biomass and food; textiles; and mining and metallurgy, were highlighted in the OECD (2024) CE roadmap for North Macedonia, while the cultural and creative industries have been added through the present analysis as a new, strategically relevant priority sector.

By combining substantial economic weight, high circularity and decarbonisation potential, and strong policy relevance, these sectors can deliver transformative impacts if targeted through coherent policy, investment, and stakeholder engagement. The findings highlight that focusing on these sectors will not only address pressing environmental challenges such as waste generation, greenhouse gas emissions, and inefficient resource use, but also create new economic opportunities through innovation, job creation, and enhanced competitiveness in EU and global markets. For example, scaling up selective demolition and recycled aggregate markets in construction, valorising agricultural residues into bioenergy and bio-based products, implementing fibre-to-fibre recycling in textiles, adopting industrial symbiosis in metallurgy, and promoting sustainable design and adaptive reuse in CCIs can jointly reinforce the national CE transition.

A successful transition will depend on several enabling conditions: embedding CE principles into legislation and sectoral strategies; developing targeted economic incentives; modernising recycling and reuse infrastructure; building skills and awareness across industries; fostering research, development, and innovation; and establishing robust monitoring systems. Special emphasis should be placed on cross-sectoral synergies, where outputs from one sector, such as biomass residues, metallurgical by-products, or reclaimed textiles, can serve as inputs for another, maximising resource efficiency and value creation.

In conclusion, prioritising these five sectors provides a clear roadmap for action, enabling RNM to move from fragmented initiatives towards a coordinated, economy-wide CE strategy. By leveraging both the established OECD-identified sectors and the newly recognised potential of the cultural and creative industries, the country can align environmental objectives with socio-economic development, ensuring that the CE transition delivers lasting benefits for people, the economy, and the environment.

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THE USE OF AI AGENTS IN GREEN ECONOMY ANALYSIS: THE CASE OF THE MACEDONIAN ECONOMY

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Abstract: *The transition to a Green Economy is a critical imperative for the Western Balkans, particularly for North Macedonia, which faces significant environmental challenges, including high carbon intensity and reliance on fossil fuels. However, the first point of this transition is often the existence and reliability of datasets, limited technical capacity for forecasting, and data latency. This paper explores the transformative potential of Artificial Intelligence (AI) Agents—autonomous systems capable of analyzing Green Economy time series data. Specifically, the study¹ focusses on Greenhouse Gas (GHG) emissions from 1990 to 2019. Utilizing a framework built on Python (Pandas), LangChain, and the Ollama LLM (gpt-oss-20b), we deployed AI agents to perform both descriptive and predictive analytics. The results demonstrate that AI agents can successfully autonomously query historical data to identify critical low-emission periods and generate numeric forecasts for 2025 across six key sectors: Total Emissions, Energy, Industrial Processes, Agriculture, Forestry, and Waste. The study validates the hypothesis that AI agents can serve as robust tools for evidence-based climate governance, offering a pathway toward more adaptive and real-time environmental policy formulation.*

Keywords: AI Agents, Green Economy, Time Series Data, GHG Emissions, North Macedonia, Generative AI.

JEL Classification: Q01, Q54, Q56, C53, C55, O33, O13

INTRODUCTION

The transition to a Green Economy represents one of the most significant challenges and opportunities for North Macedonia as it expected to align with European standards and achieve net-zero emissions by the year 2050. The motivation for this research is based on the urgent need to address the country's high climate vulnerability and reliance on carbon-intensive energy sources. This critical environmental issue is currently treated without any sophisticated

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analytical tools and the difficulty of managing fragmented, non-standardized datasets. Therefore, the impact of successfully automating environmental analysis could be transformative, shifting the national strategy from reactive observation to proactive, evidence-based climate governance.

The scope of the work is specifically focused on the Macedonian economy, analyzing Greenhouse Gas (GHG) emissions across six key sectors such as total emissions, energy, industrial processes, agriculture, forestry, and waste over a historical period from 1990 to 2019. The research seeks to determine if autonomous AI agents can overcome these structural data barriers to provide accurate descriptive analytics and reliable future forecasts without the need for complex, manual statistical modeling.

To solve this problem, the study utilized an approach based on "Agentic" workflows, which differ significantly from traditional static software. The technical architecture involved loading official National Bank data into a Jupyter Lab environment and connecting it to the Ollama Large Language Model (LLM) using the LangChain library. This setup allowed the AI to autonomously perceive the digital environment, write its own Python code to manipulate the Pandas data frames, and validate its own outputs. The variables controlled included the six specific GHG emission categories, while the agent was tasked with ignoring irrelevant noise in the dataset to focus on identifying historical minimum and projecting future trends.

1. LITERATURE REVIEW AND THEORETICAL BACKGROUND

The environmental pattern of North Macedonia embodies a prime example of a transitional economy working towards satisfying strict international climate norms while dealing with their existing infrastructural base. From the extant literature, it has been observed time and again that the Western Balkans embody a region of "high climate vulnerability," which gets further exacerbated by their reliance on fossil fuel sources. As pointed out by international organizations such as the International Monetary Fund, it has been observed that the energy sector of North Macedonia still has a disproportionately high reliance on low-grade lignite coal (Ritchie, data and 2017).

However, the difficulty is not only physical or infrastructure related; it is, rather, informationally complex. To effectively develop and implement adaptation strategies, one would need exact and high-resolution information to simulate the effects of changes in policy. However, researchers and policymakers in this area have been faced with the phenomenon of a 'data gap,' which occurs when crucial information related to the environment is dispersed, outdated, or incongruent (Jonas *et al.*, 2019). In North Macedonia, information related to the environment is dispersed among different governmental ministries, such as Environment, Economy, and Transport, and is not machine-readable.

Thus, the "insufficient data and tools" situation presents a bottleneck for forecasting. In the absence of comprehensive and robust datasets, the technical ability to forecast is grossly impaired. Conventional econometric models employed in Green Economy assessments, like linear regression models and ARIMA models, depend on clean and formatted datasets. In the absence of comprehensive datasets, the "cost of analysis" becomes substantially high, as the analyst would spend most of their time manually cleaning the dataset instead of engaging in

strategic thinking. This paper asserts that overcoming this inefficiency in information is essential to effective adaptation to climate change (Jonas *et al.*, 2019).

To overcome these challenges, this study shifts focus away from conventional software approaches and explores the use of Artificial Intelligence (AI) Agents. In computer science and data analysis-related literature, an “agent” can be conceptualized as something different from an ordinary computer program or a statistical tool. We can define AI agents as autonomous systems that can perceive their digital environment, reason about how they can attain a certain goal, and act independently in pursuit of that goal. This definition corresponds to the 'Agentic' workflows that are being developed in the current state of Generative AI (Vinuesa *et al.*, no date).

2. METHODOLOGY IN DESIGN AND IMPLEMENTATION OF A SOVEREIGN AGENTIC AI SYSTEM FOR GREEN ECONOMY DATA INTEGRATION AND FORECASTING

This study establishes a rigorous methodological framework to demonstrate how AI agents can autonomously achieve complex analytics goals, specifically focusing on data collection, real-time validation, and the seamless integration of fragmented datasets. The core of this research is built upon the utilization of official Green Economy data provided by the National Bank of the Republic of North Macedonia. This dataset spans a critical thirty-year period from 1990 to 2019, offering a comprehensive historical view of the country's environmental trajectory. To ensure a holistic analysis, the study incorporates six distinct categories of Greenhouse Gas (GHG) emissions: total national emissions, energy sector output, industrial processes and product use, agriculture (excluding livestock), forestry and other land uses, and the waste sector. This multi-categorical approach allows for a granular assessment of where the most significant environmental challenges and opportunities lie within the Macedonian economy (Ragulina *et al.*, 2022).

The technical architecture of the study was designed to prioritize open-source flexibility and local processing capabilities. The data ingestion and preliminary cleaning processes were executed using the Pandas library within a Jupyter Lab environment, providing a robust foundation for data manipulation. To unlock the "agentic" capabilities, transforming the software from a passive tool into an active analyst—the study employed the LangChain library. LangChain serves as the orchestration layer, enabling the system to reason about data structures and execute code. Distinct from cloud-dependent models, this implementation was run entirely locally using Ollama to host the gpt-oss:20b model. This choice of a locally hosted, open-source Large Language Model (LLM) underscores the potential for sovereign, secure, and cost-effective AI deployments in government or academic settings where data privacy is paramount (Isachenko and Bhuiyan, 2024).

By keeping the processing loop local, the methodology mitigates latency and ensures that sensitive economic data remains within a controlled environment. To rigorously evaluate the efficacy of this agentic framework, the AI agents were subjected to a series of structured tests using predefined prompts designed to assess different cognitive and analytical capabilities. The first phase focused on descriptive analytics, challenging the agent with questions such as

"Which was the lowest variable value?" to test its ability to accurately retrieve and interpret historical facts from the dataset. The second phase as advanced to predictive analytics, requiring the agent to extrapolate future trends with prompts like "Please predict the value of the variable in 2025." This dual-phase testing strategy was critical for validating the central hypothesis: that AI agents are not merely text processors, but capable analytical engines that can be effectively applied to the specific, quantitative demands of Green Economy data analysis. Through this design, the methodology provides a replicable blueprint for deploying autonomous AI in environmental science (Isachenko and Bhuiyan, 2024).

3. RESULTS FOR EMPIRICAL VALIDATION AND PREDICTIVE CAPABILITY OF AGENTIC AI FRAMEWORKS IN GREEN ECONOMY EMISSIONS ANALYSIS

The primary objective of this study was to empirically validate the hypothesis that AI agents can serve as effective, autonomous tools for descriptive and predictive analysis of Green Economy data. The proposed AI agent framework met this objective, providing actionable, data-driven insights that bridge the gap between raw, fragmented datasets and strategic environmental governance. The experimental results, derived from a comprehensive analysis of Greenhouse Gas (GHG) emissions in North Macedonia from 1990 to 2019, clearly distinguish the capabilities of standard statistical software from the adaptive reasoning of agentic AI workflows.

In the phase of descriptive analysis, the performance of the AI agents was exemplary. When tasked with querying the historical dataset to identify critical turning points in the country's environmental history, the agents performed perfectly. They demonstrated an ability to navigate the temporal structure of the data frame without error, correctly answering every query regarding historical minimum values. For instance, the agent autonomously identified that the lowest total GHG emissions occurred in 2014, a crucial benchmark for evaluating current decarbonization efforts. Similarly, it pinpointed 2018 as the year with the lowest emissions in the energy sector and 1993 as the historical low for the waste sector. This level of precision confirms that AI agents possess the necessary "data literacy" to function as reliable assistants for historical auditing, capable of replacing manual data review processes that are often prone to human error.

The predictive analysis section of the study provided a more nuanced, but equally compelling set of results, particularly highlighting the differences in model behavior. The experiment utilized two distinct Large Language Models to power the agents: the cloud-based Google Gemini gemini-1.5-flash model and the locally hosted gpt-oss:20b model running via Ollama. This comparative approach revealed significant insights into how different AI architectures handle quantitative forecasting tasks.

When connected to the Google Gemini gemini-1.5-flash model via the API, the agent initially exhibited a learning curve. In the early iterations of the predictive tasks, the model struggled to provide perfectly "clean" numerical outputs immediately. Instead of simply returning a forecasted value, the agent would occasionally output the raw Python code blocks or lengthy explanations of its statistical methodology. However, a key finding of this study is the agent's

capacity for iterative learning. With each subsequent prompt and interaction, the Gemini-powered agent refined its outputs. It effectively "learned" the user's preference for concise numerical data, eventually presenting clear, actionable forecasts. Furthermore, in several instances, the agent went beyond the text-based prompt requirements and autonomously generated graphical visualizations of the emission trends. This emergent behavior—where the agent proactively visualizes data to aid human understanding—underscores the potential of cloud-based models to act as collaborative research partners rather than simple calculators.

In contrast, the tests conducted with the locally hosted gpt-oss:20b model demonstrated a different strength. There was a clear, immediate execution of tasks with this model. The local agent showed a high degree of reliability in following strict instruction formats, producing clean, direct numerical forecasts without the initial "noise" observed in the cloud-based interaction. This finding suggests that for sensitive government applications where data privacy and strict adherence to formatting are paramount, locally hosted open-source models may offer a robust alternative to commercial APIs.

Ultimately, both models converged on significant quantitative forecasts for the year 2025, offering a glimpse into North Macedonia's future environmental trajectory if current trends continue. The agents predicted that Total GHG emissions would reach approximately 13,322.42 Gigagrams of CO₂ equivalent in 2025. Breaking this down by sector, the agents forecasted Energy sector emissions to reach 7,779.34 Gg CO₂-eq, reaffirming the sector's dominance as the primary polluter. The Industrial Processes sector was forecasted at 722.35 Gg CO₂-eq, while the Waste sector showed a concerning upward trend with a prediction of 646.64 Gg CO₂-eq, significantly higher than its 1993 baseline. Interestingly, the agent predicted emissions for Forestry and Other Land Uses to be approximately 1.55 Gg CO₂-eq, a near-zero value that highlights the potential stabilization of land-use emissions.

These findings, while derived from a limited and predefined experimental set-up, indicate the immense potential of AI agents for future use in Green Economy analytics. The ability of the agent to move from simple descriptive retrieval to complex predictive modeling—and to do so while adapting its communication style through iteration—provides solid proof for the acceptance of the research hypothesis. The successful generation of specific, sector-level forecasts for 2025 validates that AI agents can be effectively used for descriptive and predictive analysis, offering a powerful new instrument for policymakers to visualize the future of the climate transition.

4. DISCUSSION AND POLICY IMPLICATIONS

Overall, the insights generated by AI agents can establish a significant data-support framework to strengthen evidence-based decision-making in the green economy transition. The implementation of this technology represents a fundamental departure from the traditional, static methods of environmental reporting that have historically constrained policymaking in the Western Balkans. By automating the complex processes of data retrieval, validation, and forecasting, AI agents create a robust digital infrastructure that empowers government institutions to operate with greater agility and precision. This data-support framework is particularly critical for North Macedonia, where the scarcity of technical resources and the

fragmentation of environmental datasets have often forced policymakers to rely on intuition or outdated reports rather than empirical reality.

This approach enables a transformative shift from reactive, periodic analysis toward proactive, continuous, and adaptive climate governance. In the current paradigm, environmental assessments are frequently retrospective, analyzing emissions data years after the pollution has occurred. This latency renders policy reactive, addressing problems only after they have entrenched themselves in the economy. In contrast, the AI agent framework demonstrated in this study facilitates continuous monitoring. By generating real-time insights and forward-looking forecasts, such as the specific sector-based predictions for the year 2025, agents allow policymakers to anticipate emission spikes before they happen. This predictive capability turns climate governance into a proactive discipline, where interventions in the energy or waste sectors can be deployed preemptively based on credible data trends rather than lagging indicators.

Furthermore, the adoption of autonomous analytics supports a more adaptive model of governance that is essential for navigating the uncertainties of climate change. As the agents demonstrated an ability to "learn" and refine their output through iteration, so too can the policy frameworks they support. An adaptive governance system driven by AI can rapidly adjust to new variables, whether they be economic shifts, changes in industrial output, or the introduction of new renewable energy sources. This creates a feedback loop where policy measures are constantly tested against the latest data, ensuring that the national strategy remains resilient and effective. For a developing economy like North Macedonia, this capacity to adapt quickly is a potent equalizer, allowing the state to maximize the impact of limited financial and administrative resources.

Ultimately, the integration of these intelligent systems is an essential step for North Macedonia to accelerate its green transition and achieve its net-zero emissions target by 2050. The path to decarbonization requires not just political will but granular, actionable intelligence. The ability to break down emissions forecasts by specific sectors, isolating the trajectory of industrial processes versus agriculture, for instance, allows for the design of targeted interventions that minimize economic disruption while maximizing environmental benefit. By delegating the heavy lifting of data processing to AI agents, human decision-makers are freed to focus on the strategic, ethical, and diplomatic aspects of the Green Deal, ensuring that the journey toward a sustainable future is both evidence-based and justified.

CONCLUSION

This paper presents an innovative approach to the descriptive and predictive analysis of green economy data, marking a significant departure from the manual and static methodologies that have traditionally defined environmental reporting in the Western Balkans. By deploying autonomous AI agents to interact with the emission datasets of North Macedonia, this research has successfully validated a new digital paradigm: one where intelligent system act as active collaborators in the research process rather than passive tools. The study confirms that Generative AI, when structured through agentic workflows, can bridge the gap between

complex raw data and actionable policy insights, offering a streamlined path to understanding historical trends and forecasting future scenarios (Ragulina *et al.*, 2022).

While experimental in nature, the study aims to demonstrate the potential of AI agents in this field rather than to provide definitive, unalterable results. The primary contribution of this work is not merely the specific numerical forecasts for 2025, but the validation of the underlying architecture. We have established a proof-of-concept that demonstrates how Large Language Models can be grounded in factual data to perform rigorous quantitative tasks. This finding highlights the considerable promise of this technology for future applications in green economy analysis, particularly for developing nations that face the dual challenge of urgent climate action and limited technical human capital. The agents proved that they could navigate the ambiguity of real-world data, correct their own errors through iteration, and deliver insights that are both statistically relevant and structurally sound (Vinuesa *et al.*).

Further advancements may involve the use of open prompts and enhanced configurations designed specifically for policy and research purposes. Future iterations of these agents could be engineered with domain-specific "personas" such as a "Policy Analyst Agent" or a "Risk Assessment Agent" each tuned to interpret data through the lens of specific government ministries or international standards. This would allow for a more nuanced exploration of the data, where users can ask complex, unstructured questions about the socio-economic impacts of decarbonization and receive comprehensive, multi-layered answers.

Crucially, the next phase of research must focus on integration with larger datasets or API-connected databases to support more comprehensive and scalable solutions, or with real time measurement data. The current study relied on static historical files; however, the true potential of AI agents lies in their ability to connect to live data streams. Future frameworks could integrate real-time energy grid data, live air quality readings, and economic indicators from international bodies like Eurostat or the World Bank. Such an interconnected ecosystem would allow for dynamic forecasting that updates instantly as new data becomes available. By scaling this kind of solution or consider its ideas to be integrate to national digital infrastructure, North Macedonia can secure the technological capabilities necessary to navigate the complexities of the green transition and meet its ambitious 2050 climate goals.

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TOWARDS A CIRCULAR ECONOMY: A COMPREHENSIVE REVIEW OF CIRCULAR BUSINESS MODELS

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Abstract:

The transition to a circular economy (CE) requires innovative business models that move beyond traditional linear practices. This paper systematically reviews Circular Business Models (CBMs) using the PRISMA methodology, analysing 42 peer-reviewed publications¹. Two complementary classification perspectives are identified: The Strategic Focus Classification (design, use, recovery-focused, and hybrid models) and the Operational Typology (product, service, resource, and design-innovation CBMs). Together, these frameworks clarify both the rationale for circularity and its practical implementation. Key findings highlight significant challenges, including regulatory gaps, high upfront costs, organizational resistance, and digital infrastructure needs. The review underscores the importance of standardized frameworks and cross-sectoral collaboration to advance CBM adoption and support sustainable economic transitions.

Keywords: Circular Business Models (CBMs), Circular Economy (CE), Sustainability, Systematic Literature Review PRISMA Methodology, Business Model Innovation

1 INTRODUCTION

The CE addresses the ecological and economic limitations of the linear model by promoting reuse, repair, remanufacturing, and recycling (Geissdoerfer et al., 2020). At its core are CBMs, which reshape value creation and capture to support resource circularity (Hofmann, 2019). Yet research on CBMs remains fragmented, with diverse definitions and approaches limiting clarity and adoption. While many earlier reviews have specific focus, this paper offers a broader synthesis that integrates strategic intent and operational architecture across sectors. It addresses this gap through a systematic literature review that traces the evolution of CBM definitions, synthesizes key conceptual categories, and introduces a dual classification, Strategic Focus and Operational Typology, that explains both the rationale for circularity and its implementation. The framework enables cross-sectoral comparison and offers a conceptual foundation for future CBM research and application.

2 MATERIALS AND METHODS

The literature search was conducted between April and May 2025, focusing on peer-reviewed articles published between 2010 and 2025. It was carried out across major scientific databases, including Google Scholar, Scopus, Web of Science, Copernicus, and EBSCO. The search strategy combined

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keywords such as “Circular Business Models”, “Circular Economy”, “Sustainability” and “Business Model Innovation”. The analysis focused on two objectives: (1) tracing the historical evolution and definitional variations of CBMs; and (2) classifying conceptual models based on strategic focus and operational characteristics. The selection and screening of publications followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a structured and transparent review process.

2.1 Sample

From 234 records initially identified, 9 were removed as duplicates or irrelevant. In title&abstract and full-text screening, 42 studies were excluded for superficial coverage of CBMs, 32 for addressing isolated sustainability topics, and 37 for being overly context or product-specific. The final sample included 42 publications offering conceptual or theoretical insights on CBMs. Thematic categories were derived inductively, based on their relevance to CBM theory and practice.

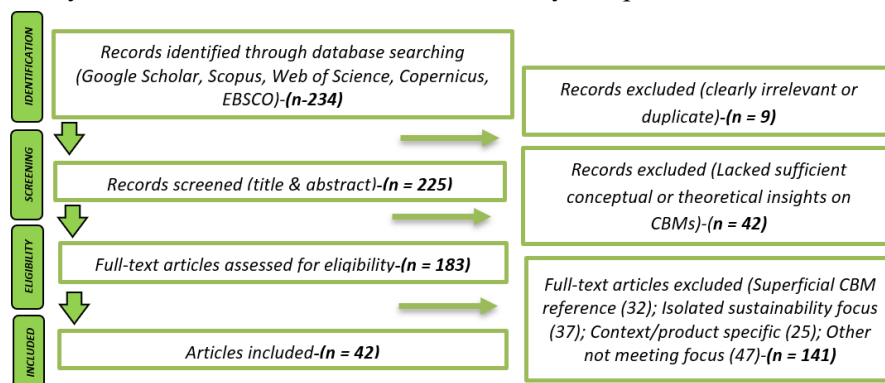


Figure 1: PRISMA DIAGRAM

(Limitation: Using specific keywords may have excluded studies addressing CBMs indirectly, though the sample remains sufficient for analyzing their evolution and strategic implications.)

3 RESULTS AND DISCUSSION

CBMs have evolved from early eco-innovation efforts into structured approaches supporting reuse, repair, remanufacturing, and recycling, which is essential for transitioning beyond the limitations of linear systems. (Zafar et al., 2021). This review identifies four dominant definitional categories, each aligned with distinct business model configurations. The resulting classification framework reflects recurring patterns across the analysed literature and is grounded in the following dominant definitional approaches:

- *Strategy-Oriented Definitions*-emphasize long-term competitiveness and value retention through closed-loop systems (Puglieri et al., 2022; Konietzko et al., 2020) and next-generation sustainable business models leveraging circular principles (Rosa et al., 2019).
- *Activity-Based Definitions*-emphasize actions like product-as-a-service and reverse logistics (Urbinati et al., 2017), with reverse logistics noted as a strong marketing strategy (Lahti et al., 2018; Guillén et al., 2023).
- *Value-Focused Definitions*-stress the shift from linear to shared or regenerative value (Bocken et al., 2018), with frameworks proposing CBMs that realign value creation to circular principles (Kirchherr et al., 2017).
- *Hybrid (or Holistic) Definitions*-provide integrated perspectives that transcend sector-specific models, supporting wider adoption of CE concepts (Sjödin et al., 2023). For example, a finance-marketing hybrid based on customer lifetime value shows how circular strategies can enhance market equity (Awan & Sroufe, 2022).

The variety of definitions reflects disciplinary differences: while engineering and environmental sciences focus on technical processes, business and management studies emphasize value configuration and strategic orientation. This disciplinary divergence has created challenges in forming a unified definition. However, several researchers (Kirchherr et al., 2023) advocate for hybrid approaches that integrate ecological, economic, and systemic dimensions.

The definitional review shaped the classification framework by revealing recurring patterns that conceptually distinguish strategic from operational CBM typologies.

The implementation of a viable business model is critical to achieving the goals of a CE. Literature on CBMs reveals a wide spectrum of approaches, generally focusing on strategic goals, value creation mechanisms, and business model components. Two complementary classification perspectives are identified: *Strategic Focus Classification* and *Operational Typology* based on business model (BM) architecture.

Strategic Focus Classification is based on the primary logic for achieving circularity, emphasizing distinct approaches to value creation, delivery, and capture:

- a) Design-Focused CBMs-rely on eco-design to extend lifecycles, reduce inputs, and enable modularity. Strategies include repair, reuse, remanufacturing, and recycling (Lüdeke-Freund et al., 2019). Key archetypes are design for longevity (Lee & Sicklinger, 2024), disassembly (Den Hollander et al., 2017; Rosa et al., 2019), and reuse (Schulte, 2013; Ferasso, 2020).
- b) Use-Focused CBMs-promote access over ownership through Product-Service Systems, leasing, and sharing platforms, reducing idle capacity (Yang et al., 2017; Loon, 2020).
- c) Recovery-Focused CBMs-close loops through remanufacturing, recycling, and take-back schemes, enhancing both cost efficiency and consumer participation (Schwanholz et al., 2020; Nußholz, 2018; De Keyser & Mathijs, 2023)
- d) Hybrid and Emerging CBMs-integrate design, use, and recovery logics, exemplified by emerging archetypes such as waste-based and platform-based start-ups (Marvin et al., 2019).

Operational Typology is based on BM Architecture and is focusing on business model elements such as value proposition, customer interface, and supply chain design:

- a) Product-Oriented CBMs-extend lifecycles through reuse and remanufacturing, common in electronics and machinery (Ertz et al., 2019; Whalen, 2019).
- b) Service-Oriented CBMs-emphasize access over ownership, particularly in mobility and fashion, via leasing and sharing models (Heyes et al., 2017; Coscieme et al., 2022).
- c) Resource-Oriented CBMs-focus on input substitution and industrial symbiosis in bio-based and agricultural sectors (Donner et al., 2020; Carraresi & Bröring, 2021)
- d) Design-Innovation CBMs-embed circularity at the design stage, enabling modularity and repair (Santa-Maria et al., 2022; Scholtysik et al., 2023).

Despite their potential, CBMs face persistent challenges: limited regulatory incentives (Fraccascia et al., 2019), high upfront costs and uncertain returns (Vermunt et al., 2019), organizational resistance to shifting from linear models (Linder & Williander 2015), and infrastructure demands for digital technologies such as IoT and analytics (Sjödén et al., 2023).

Together, the two classifications provide a holistic framework. The strategic perspective clarifies *why* circularity is pursued, while the operational perspective shows *how* it is implemented. This dual lens highlights both overarching logics and practical architectures, while the diversity of classifications

underscores the need for greater coherence and standardized frameworks to guide adoption (Frishammar & Parida, 2018). Strategically, CBMs range from incremental innovations that enhance efficiency and recycling, to transformational models that redesign entire value systems through systemic solutions such as closed-loop supply chains and cross-sectoral collaboration (Palmié et al., 2021; Averina et al., 2021). Their application spans firm-level strategies by reducing material dependency and meeting regulatory demands (Moggi & Dameri, 2021;), to broader initiatives like industrial symbiosis and circular ecosystems, reinforcing their role as drivers of sustainable transitions (Angelis, 2022; Geissdoerfer, 2022).

4 CONCLUSIONS

This review confirms that CBMs are central to advancing the circular economy by enabling extended product lifecycles, resource optimization, and material regeneration. Based on a PRISMA-guided synthesis of the literature, this paper introduces a dual typology, Strategic Focus and Operational Architecture, that clarifies both the intent and implementation of CBMs. This typology offers a conceptual framework for interpreting and applying CBMs across sectors, allowing organizations to align model selection with their specific goals and contexts. In doing so, it enhances the likelihood of reconciling ecological objectives with economic feasibility. Despite their promise, different CBM types face distinct implementation challenges. Strategic models often struggle with systemic inertia, misaligned incentives, and insufficient policy support, while operational models confront infrastructure demands, limited digital capabilities, and scaling difficulties. Understanding these barriers through the lens of typology enables more targeted, type-specific interventions-regulatory, financial, or technological. The proposed framework provides a structured approach for navigating the fragmented CBM literature and supports cross-sectoral comparison and practical application. As interest in circular strategies continues to grow, such integrative typologies will be essential for bridging academic insight with real-world implementation in the transition towards a sustainable CE.

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GREEN BUSINESS MODEL VS. BUSINESS MODEL INNOVATION: CONFLICT OR CONVERGENCE IN VALUE CREATION?

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Abstract: *Businesses face increasing pressure to adopt innovative and sustainable practices in response to growing environmental and economic challenges. This paper examines the relationship between green business models (GBMs), which integrate environmental and social objectives into value creation, and business model innovation (BMI), which focuses on competitiveness and growth by reconfiguring value creation and capture mechanisms. The central question is whether these approaches conflict or conditionally converge. The study builds on sustainable business model archetypes and established frameworks such as Business Model Canvas and the Business Model Navigator. Using a conceptual and comparative research design, it systematically analyzes how value is defined, how sustainability is positioned within the business model, and the depth of transformation involved. The findings indicate that while traditional innovation logic has often prioritized short-term economic performance, there is a growing change toward hybrid and sustainable business model innovation approaches that combine economic competitiveness with environmental and social value creation. Convergence emerges when sustainability is embedded within innovation processes rather than treated as an external constraint. The paper concludes by proposing a conceptual typology distinguishing innovation-focused, sustainability-focused, and integrated business models, offering guidance for firms and policymakers navigating sustainability transitions.*

Keywords: Business Model Innovation, Green Business Model, Sustainability, Innovation.

JEL Classification: O31, Q56, M13

Introduction

Businesses are increasingly pressured to adopt innovative and sustainable practices in response to growing environmental and economic challenges. In this context, sustainability has emerged not only as an ethical concern but also as a strategic factor influencing competitiveness and long-term performance.

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This paper examines the relationship between green business models (GBMs), which integrate environmental and social objectives into value creation, and innovation-driven business models that focus on competitiveness and growth through changes in value chain configuration, commonly referred to as business model innovation (BMI). The central question is whether these approaches are in conflict or whether they are gradually converging into an integrated strategy for addressing contemporary business challenges.

Such transformations require a rethinking of firms' core missions and operational practices. Business model innovation provides a mechanism for enabling this change by redefining organizational purpose, reshaping value creation, and expanding the notion of value beyond purely financial outcomes. Through deliberate business model redesign, firms can embed sustainability into their operations while continuing to innovate.¹

Despite the growing interest in both sustainability and innovation, the relationship between GBMs and BMI remains insufficiently clarified. This paper aims to address this gap by exploring whether and under what conditions green business models and business model innovation conflict or converge in the process of value creation.

1. LITERATURE REVIEW / THEORETICAL BACKGROUND

The study is based on key theoretical basics from sustainable business model archetypes² and two established business model frameworks: the Canvas Model³ and the Navigator Model⁴. It explores how companies that are often perceived as sustainability leaders embed environmental and social value while disrupting traditional markets.⁵ In comparison, innovation-driven firms have historically prioritized rapid growth and efficiency but are under pressure to integrate sustainability into their strategies.⁶

1.1. Business Model Innovation (BMI)

Business model innovation has been described as a fundamental change in the way a firm competes. Markides describes how BMI does not necessarily require radical technological breakthroughs, but rather focuses on rethinking the logic of value creation and capture.⁷ Tidd and Bessant emphasize that this process is about challenging the dominant assumptions of the firm and redesigning activities to

¹ Bocken, N. M. P., Short, S. W., Rana, P., Evans, S.: A literature and practice review to develop sustainable business model archetypes, *Journal of Cleaner Production*, 65, 2014, p.63

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⁶ Evans, S., Vladimirova, D., Holgado, M., Van Fossen, K., Yang, M., Silva, E. A., & Barlow, C. Y. , *Business Model Innovation for Sustainability: Towards a Unified Perspective for Creation of Sustainable Business Models.*, 2017

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create economic advantage.⁸ The Business Model Navigator conceptualizes BMI through four core questions: who, what, how, and why, providing a structured way to analyse value creation and capture.⁹ In this sense, BMI offers firms flexibility to adapt to changing market conditions. In relation to the research question, BMI provides the structural logic and mechanisms for business model change, but it does not specify sustainability as a goal. This creates a conceptual limitation, as innovation remains primarily evaluated through economic performance unless additional value criteria are introduced.

1.2 Business Model Canvas (BMC)

One of the most widely used tools for studying BMI is the Business Model Canvas. Osterwalder and Pigneur present the BMC as a structured framework that describes how organizations create, deliver, and capture value. The model is organized around nine building blocks: customer segments, value proposition, channels, customer relationships, key resources, key activities, key partnerships, revenue streams, and cost structure.¹⁰ Conceptually, the BMC should be understood as an analytical tool rather than a theoretical model. Its relevance for this study lies in its ability to visualize and compare different value logics, including green extensions, without prescribing sustainability outcomes.

1.3 Green Business Models (GBM)

Green business models extend the traditional logic of value creation by embedding environmental and social concerns.¹¹ The sustainable business model is defined as one where sustainability concepts form the core driving force of the firm are transforming rather than supplementing the neoclassical economic logic. Such models also emphasize the creation of multiple forms of value, extending beyond financial returns.¹²

Green business models redefine value by placing environmental and social outcomes alongside economic returns, shifting the focus from customers alone to a wider network of stakeholders. Value creation is organized across the entire lifecycle of products and services to support long-term sustainability rather than short-term gains.¹³ Studies show that GBMs often remain incremental in practice, they introduce important innovations such as circular strategies that replace linear ‘take–make–dispose’ models.¹⁴

GBMs are built on the logic of BMI, but they redefine value by including environmental and social outcomes. This challenges the traditional BMI focus on efficiency and short-term financial performance. At the same time, GBMs still rely on BMI’s innovation mechanisms, revealing an unresolved tension between expanded value goals and existing innovation logics.

⁸ Ibid 207

⁹ Gassmann, O, Frankenberger, K, Csik, M, *The Business Model Navigator, 55 Models That Will Revolutionize Your Business*, Pearson, India, 2015, pp.33-40

¹⁰ Osterwalder, A., Pigneur, Y.: *Business model generation: A handbook for visionaries, game changers, and challengers*, John Wiley & Sons, Hoboken, 2010, pp.28-49

¹¹ Stubbs, W., Cocklin, C.: Conceptualizing a “sustainability business model,” *Organization & Environment*, 21(2), 2008, p.103

¹² Ibid p.484

¹³ Boons, F., Lüdeke-Freund, F.: Business models for sustainable innovation: State-of-the-art and steps towards a research agenda, *Journal of Cleaner Production*, 45, 2013, pp.12-13

¹⁴ Lindgren, P., Knoth, N. S. H., Sureshkumar, S., Friedrich, M. F., & Adomaityte, R.: Green Multi Business Models: How to measure Green Business Models and Green Business Model Innovation?, *Journal of Multi Business Model Innovation and Technology*, 9, 2021, pp.7-8,11

1.4. Sustainable Business Model Innovation (SBMI)

Sustainable business model innovation can be seen as the bridge between BMI and GBMs. SBMI refers to the conceptualization and implementation of business models that directly contribute to sustainable development. According to research, SBMI may involve the development of entirely new business models, the diversification into additional business models, the acquisition of new business models, or the transformation from one business model to another.¹⁵

A process can be noted as SBMI, or as BMI oriented toward sustainability, when it fulfills one of two conditions. First, it may directly contribute to sustainable development by generating positive impacts, or by minimizing negative ones, for the environment, society, and the long-term well-being of the organization and its stakeholders. Second, it may incorporate practices or features that strengthen sustainability within the business model's value proposition, value creation, value capture, or across its wider value network.¹⁶ This definition highlights that SBMI is both a design activity and a strategic orientation, pushing businesses to integrate sustainability into the core logic of their models.

1.5. Green Business Model Innovation (GBMI)

Green Business Model Innovation focuses specifically on combining economic value with ecological performance. It is defined as “when a business changes part(s) of its business model and thereby both captures economic value and reduces the ecological footprint in a life-cycle perspective”.¹⁷ GBMI is not a separate framework but an extension of BMI that applies sustainability criteria to its redesign process.

The Business Model Canvas provides a practical framework for conceptualizing GBMI. By mapping its core components, it enables firms to identify how sustainable or environmentally oriented practices are embedded within their value creation, delivery, and capture processes. In this way, the tool serves not only as a diagnostic instrument but also as a guide for integrating green strategies into the overall business model.¹⁸

GBMI represents a narrower and more practical application of BMI, focusing on changes that deliver both economic benefits and reduced environmental impact. In contrast to broader GBM concepts, GBMI typically involves partial adjustments, such as improvements in products, processes, or partnerships, rather than a full redesign of the firm's value logic.

1.6. Green Business Model Canvas (GBMC)

In the transition from the classical Business Model Canvas (BMC) to the Green Business Model Canvas (GBMC), the crucial step is the integration of environmental sustainability values into the existing building blocks. This extension transforms sustainability into an operational feature of the model, ensuring that ecological and social responsibility are systematically incorporated into value creation, delivery, and capture. By maintaining the structure of the BMC, the GBMC offers continuity while

¹⁵ Geissdoerfer, M., Vladimirova, D., & Evans, S.: Sustainable business model innovation: A review, *Journal of Cleaner Production*, 198, 2018, p.408

¹⁶ Ibid p.7

¹⁷ Bisgaard, T., Henriksen, K., & Bjerre, M.: Green business model innovation – Conceptualization, next practice and policy, *Nordic Innovation Report 2012:12*, 2012, p.20

¹⁸ Ibid p.26

simultaneously expanding its scope, making it especially practical for SMEs that need accessible tools for sustainable transformation.¹⁹

The Green Business Model Canvas translates sustainability goals into concrete business model design choices by adding green dimensions to each element of the traditional BMC. Instead of replacing the logic of BMI, it builds on it, making sustainability operational and measurable. This approach supports gradual but scalable sustainability-oriented innovation, particularly suited to firms seeking practical entry points for change.

Taken together, the six models demonstrate a clear pattern of both convergence and divergence. As reflected in the comparative table, all approaches share a common structural foundation: they treat the business model as the central mechanism for organizing value creation, delivery, and capture, and they rely on innovation as a key means of responding to changing market and societal conditions. In this respect, GBMs, SBMI, GBMI, and the GBMC do not replace BMI or the BMC, but build upon them by extending their logic to include environmental and social considerations.

Table 1. Comparative Table

Dimension	BMI	BMC	GBM	SBMI	GBMI	GBMC
Primary purpose	Improve competitiveness through new value logic	Visualize how a business model works	Integrate environmental and social goals into value creation	Use innovation processes to achieve sustainability	Combine economic value with lower environmental impact	Translate sustainability goals into business model design
View of value	Mainly economic (efficiency, growth, profit)	Economic value made visible	Multiple forms of value (economic, environmental, social)	Sustainable value linked to long-term development	Economic value plus ecological performance	Economic, environmental, and social value embedded
Innovation focus	Reconfiguration of value creation and capture	Analytical support for innovation	Often incremental, sometimes systemic	Sustainability-driven innovation process	Partial or component-level innovation	Incremental and scalable sustainability-oriented innovation
Role of sustainability	Not inherent; included only if explicit	Not inherent; can accommodate	Core driver of the model	Central driver of innovation	Criterion guiding model changes	Embedded across all model elements
Level of change	Incremental or radical	Descriptive	Ideally systemic, often incremental	Model-level transformation over time	Usually partial adjustments	Extension of existing model structure
Time orientation	Short- to medium-term	Neutral	Long-term environmental and social outcomes	Long-term sustainable development	Short- to medium-term improvements	Gradual long-term transition
Relation to BMI	Reference model	Tool used within BMI	Builds on BMI but challenges its assumptions	Explicit link between BMI and sustainability	Narrow green application of BMI	Sustainability-based extension of BMI
Role in this study	Baseline for comparison	Analytical framework	Challenges traditional value logic	Conceptual bridge	Practical green innovation form	Operational tool for integration

At the same time, the comparison highlights important differences in purpose, value focus, and innovation logic. BMI and the classical BMC remain primarily oriented toward economic value, competitiveness, and efficiency, often emphasizing short- to medium-term performance. In contrast, GBMs shift the definition of value toward long-term environmental and social outcomes, creating tensions with traditional BMI assumptions. SBMI and GBMI occupy an intermediate position, translating sustainability goals into innovation processes but often operating through partial or gradual changes rather than full systemic redesign. The GBMC represents the strongest point of convergence by operationalizing sustainability within an established innovation framework, showing how green objectives can be integrated into existing business model elements without abandoning the core logic of BMI.

In conclusion, the table illustrates that the relationship between BMI and GBMs is not in direct opposition, but one of conditional convergence, where alignment depends on firms' strategic priorities, temporal focus, and willingness to move beyond incremental change toward deeper business model transformation.

¹⁹ Aini, N. 2025. "Green Business Model Canvas: A Framework for Sustainable Business Practice." IOP Conference Series: Earth and Environmental Science 1441 (1): 012029, p.2-6

2. METHODOLOGY

This paper uses a conceptual and comparative research approach. The aim is not to test hypotheses statistically, but to clarify how different business model concepts relate to each other in the context of sustainability transitions. This approach is suitable because research on GBMs is still limited and fragmented, while the literature on BMI is more developed but rarely examined together with GBMs in a systematic way.

The analysis follows a step-by-step comparison. First, BMI and GBMs were selected as the two core models for comparison. They represent the two main positions in the debate: BMI, which is traditionally driven by innovation, competitiveness, and economic value, and GBMs, which place environmental and social value at the center of the business model. These two models were analyzed in detail to understand how they define value, what assumptions they make about business success, and where tensions between them may arise.

In the second step, the analysis was expanded to include four closely related models: the BMC, SBM, GBMI, and the GBMC. These models were not treated as independent theories, but as extensions or bridges that help explain how firms combine innovation and sustainability in practice. Including these models made it possible to trace different pathways between BMI and GBMs, ranging from partial and incremental changes to more integrated and sustainability-oriented business model redesigns.

To support the conceptual comparison, the study draws on multiple sources. Academic literature was reviewed to identify definitions, frameworks, and key assumptions across the models, as well as publicly available materials. In conclusion, this layered comparison allows the paper to move beyond isolated model descriptions and to systematically examine convergence and conflict between BMI and GBMs. The methodology helps clarify how sustainability can be integrated into BMI, and under what conditions this integration remains incremental or becomes transformative. This provides a clearer conceptual foundation for firms and researchers seeking to navigate sustainability transitions through business model change.

This study is explicitly theoretical and conceptual in nature. It does not rely on primary empirical data, but instead uses a structured comparative analysis to examine how different business model concepts define value, innovation logic, sustainability orientation, and level of transformation. The comparison is based on three core criteria: definition of value, role of sustainability within the business model, and depth of business model change. This approach ensures conceptual clarity and strengthens the theoretical contribution, while creating a basis for future empirical research.

3. RESULTS

The findings show that while many early-stage innovations still overlook sustainability, there is a growing movement toward hybrid business models that combine economic performance with environmental and social responsibility. These models emerge when sustainability is integrated directly into the logic of value creation, rather than treated as a secondary concern.²⁰

²⁰ Evans, S., Vladimirova, D., Holgado, M., Van Fossen, K., Yang, M., Silva, E., & Barlow, C.: Business model innovation for sustainability: Towards a unified perspective for creation of sustainable business models, *Journal of Cleaner Production*, 65, 2017,3,9

Practical frameworks play a key role in this shift. The GBMC extends the traditional BMC by adding “green” elements to all building blocks, which helps firms embed sustainability into their operations without losing structural clarity.²¹ Recent systematic reviews also show that more companies are experimenting with innovation types that support circularity and system-wide transformation, moving beyond narrow efficiency improvements like reducing energy use or waste.²²

Despite the rise of hybrid and circular models, adoption remains uneven across industries. Many small and medium-sized enterprises continue to treat sustainability as a set of technical fixes rather than a basis for full transformation. Although green innovative practices support long-term sustainability, they are often limited to incremental technical improvements rather than systemic change. Their adoption is further constrained by limited resources, lack of expertise, and weak enabling conditions, leading many firms to rely on conventional production approaches.²³ Furthermore, challenges remain in measuring the social and environmental outcomes of these models, which continues to slow progress toward systemic transformation.²⁴ A key result of the comparative analysis is the identification of “conditional convergence” between BMI and GBMs, which emerges when sustainability is integrated into innovation processes rather than treated as an external constraint.

4. DISCUSSION

This paper examines whether GBMs and BMI represent competing approaches to value creation or whether they are increasingly converging in practice. The analysis of the six models and supporting literature suggests that the relationship between GBMs and BMI is neither purely conflicting nor fully aligned, but instead reflects a conditional convergence shaped by differences in value orientation, time horizon, and depth of business model change. BMI and GBMs are often seen as starting from different priorities. BMI has traditionally focused on competitiveness and growth through new ways of creating and capturing value. Within this perspective, value is mostly defined in financial terms, as a mechanism for efficiency and profit.²⁵

From a conceptual perspective, the main source of tension lies in how value is defined and prioritized. Traditional BMI literature frames value creation primarily in economic terms, focusing on competitiveness, efficiency, and growth through the reconfiguration of value propositions, activities, and revenue mechanisms.²⁶ In contrast, according to Boons and Lüdeke-Freund, green business models can be understood as challenging this narrow interpretation of value by setting environmental and social objectives into the core logic of the business model, rather than treating sustainability as an external constraint or an additional responsibility layered onto existing models.²⁷ This change in how value is

²¹ Aini, N.: Green business model canvas: A framework for sustainable business practice, IOP Conference Series: Earth and Environmental Science, 1441, 2025, p.3

²² Brenner, B., & Drdla, D.: Business model innovation toward sustainability and circularity – A systematic review of innovation types, Journal of Cleaner Production, 2023, pp.12-14

²³ Mathushan, P., Pushpanathan, A.: Does green innovative practices matter? The effect of green innovation on green entrepreneurship sustainability, Sustainability, Journal of Business Studies, 7(1), 2020, pp.13-14

²⁴ Geissdoerfer, M., Vladimirova, D., Evans, S.: Sustainable business model innovation: A review, Journal of Cleaner Production, 198, 2018, pp.405-406

²⁵ Massa, L., Tucci, C. L.: Business model innovation, Journal of Cleaner Production, 45, 2013, p.5

²⁶ Markides, C., Disruptive innovation: in need of a better theory. Journal of Product Innovation Management, 2006 and Tidd, Joe, Bessant, John, Managing Innovation, Integrating Technological, Market and Organizational Change, 4th Edition, John Wiley and Sons Ltd, England, 2009

²⁷ Boons, F., Lüdeke-Freund, F.: Business models for sustainable innovation: State of the art and steps towards a research agenda, Journal of Cleaner Production, 45, 2013, pp.6-11

defined can conflict with traditional BMI assumptions, especially in contexts where success is still measured mainly through short-term financial results.

However, the literature also shows that this tension does not imply incompatibility. Rather, several authors argue that sustainability can function as a driver of innovation, not a limitation. New business models oriented toward sustainability often arise when firms have to reconsider how value is created, delivered, and captured in response to environmental pressures.²⁸ Similarly, there is increasing evidence that firms are beginning to integrate innovation capabilities with sustainability objectives as they respond to broader systemic challenges, including climate change and resource limitations.²⁹ In this sense, sustainability pressures can stimulate BMI by opening new markets, improving resource efficiency, and supporting the development of new value propositions.

The existing literature on green and sustainable business models is still fragmented and underdeveloped, leaving important relationships, particularly the connection, differences, and potential convergence between GBMs and mainstream BMI,³⁰ unexplored. While research on BMI has progressed rapidly, studies of green and sustainable business models have largely evolved in parallel, with little systematic work examining how the two streams relate. As a result, there is still no clear account of whether, and in what ways, SBMs and BMI converge or diverge in practice, which creates a knowledge gap that this paper seeks to address.³¹

The convergence between innovation and sustainability becomes particularly visible in the discussion on SBMI. SBMI approaches sustainability not as a separate strategic choice, but as a guiding principle within the BMI process itself, using experimentation, iteration, and reconfiguration to achieve environmental and social objectives alongside economic ones.³² SBMI does not treat innovation and sustainability as opposing goals, but integrates sustainability directly into the innovation process. It builds on established BMI mechanisms such as experimentation and gradual change, while redirecting them toward long-term environmental and social value.³³ Taken together, these perspectives suggest that convergence occurs when firms intentionally align innovation processes with sustainability objectives.

At the same time, the comparison highlights that convergence is uneven and often partial. GBMI, for example, tends to operate at the level of specific components rather than full business model redesign. As discussed in the paper, GBMI frequently involves targeted changes, such as greener products, cleaner processes, or revised partnerships, that reduce environmental impact while preserving the underlying economic logic of the firm. This observation is consistent with empirical findings, where is shown that many firms adopt green innovations incrementally, focusing on technical improvements

²⁸ OECD: Why new business models matter for green growth, OECD Green Growth Papers, No. 2013-01, OECD Publishing, Paris, 2013, pp.9-14

²⁹ Azmat, F., Lim, W. M., Moyeen, A., Voola, R., & Gupta, G.: Convergence of business, innovation, and sustainability at the tipping point of the sustainable development goals, *Journal of Cleaner Production*, 2023, pp.2-5

³⁰ Bocken, N. M. P., Short, S. W., Rana, P., Evans, S.: A literature and practice review to develop sustainable business model archetypes, *Journal of Cleaner Production*, 65, 2014, p.55

³¹ Minatogawa, V., Franco, M., Rampasso, I., Holgado, M., Garrido, D., Pinto, H., & Quadros, R.: Towards systematic sustainable business model innovation: What can we learn from business model innovation?, *Journal of Cleaner Production*, 2022, p.2

³² Ibid, pp.6-9

³³ Ferlito, R., Faraci, R.: Business model innovation for sustainability: A new framework, *Journal of Cleaner Production*, 2022, pp.8-12

rather than systemic transformation.³⁴ As a result, GBMI often represents a pragmatic compromise between sustainability ambitions and existing business constraints.

GBMs, however, are shaped by another logic. Literature shows that Sustainable business model archetypes combine economic, social, and environmental goals and show different ways sustainability can be integrated into value creation. Building on this perspective, the paper examines whether GBMs require new forms of innovation or can operate within traditional BMI. These examples show that GBMs aim to shift businesses from being only market actors to becoming active contributors to sustainability transitions.³⁵

The Green Business Model Canvas represents the most concrete point of convergence identified in this study. By extending each element of the traditional Business Model Canvas with green dimensions, the GBMC translates sustainability goals into practical design choices without abandoning the familiar structure of BMI. This approach is particularly relevant for small and medium-sized enterprises, as it relies on simple and adaptable frameworks that allow sustainability considerations to be introduced into everyday business decisions without requiring radical restructuring or high implementation costs.³⁶ The GBMC demonstrates that convergence does not require redefining the concept of the business model itself but rather reinterpreting its components through a sustainability lens.

The main theoretical contribution of this paper lies in conceptualizing the relationship between GBMs and BMI as conditional convergence. Rather than treating sustainability and innovation as opposing logics, the analysis shows that convergence depends on how value is defined, over what time horizon performance is assessed, and whether innovation is evaluated beyond short-term financial outcomes. By positioning conditional convergence as an analytical concept, this paper contributes to ongoing debates on sustainable business models and clarifies how innovation frameworks can be expanded to support sustainability transitions.

Conclusion

This paper examined whether Green Business Models and Business Model Innovation should be understood as competing approaches to value creation or as increasingly connected strategies. Based on a conceptual comparison of six related models, the analysis shows that their relationship is best described as one of conditional convergence rather than direct conflict. While tensions persist, especially in contexts where innovation is still judged mainly by short-term financial performance, the literature and frameworks reviewed demonstrate several ways in which sustainability and innovation can reinforce each other.

The key tension lies in how value is defined. Traditional BMI focuses mainly on economic performance, while GBMs place environmental and social outcomes at the center of the business model. Although this shift challenges short-term, profit-oriented views of success, it does not make the two approaches incompatible. Convergence emerges when innovation processes are deliberately used to support broader forms of value creation.

³⁴ Mathushan, P., Pushpanathan, A.: Does green innovative practices matter? The effect of green innovation on green entrepreneurship sustainability, *Sustainability, Journal of Business Studies*, 7(1), 2020, 132-136

³⁵ Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S.: A literature and practice review to develop sustainable business model archetypes, *Journal of Cleaner Production*, 65, 2014, pp. 42–56

³⁶ Aini, N.: Green business model canvas: A framework for sustainable business practice, *IOP Conference Series: Earth and Environmental Science*, 1441, 2025, pp.4-6

This convergence is most clearly illustrated through models such as SBMI, GBMI, and the GBMC. SBMI treats sustainability as a guiding principle within the innovation process itself, while GBMI reflects more incremental changes that improve environmental performance without fully redesigning the business model. The GBMC offers a practical way to integrate sustainability into everyday business model decisions by extending the familiar structure of the BMC. Together, these approaches point to the emergence of hybrid business models that combine innovation-driven competitiveness with environmental and social value creation, rather than privileging one over the other. By clarifying points of difference, overlap, and integration, this paper contributes to a clearer understanding of sustainable value creation and supports both future research and managerial decision-making.

From a practical perspective, the findings suggest that managers and policymakers should focus on business model redesign as a key leverage point for sustainability transitions. Tools such as the GBMC offer accessible entry points for integrating sustainability into strategic decision-making, particularly for SMEs. At the same time, this study is limited by its conceptual nature and does not assess empirical outcomes across industries. Future research could build on this framework through case studies or quantitative analysis to test how conditional convergence unfolds in practice.

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THE ROLE OF ACCOUNTING INFORMATION SYSTEMS IN SUPPORTING CIRCULAR ECONOMY GOALS: A CASE STUDY OF WASTE COLLECTION AND COST MANAGEMENT IN THE REPUBLIC OF NORTH MACEDONIA

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Abstract: *The paper explores the strategic role of Accounting Information Systems (AIS) in supporting circular economy (CE) goals, focusing on cost management and waste tracking in North Macedonia. Through a case study of Pakomak DOO Skopje, the research highlights how AIS enhances transparency, efficiency, and decision-making in packaging waste collection.*

The integration of AIS with CE practices enables precise cost allocation, environmental impact assessment, and legal compliance. Findings suggest that AIS, when aligned with digital technologies and sustainability strategies, serves as a key enabler for achieving long-term environmental and economic value in circular systems and sustainability.

Keywords: Circular economy, Accounting management system, Strategic cost management, Packing waste, Sustainability

JEL Classifications: M41, Q56

INTRODUCTION

In response to increasing environmental concerns and stricter regulatory frameworks, the circular economy (CE) has become a vital pathway toward sustainable development. Unlike the traditional linear model of “take, make, dispose,” the circular economy emphasizes reducing waste, improving resource efficiency, and extending product life cycles through reuse, recycling, and regeneration. As industries and governments move toward this model, the role of digital technologies, particularly Accounting Information Systems (AIS) is becoming increasingly important.

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AIS, originally designed for financial reporting and internal control, are now evolving into tools that support broader strategic goals, including sustainability and circular practices. When adapted to the needs of the circular economy, AIS can deliver valuable insights through accurate and timely data on material flows, waste management, cost efficiency, and compliance with environmental regulations. Despite their potential, the integration of AIS with circular economy strategies remains a relatively underexplored area in both academic and practical contexts.

This paper investigates the implementation and role of AIS in achieving circular economy objectives, with a specific focus on waste collection and cost management. Using the case of Pakomak DOO Skopje, the primary collective waste operator in North Macedonia, the study explores how AIS enhances operational performance, monitors costs, and contributes to environmental outcomes.

The main research goal is to assess the contribution of AIS to CE targets through improved reporting, strategic cost management, and system optimization. Additional objectives include identifying system functionalities that support CE and proposing recommendations for future improvements.

1. INFORMATION SYSTEMS AND THE CIRCULAR ECONOMY INTEGRATION-THEORETICAL ASPECTS

Information systems play a crucial role in integrating with the CE by enabling efficient resource management, extending product lifecycles, and supporting sustainability. Theoretical aspects focus on how digital technologies and information systems empower CE practices by enhancing data flows, traceability, stakeholder collaboration, and operational processes across product lifecycles and supply chains. Actually, “the integration of digital technologies and CE principles synergistically contributes to sustainability, making it imperative for firms striving for long-term sustainability to adopt a comprehensive strategic approach that embraces both digital technologies and CE”.¹ In addition “information systems (IS), being fed with appropriate data thanks to the support and the integration with Industry 4.0 technologies, can be useful for the fulfilment of sustainable and circular goals”.² This integration is framed through multiple theories that address motivators, enablers, synergy, environmental context, and multi-level stakeholders, facilitating the shift towards sustainable production and consumption.

These systems enable strategies like reduce, reuse, recycle, remanufacture, and extend product life by optimizing resource use and reducing and proper collecting of waste. It is obvious that, “by adopting circular economy principles, organizations can greatly reduce their environmental impact, enhance resource efficiency, and generate long-term value while also mitigating issues such as climate change and greenhouse gas emissions. Essentially,

¹Soode V., Mahtab K., Dara S., Joseph S.: Digital Technologies and the Circular Economy: A Theoretical Perspective, *Computers & Industrial Engineering*, Vol. 206, August 2025. (<https://doi.org/10.1016/j.cie.2025.111225>) .

² Doroteja V., Marjeta M., Andreja P.: Information Technology for Business Sustainability: A Literature Review with Automated Content Analysis, *Sustainability*, MDPI, vol. 13(3), January 2021. (RePEc:gam:jsusta:v:13:y:2021:i:3:p:1192-d:485843).

sustainability is meeting present needs without compromising the ability of future generations to meet their own needs”.³ “As companies, governments, and communities increasingly acknowledge the advantages of this strategy, the circular economy will become a fundamental aspect of sustainable development, promoting economic expansion while protecting our planet for future generations.”⁴

Continuously, economies should take into consideration the interplay between information systems and circular economy principles, guiding both research and practical adoption in order to achieve sustainable value creation and competitive advantage in all areas. In other words, “embedding information systems capabilities into organizational processes for transitioning to a circular economy model can present economic benefits depending upon the uncertainty within their specific operating environment.”⁵ Through this synergy, businesses and society can achieve greater competitiveness and sustainability by driving innovative and environmentally responsible solutions that create value and promote sustainable development.

2. ACCOUNTING INFORMATION SYSTEMS AS A TOOL FOR STRATEGIC COST MANAGEMENT

As a part of the information systems that can and should be related to implementation of circular economy is AIS of companies that serves as vital tools for strategic cost management. By providing timely, relevant, and accurate financial and operational data AIS enables organizations to analyze, control, and reduce costs effectively. From a scientific research perspective, AIS integrate accounting methods with information technology to support strategic decision-making, optimize value chains, and align cost management strategies with organizational goals.”AISs are systems used to process data and transactions to provide users with the information needed for planning, controlling, and business operations. Therefore, high-quality information is very important, which means accurate and timely information. The role of accounting information systems in a company is very crucial and essential for management, because it provides financial reports that can be used to evaluate various business activities and assess the performance of each unit given authority and responsibility.”⁶

From the strategic cost management point of view, AIS gives support in the processes of: evaluating all value-adding activities to identify cost advantages or inefficiencies and improve customer value delivery; deciding competitive approaches such as cost leadership or differentiation that guide cost management priorities and in cost driver analysis by understanding the factors that influence costs to optimize resource use proper, reduction and collection of waste.

³ Purushothaman R., Alamelu R., Selvabaskar S., Sudha M.: Theories, techniques and strategies of sustainable circular economy: A systematic literature review, *Discover Sustainability* April 2025 6:297. (<https://doi.org/10.1007/s43621-025-01161-5>).

⁴ Ibidem.

⁵ Randy R., Carmen M. F., Jos'e L. R., Juan C. R.: Information systems capabilities value creation through circular economy practices in uncertain environments: A conditional mediation model, *Journal of Business Research* 175, 2024. (<https://doi.org/10.1016/j.jbusres.2024.114526>)

⁶ Wardatun N., Muhammad N., Tri W., Chandra P.: The Role Of Accounting Information Systems In Improving Management Strategic Decision, *MSR Journal*, Vol 3 issue-3, 2024.

Overall, AIS is conceived, not merely as transactional recorders but as strategic assets that provide a comprehensive data-driven foundation for managing costs proactively and sustaining competitive advantage in dynamic business environments. This approach highlights the pivotal role of AIS in aligning accounting information flows with strategic objectives and enhancing organizational performance through effective cost management. AIS improves strategic cost management by automating data collection and processing, enabling real-time reporting, improving accuracy, and integrating financial data with other business operations. This leads to better analysis of costs over product life cycles, life-cycle costing, activity-based costing, and supports sustainability and quality cost management. AIS also plays a strategic role by aligning with overall business strategies, providing information for external competitive analysis, and supporting diversification and differentiation efforts. “Decision-makers can receive relevant information from AISs and utilize it in decision making and strategy development to help the firm accomplish its goals and objectives and improve its performance.”⁷ Moreover, AIS contributes to cost management by reducing operational costs through automation, improving interdepartmental collaboration, and safeguarding data integrity with internal controls. These improvements enhance profitability and efficiency, making AIS a critical tool for managing costs strategically in competitive environments.

3. AIS IMPLEMENTATION IN PAKOMAK DOO SKOPJE FOR WASTE COLLECTION COST TRACKING

3.1 Pakomak DOO: Organization and Role in Waste Management

Pakomak DOO is the first collective waste operator in North Macedonia, primarily engaged in the management of packaging and packaging waste (PW). Its mission is closely aligned with the principles of the circular economy, which emphasize minimizing waste and maximizing resource efficiency through the sorting, collection, and transportation of waste to authorized final handlers. Through its operations, the company reduces the negative impact of PW on the environment and promotes responsible corporate behavior in waste management, thereby contributing to a better quality of life and establishing a system in line with the principles of sustainable development.

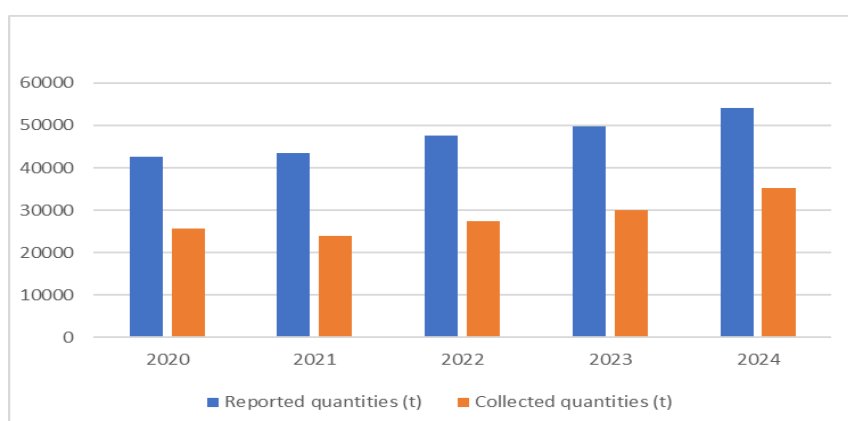
With the introduction of the Law on Packaging and Packaging Waste Management (LPPWM) in 2011, all producers⁸ became responsible for the entire PW generated from the sale of their products on the territory of North Macedonia. In other words, their responsibility extends beyond the point of sale they are obliged to manage the waste resulting from the packaging of their products. Therefore, systems like Pakomak are also referred to as Extended Producer Responsibility (EPR) systems. These companies are required to register their PW under an EPR system and finance its collection based on the quantities of PW placed on the market, in accordance with the legally established annual collection targets.

⁷ Emad H., Ahmed Hussein R.: The Influence of Accounting Information Systems (AIS) on Performance of Small and Medium Enterprises (SMEs) in Iraq, *Journal of Business & Management* 3(4):48-57,2014 (DOI:10.12735/jbm.v3i4p48)

⁸ Producers – manufacturers and importers who, along with their products, place packaging waste on the territory of the Republic of North Macedonia (in accordance with the Law on Extended Producer Responsibility for the Management of Specific Waste Streams).

In 2024, more than 790 companies reported their PW through Pakomak's system, delegating the responsibility to Pakomak to manage the PW that ends up on the market in the Republic of North Macedonia. Through collaboration with municipalities, the private sector, and citizens, Pakomak has been increasing the rate of proper sorting and collection of PW (Chart 1), year by year. This progress is an indicator of advancement toward a circular economy and long-term reduction of environmental impact, achieved through the following three main activities, in accordance with legal responsibilities: installing infrastructure for the separation of PW as part of municipal and industrial waste; organizing the collection of sorted PW from this infrastructure and from other appropriate collection channels; raising public awareness about the need for waste separation in general, with an emphasis on PW and the benefits for individuals and society, as a whole.

Chart 1. Reported and Collected Quantities of PW by Pakomak for the Period 2020–2024 (in t)



Source: Annual Reports on the Operations of Pakomak for the Respective Years.

During the analyzed period, the company achieved positive results by continuously increasing the amounts of reported, properly sorted, and collected waste. In accordance with the LPPWM, Pakomak exceeded the nationally set targets. According to estimates by the Ministry of Environment and Physical Planning, the total amount of packaging waste generated in North Macedonia in 2025 will be approximately 116,029 t annually (Annex 6 – National Waste Management Programme 2021–2031). Pakomak is contracted to manage (collect and deliver for recycling) around 54,000 t of the above, or roughly 47%.

3.2 Functionalities and Application of AIS

To support and implement these goals, Pakomak uses a modern AIS Betako Soft, custom-designed for the needs of Pakomak. It is a key tool for ensuring financial transparency and operational efficiency in PW management processes. The system is designed to integrate financial and operational data, enabling precise tracking of costs by activity, geographic area, collection channel, type of packaging waste (paper, plastic, glass, cans, etc.), collecting company, and time period. It allows detailed monitoring of all transactions related to the company's activities. The system can also be easily adapted for other waste streams (e-waste, waste tires, used oils, textile waste).

Through this capability, the AIS generates reports that monitor overall operations. Operational reports demonstrate collection efficiency (by quantity and cost), the share of each type of sorted PW in the total collected amount, and the efficiency of collection routes. This allows management to identify and improve operational segments in the most efficient way (Table 1).

Table 1. Collected PW by Category for the Period 2020–2024 (in t)

Year	Plastic (t)	Paper (t)	Metal-Fe (t)	Metal-Al (t)	Glass (t)	Wood (t)	Composite (t)	Total (t)
2024	5.637,528	19.236,129	2.068,48	232,802	6.172,843	1.803,977	0	35.151,759
2023	5.235,749	15.328,248	1.807,755	203,511	5.806,919	1.556,754	0	29.938,936
2022	5.021,992	15.718,727	684,426	182,369	5.121,083	792,266	0	27.520,863
2021	4.775,357	13.050,596	652,611	178,892	4.687,467	663,942	0	24.008,865
2020	4.194,971	16.124,214	800,207	68,815	3.778,821	793,88	0	25.760,908
Total (2020–2024)	24.865,597	79.457,914	6.013,479	866,389	5.567,133	5.610,819	0	142.381,331

Source: Annual Operations Report of Pakomak for the respective years

The table above clearly illustrates the practical use of the system in recording the separate quantities of packaging waste by category, collected on behalf of Pakomak's clients for the 2020–2024 period, in line with the LPPWM. It can be observed that during this period, the company shows a continuous annual increase in collected quantities. This is largely due to the availability of analytical data from the implemented AIS, which helps the company focus on the collection channels that can achieve the greatest increase in collected PW with reducing operational costs.

The presented results are in accordance with Article 21 of the LPPWM and the specified percentage targets per year and per type of PW, which must be collected by the collective waste operator relative to the amount of packaging placed on the market in North Macedonia. This, also aligns with the company's strategic plan to comply with legal regulations. The data are key business (KPI) and environmental indicators, as they signal which regions or collection points are the least or most efficient within the established collection system, and how the collection network should be adjusted. The continuous increase in collected PW is directly related to improved efficiency of the infrastructure in identified weak segments/regions/channels and optimizing the collection scheme, while also applying circular practices.

An overarching goal of all these activities is to generate the minimum possible carbon footprint from the collection and transport of PW. At the same time, the company strives to work with regional or local partners who collect the PW and deliver it to the nearest collection center. Moreover, the implemented AIS is crucial for detecting operational efficiency by activity. This is enabled through cost allocation by activity (collection channel, PW type, region, collecting company) and ongoing comparison with the company's planned budget. (Table 2)

Table 2. Average Cost of Packaging Waste Collection 2020–2024

Collection costs by year			
Year	Waste (t)	Total costs (den)	Average costs
2024	35.151,59	78.102,074	2.221,583
2023	29.938,936	61.409,993	2.000,929
2022	27.520,863	47.957,440	1.540,406
2021	24.008,865	40.027,991	1.658,93
2020	25.760,908	37.861,156	1.469,235
Total (2020–2024)	142.381,331	265.358,654	9.161,09

Source: Annual Operations Report of Pakomak for the respective years

The cost analysis provides insight into and assessment of the system's economic efficiency over a given period and for specific PW types and collection channels. Table 2 illustrates how the AIS tracks the cost dynamics of waste collection by year, both in absolute terms and as average cost/t of collected packaging waste. Even though in 2024 there is a 51.6% increase in the average collection cost compared to 2020—which may seem illogical given the “economy of scale” principle (a 38% increase or 7% more PW was collected)—these outcomes were forecasted and expected thanks to the KPIs from the AIS. This is due to two main reasons: the share of waste fractions with the highest collection costs (glass, plastic, and aluminum) increased as required by the Ministry of Environment and Physical Planning and each additional ton collected requires more effort and cost, as the easier-to-collect quantities are already exhausted ("no low-hanging fruit").

In addition to costs by collected PW type as business indicators, the system also calculates: the fill-time of Reverse Vending Machines (RVMs) and containers, the number of users per RVM, the number of collected items per RVM and container location, etc. The AIS also enables the generation of environmental indicator reports, which provide analytical insights into the company's ecological efficiency and its contribution to the goals of the circular economy. These reports show the amount of PW sorted and delivered for further treatment, and therefore the direct savings of natural resources.

The indicator for collected PW quantities (especially glass) and kilometers traveled (KPI: km/ton) directly show the CO₂ emissions for a given activity. The number of RVM users and the amount of PW collected via RVMs are also key environmental indicators. The aim is to have the selection equipment (containers, RVMs) as close to citizens as possible to motivate them to separate their waste. With this information, Pakomak can measure waste reduction through proper sorting and collection of PW, which serves as a relevant indicator of the success of circular practices.

The automation of processes allows the system to deliver accurate and timely data, minimize the risk of errors, improve forecasting and planning, and increase operational efficiency. Additionally, the system is designed to be flexible and able to adapt to changes in legislation, ensuring sustainability and continuous operational development in alignment with circular economy goals. In this way, the AIS not only supports the financial and operational efficiency of Pakomak but also provides critical insights for achieving the goals of the circular

economy and the long-term transition of North Macedonia toward a sustainable economic model.

4. IMPLICATIONS AND RECOMMENDATIONS FOR ENHANCING AIS FOR CIRCULAR ECONOMY GOALS

The AIS is a crucial element and foundational component in modern PW management and company operations in general. Through data processing, storage, and analysis, this system enables timely and accurate information to be provided to management, directly influencing the ability to make high-quality strategic decisions. Its application ensures transparency, increased efficiency, improved control over all business processes, and alignment with both European and national standards.

In this regard, Pakomak serves as a positive example of how its accounting information system not only supports accurate and timely event tracking but also plays a broader role: facilitating planning, performance monitoring, legal compliance with PW management regulations, and serving as a key tool for strategic decision-making. This highlights the importance of continuous maintenance, upgrades, and adaptation of the system in line with changing company needs and external conditions.

To achieve higher results within the circular economy framework, there are opportunities for further enhancement of the system. The following recommendations address the technological, organizational, and regulatory aspects of the AIS:

- Continuous implementation of new generations of sensors on containers/infrastructure to obtain real-time data on the fill level of sorting containers and RVMs. This enables route optimization for collection. One of the main drivers of the circular economy will be the Internet of Things (IoT), which is becoming more precise and affordable to implement.
- Introduction of digital tracking solutions for the flow of PW through integration into the AIS. The use of barcodes in the HORECA⁹ channel and on RVMs, along with GPS technology, enables precise identification and monitoring of PW from the pickup point to the final handler. Integration of this data into the AIS increases transparency and reduces the risks of unverified or improper PW handling, as well as manipulation of legal and system obligations.
- Installation of solar panels on secondary PW sorting lines. In addition to the primary sorting done by citizens via the aforementioned infrastructure, secondary sorting is necessary to remove improperly sorted waste and further sort well-separated PW by type and color. If these sorting facilities are automated and of higher capacity, they require significant electricity, which can be partially or fully offset by installing efficient solar panels.
- Use of Artificial Intelligence (AI) to analyze large datasets for decision-making. The vast amount of data generated by the AIS can be processed with AI algorithms to identify patterns and trends, enabling managers to make faster and more informed

⁹ HORECA- an international abbreviation commonly used for the sector: of hotels, restaurants, and cafés.

decisions. Predictive analytics can help forecast future behavior or detect system irregularities.

- Inclusion of producers who are either not part of the EPR system or underreport the quantities of packaging placed on the market. This can be addressed through digital comparison of companies within the same industry, evaluating their market share versus their reported PW quantities. One of the biggest challenges remains the partial participation of producers and importers in the EPR system. Some companies are not included at all, while others report unrealistically low packaging quantities. It is estimated that at least 30% (over 30.000 t) of all PW placed on the market is not financed by any collective waste management system (apart from Pakomak, there are two smaller systems). This results in a shortfall of at least €1.2 million per year for the waste sorting and recycling systems. Proper participation would significantly accelerate the transition to a circular economy.

A possible solution is the development of a digital mechanism for comparing companies within the same industry. Using the AIS, a company's market share can be compared to its reported PW quantities. This would allow for the timely detection of irregularities, enabling more efficient control and fair obligations among all producers.

The implications and recommendations for the enhancement of the AIS, in line with circular economy principles, indicate that future development must be based on integration of digital technologies, automation via IT, and transparency. This feedback mechanism shows that the system should not just be a passive data repository, but rather an interactive tool for improving operations and achieving both corporate and circular economy goals.

CONCLUSION

The paper highlights the vital role of AIS in supporting CE goals through enhanced cost management, transparency, and operational efficiency. The case of Pakomak DOO Skopje demonstrates how AIS can be effectively utilized to monitor packaging waste collection, track costs, assess environmental impact, and ensure regulatory compliance. AIS, when integrated with digital tools and sustainability strategies, evolve from simple data processors into strategic systems that support informed decision-making and long-term value creation.

The findings underscore the need for continuous development of AIS functionalities, including automation, real-time data collection, and environmental reporting, to align more closely with CE principles. Strengthening this synergy is essential for accelerating the transition toward a sustainable and resource-efficient economic model in North Macedonia and beyond.

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REDUCING FOOD WASTE THROUGH CIRCULAR ECONOMY: EVIDENCE FROM HOSPITALITY PRACTICES

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Abstract: *This paper explores the application of circular economy (CE) principles within the hospitality industry through a case study of Ibis Skopje City Center, part of the Accor hotels group.¹ The focus is on strategies to reduce food waste - one of the most significant sustainability challenges in the sector. Using qualitative research methods, including semi-structured interviews and internal data analysis, the study examines how the hotel integrates CE strategies such as waste prevention, resource tracking, food repurposing, and guest behaviour modification. Central to the implementation is Gaia, a digital monitoring tool that enables precise food waste tracking across service categories. Between 2018 and 2023, the hotel achieved a 63% reduction in food waste, largely due to operational redesigns (e.g., portion control, kitchen reuse), employee training, and guest engagement initiatives. The findings underscore the viability of CE practices in hospitality and highlight the importance of digital tools, stakeholder involvement, and supportive policy frameworks. This case contributes to the growing discourse on circular business models in service-based industries and offers a replicable blueprint for sustainable transformation in hotel management.*

Keywords: Circular economy; food waste; hotel management; hospitality sustainability; resource efficiency

JEL Classification: L83; Q01; Q53; M14

Introduction

The hospitality industry stands as one of the largest contributors to global food waste, while simultaneously being a major consumer of non-renewable resources such as water, energy, and raw materials (Bohdanowicz, 2006; FAO, 2017). Hotels, in particular, operate within consumption-intensive environments, where high service standards and customer expectations

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frequently result in surplus food production, inefficient inventory practices, and elevated levels of waste generation (Papargyropoulou et al., 2014). Traditionally, such operations have been shaped by linear economic models characterized by the “take-make-dispose” logic-where resources are extracted, used briefly, and discarded without systematic recovery or reuse. These models are becoming increasingly unsustainable amid growing environmental degradation, economic volatility, and heightened social awareness of global inequality (UNEP, 2021).

In response to these challenges, the CE has emerged as a paradigm aimed at redefining economic systems in a way that decouples growth from resource consumption. CE strategies emphasize the retention of value within economic and biological systems by minimizing waste, extending product life cycles, and restoring ecological systems (Geissdoerfer et al., 2017; Bocken et al., 2016). Within the hospitality industry, and food services in particular, CE implementation involves practices such as portion control, food redistribution, composting, design optimization, and the use of digital tools to track and reduce food loss (Principato et al., 2021).

This paper investigates the integration of CE principles into hotel operations through a qualitative case study of Ibis Skopje City Center, a hotel operating under the international Accorhotels group. The findings of this case study offer valuable insights into how CE principles can be operationalized in real-world hospitality settings, demonstrating their practical viability, strategic benefits, and potential for replication across similar service-based industries.

1. IMPLEMENTING CIRCULAR ECONOMY PRINCIPLES IN HOSPITALITY

The concept of the circular CE has gained considerable traction as an alternative to the traditional linear economic model of “take-make-dispose”, which is largely unsustainable in the context of growing environmental degradation, resource scarcity, and increasing waste generation. CE seeks to close material loops by retaining the value of resources within the system through reuse, recycling, and regeneration (Geissdoerfer et al., 2017). At its core, CE is predicated on three principles: designing out waste and pollution, keeping products and materials in use for as long as possible, and regenerating natural systems (Ellen MacArthur Foundation, 2013). While CE has seen extensive application in manufacturing and urban infrastructure, its adaptation to the service economy - particularly the hospitality sector - remains in the early stages of development and requires more sector-specific frameworks and empirical case studies.

Hotels consume vast amounts of water, energy, and food in delivering complex, round-the-clock services, and their operations generate significant environmental impacts throughout the supply chain (Bohdanowicz, 2006). As a result, the hospitality industry has a dual role: it contributes to environmental degradation but also holds potential to drive the shift toward sustainable, circular systems.

Operationally, hotels generate food waste at various stages of their service lifecycle - from procurement and storage to food preparation, guest consumption, and post-consumption disposal. A circular approach to hospitality requires interventions across this entire value chain. This includes preventative strategies such as demand forecasting, menu redesign to minimize perishable ingredients, staff training to reduce preparation waste, and real-time monitoring

systems to track inefficiencies. Beyond prevention, circular strategies may also involve redistribution of surplus food, repurposing edible trimmings, and composting unavoidable organic waste (Papargyropoulou et al., 2014).

The significance of food waste within the CE discourse is particularly acute due to its scale and embedded resource intensity. Globally, approximately one-third of all food produced for human consumption is lost or wasted, translating to about 1.3 billion tonnes annually (FAO, 2017). In the hospitality sector, food waste constitutes around 12% of the total food wasted worldwide, placing it as the third largest contributor after households and food manufacturing (UNEP, 2021). Given that hotels often operate buffets, cater for events, and maintain large-scale kitchens, the overproduction and disposal of food is frequently normalized as a cost of doing business (Pirani & Arafat, 2016).

From a CE perspective, food waste represents a critical breakdown in the value retention of biological resources. Unlike technical materials, food waste cannot be reused in its original form but must instead be cycled through regenerative processes such as composting or anaerobic digestion to close the biological loop (Bocken et al., 2016). The focus often shifts to inner-loop strategies such as portion control, consumer awareness, and kitchen reuse - all of which are more readily actionable within existing hotel structures (Alexander et al., 2013).

Moreover, behavioural factors further complicate the challenge of food waste in hospitality. Guests may over-serve themselves at buffets, under-consume due to portion size dissatisfaction, or leave behind culturally unfamiliar food items. Studies show that tourists waste more food in hotels than they do at home, driven by perceived abundance and the “all-inclusive” mentality (Wang et al., 2021). In this regard, the CE framework extends beyond logistics and infrastructure - it requires a reconfiguration of guest engagement strategies to influence consumption behavior and promote shared responsibility for resource use (Filimonau & Delysia, 2019).

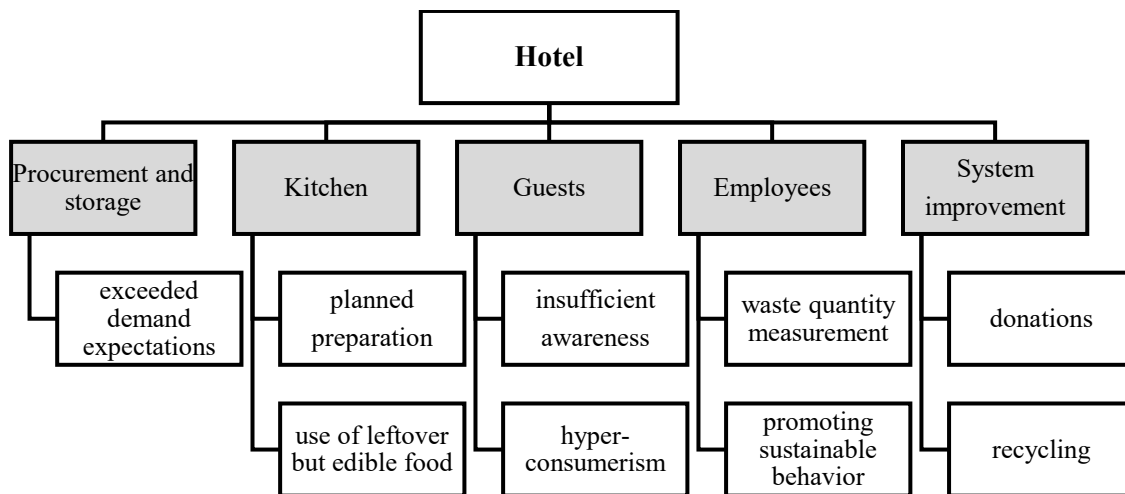
In sum, the literature emphasizes that implementing CE in hospitality is not solely a technical or operational issue but a strategic and cultural one. Hotels must reimagine their food systems holistically, integrating data-driven monitoring tools, staff empowerment programs, sustainable procurement, and consumer education. Although structural and regulatory barriers persist - such as the absence of food donation legislation in many countries or limited access to composting facilities - the potential for the hospitality industry to contribute meaningfully to circularity is substantial. Real-world case studies, such as the one presented in this paper, are essential to demonstrate that CE principles are not only theoretically applicable but also practically viable in complex service environments.

2. INTEGRATING CIRCULAR ECONOMY PRINCIPLES IN HOSPITALITY OPERATIONS: A QUALITATIVE STUDY OF FOOD WASTE MANAGEMENT PRACTICES

Given the nature of the research problem, this paper employs a qualitative methodological approach to examine how CE principles are integrated into hotel operations, with a particular focus on food waste management. As highlighted by Aditya and Kurniawati (2023), qualitative methods are effective for uncovering nuanced perspectives and identifying patterns that are not easily captured through quantitative approaches.

The study was conducted through semi-structured interviews with key personnel from the Ibis Skopje City Centre, a hotel operating under the international Accor hotels brand. This method provided the flexibility to guide conversations around specific themes while allowing participants to elaborate on relevant experiences and provide contextual examples. The interviewees included the hotel's general manager, deputy general manager, and head chef - individuals directly involved in both strategic planning and day-to-day food operations. Their insights were essential to understanding how sustainability directives from the global Accor group are translated into localized practices and how operational decisions impact food waste generation and reduction.

Figure 1: Framework for Identifying Key Food Waste Issues



Accor hotels, founded in 1967 and headquartered in France, is one of the world's leading hospitality groups, with operations in 110 countries and a portfolio of more than 30 brands catering to various market segments, ranging from luxury to economy. The company's global sustainability initiative, Planet 21, serves as a guiding framework for all its properties in implementing environmental and social responsibility goals.

The interview protocol was carefully developed to align with the research aims and was informed by a review of existing literature on food waste and CE strategies in the hospitality sector. The questions addressed several key areas, including comparative implementation of sustainability measures, food loss tracking systems, waste reduction trends, guest engagement strategies, and long-term plans for donation, recycling, or composting. Additional questions focused on identifying the most commonly discarded food items, the underlying causes of waste during kitchen operations, reuse practices, and guest behaviour related to food consumption. Participants were also asked to provide estimates of average food waste per guest and to reflect on any age-related patterns observed among customers in relation to food leftovers.

The structure of the interview itself is the result of a structured review of the key elements within the hotel food supply chain and the potential deficiencies that lead to the generation of undesirable amounts of food waste. (see Figure 1).

Responses were analysed thematically, and content was cross-referenced with internal documentation and corporate sustainability resources provided by Accor. This triangulation of data sources increased the validity of findings and allowed for a comprehensive understanding of the hotel's food waste management strategy through the lens of CE principles. The overall design of the inquiry was guided by a framework that mapped key nodes of food loss within the hotel value chain, providing a conceptual tool for interpreting operational gaps and identifying intervention points.

3. EMPIRICAL RESULTS ON CIRCULAR FOOD PRACTICES IN HOSPITALITY

3.1.Organizational Profile and Respondent Insights

In the hospitality sector, employees play a pivotal role in the successful implementation of sustainability initiatives, particularly in food waste management. Prior research emphasizes the importance of staff education, role-specific expertise, and individual attitudes toward sustainability in determining the effectiveness of environmental practices (Park et al., 2014). Accordingly, this study conducted in-depth interviews with key personnel from Ibis Skopje City Center.

Senior management representatives and the head chef were identified as most suitable sources of information's due to their involvement in both strategic planning and day-to-day operations. Since kitchen activities represent a primary source of food waste, insights from culinary staff were especially valuable (Sezerel et al., 2023).

The Ibis Skopje City Center is a centrally located, four-star hotel with 110 guest rooms. The hotel operates a self-service breakfast buffet and offers light snacks and fruits at its café. This buffet format introduces both opportunities and risks regarding food waste, depending on how consumption is managed and monitored.

3.2.Practices, Outcomes, and Behaviour

The interviews reveal that food waste is managed through a structured system rooted in Accor hotels' broader corporate sustainability program. Accor has adopted a group-wide digital reporting tool, Gaïa, which enables hotels to track waste generation daily and report results monthly. The system records waste from food preparation, buffet service, à la carte operations, and employee canteens, alongside the number of meals served, allowing precise calculation of food waste per guest.

At Ibis Skopje City Center, this system is used to guide sustainability practices and ensure alignment with group objectives. Key measures implemented at the hotel include replacing large buffet plates with smaller ones (21 cm), eliminating individual packaging for condiments, pre-portioning fruit servings, and introducing visual prompts that inform guests about the impact of food waste. Staff are trained regularly, and sustainability communication is integrated into guest interactions.

The data provided by the hotel indicate a significant reduction in food waste over a five-year period. In 2023, food waste totalled 1,868 kg or 60 grams per guest, down from 3,456 kg or 98 grams per guest in 2018 - a reduction of 63%. Approximately 40% of the waste originates from

food preparation activities, while guest plate waste primarily includes cereals, meats, and fruits. Visually imperfect fruits and vegetables are frequently repurposed into compotes or sauces. Guest behaviour emerged as a major contributing factor to waste. Youth groups and guests from less sustainability-aware cultures were found to waste more food, often due to over-serving at buffets. By contrast, guests from more developed countries showed greater awareness and more responsible consumption behaviour.

4. DISCUSSION: OPERATIONALIZING CIRCULARITY IN HOTEL FOOD SYSTEMS

The findings from Ibis Skopje City Center illustrate how a structured and standardized approach to food waste management can yield substantial environmental and operational benefits within a hotel setting. The integration of digital tools such as Gaia allows for accurate measurement, which is widely recognized as a prerequisite for meaningful reduction. Accorhotels' strategy of mandating waste tracking across various stages of service exemplifies a practical application of CE principles within the hospitality industry.

The reduction of waste by 63% over five years aligns with broader sustainability targets set by the group and reflects the effectiveness of combining data-driven monitoring with behavioural interventions. As noted by Kallbekken and Sælen (2013), changes such as reducing plate size and adding motivational messaging can significantly influence consumer behaviour, especially in buffet environments. Moreover, repurposing food that would otherwise be discarded aligns with CE priorities to retain value and minimize loss across the supply chain (FAO, 2017).

The case also underscores the critical role of staff in driving circular practices. Frontline employees - particularly kitchen staff - must be equipped with training and resources to manage waste proactively (Filimonau et al., 2019). Likewise, communication with guests is essential to creating a culture of responsible consumption. This dual focus on internal operations and consumer-facing education exemplifies the systemic thinking required to implement circularity effectively (Corrado & Sala, 2018).

However, several barriers remain. Interviews suggest that external constraints - such as the absence of food donation laws and insufficient infrastructure for composting or redistribution - limit the full realization of circular strategies. These findings are consistent with previous research indicating that systemic and regulatory support is often lacking in food service contexts (Jamnani & Jamnani, 2024).

Finally, the study reinforces that food waste behaviour is influenced by demographic and cultural variables. While some studies downplay the role of gender (Hamerman et al., 2018), the evidence here supports the notion that younger guests and less sustainability-aware groups are more prone to waste. This suggests that guest profiling and tailored awareness campaigns could further enhance waste reduction outcomes.

Overall, the experience of Ibis Skopje illustrates a replicable model of circular food management within a mid-sized hotel that is part of a global network. Its success demonstrates how the hospitality industry can move beyond symbolic sustainability gestures and achieve measurable progress through coherent, data-informed strategies and cross-functional engagement.

Conclusion

This paper has explored how the integration of CE principles in hotel operations - specifically in food waste management can contribute to sustainability outcomes in the hospitality sector. Drawing on a qualitative case study of Ibis Skopje City Center, part of the global Accor hotels network, the research highlights the strategic value of institutionalized sustainability frameworks and the role of measurement, training, and behavioural interventions in achieving tangible environmental impact.

Accor, one of the world's largest and most diverse hotel groups, demonstrates strong corporate sustainability. Operating in 110+ countries with over 5,300 properties, the group aims to cut food waste by 50% by 2030 through Gaïa, its digital waste tracking platform. As of September 2023, 71% of hotels had adopted Gaïa, with full rollout planned by 2025.

The case of Ibis Skopje City Center demonstrates the effectiveness of such a strategy. The hotel achieved a 63% reduction in food waste over a five-year period, decreasing from 3,456 kg in 2018 to 1,868 kg in 2023- equivalent to a reduction from 98 grams to 60 grams of waste per guest. These results were achieved through a combination of operational adjustments (e.g., smaller serving plates, elimination of single-use packaging), staff training, and targeted guest communication. Such measures align closely with CE principles, particularly in terms of resource optimization, waste minimization, and value retention.

The paper also identifies critical structural barriers to deeper circular transformation. These include the absence of enabling legislation for food donation, limited access to infrastructure for composting and recycling, and the lack of tax incentives to encourage sustainable investment. In addition, societal attitudes - shaped by cultural norms and consumer behaviour- remain significant obstacles to reducing food waste at the source. Findings show that younger guests and those from less sustainability-aware contexts tend to waste more, while guests from more developed countries show greater awareness and restraint.

The broader implication of this case study is that robust waste management systems, when embedded within a coherent sustainability strategy, can yield significant environmental and operational benefits for hotels. However, such efforts must be supported by conducive policy environments, staff capacity building, and continuous guest engagement. The integration of measurement technologies, such as Gaïa, plays a pivotal role in not only quantifying performance but also in fostering accountability across all levels of hotel operations.

Ultimately, the experience of Ibis Skopje City Center reinforces the importance of aligning hotel business models with CE objectives. As global environmental challenges intensify and regulatory scrutiny increases, hospitality organizations must move beyond symbolic commitments and adopt systemic, data-driven, and participatory approaches to sustainability. This case offers a replicable model for mid-sized hotels operating under international brands and contributes valuable empirical evidence to the evolving discourse on circularity in the service sector.

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COMPARATIVE ANALYSIS OF CIRCULAR BUSINESS MODELS IN AGRICULTURE

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КОМПАРАТИВНА АНАЛИЗА НА ЦИРКУЛАРНИТЕ БИЗНИС МОДЕЛИ ВО ЗЕМЈОДЕЛСТВОТО

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Abstract: This paper examines circular business models (CBMs) in agriculture through a comparative analysis of six domestic and international cases⁴. Using an inductive exploratory approach, models are assessed across technological characteristics, economic viability, environmental effects, and scalability potential. Findings indicate that CBMs in agriculture function as context-dependent configurations rather than universally transferable templates, and that circular effectiveness does not require high technological sophistication.

Key words: circular economy, circular business models, agriculture, sustainability, comparative analysis

Анстракт: Трудот ги испитува циркуларните бизнис модели (ЦБМ) во земјоделството преку споредбена анализа на шест домашни и меѓународни случаи. Со индуктивен истражувачки пристап, моделите се оценуваат според технолошки карактеристики, економска одржливост, еколошки ефекти и потенцијал за реплицирање. Резултатите покажуваат дека ЦБМ функционираат како контекстуално зависни конфигурации, а не како универзални шаблони.

Клучни зборови: циркуларна економија, циркуларни бизнис модели, земјоделство, одржливост, споредбена анализа

1. INTRODUCTION

Agriculture is increasingly confronted with structural and environmental pressures, including resource depletion, soil degradation, biodiversity loss, and climate instability. Conventional linear production models, based on extract-produce-dispose logics, are progressively inadequate for ensuring long-term sustainability and resilience. In this context, the circular economy (CE) has emerged as a framework aimed at closing material loops, reducing waste, and enhancing resource efficiency across sectors, including agriculture (Geissdoerfer et al., 2017; Ellen MacArthur Foundation, 2019).

Within agricultural systems, circular principles are operationalized through practices such as composting, nutrient recycling, anaerobic digestion, agroecological diversification, and the valorisation of organic waste (FAO, 2021). These practices are embedded in circular business models (CBMs), which integrate environmental objectives into value creation logic rather than treating sustainability as an external constraint (Bocken et al., 2016; Lüdeke-Freund et al., 2019). However, CBMs in agriculture are not uniform. Their

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technological configuration, economic structure, and scale vary significantly depending on resource availability, production structures, and broader development conditions.

Existing literature suggests that circular initiatives in more industrialized contexts are often characterized by higher technological intensity, advanced system integration, and significant capital investment, while less developed or transition economies tend to rely on simpler, locally embedded circular solutions aligned with available resources and incremental innovation pathways (Kirchherr et al., 2018; Murray et al., 2017). This variation does not imply a hierarchy of effectiveness but rather reflects different structural constraints and development trajectories. Despite growing conceptual work on circular agriculture, comparative empirical research examining how diverse CBMs function across such contexts remains limited.

The Republic of North Macedonia represents a case of a small agricultural system characterized by fragmented farm structures, limited mechanization, and constrained investment capacity. In such settings, circular initiatives are more likely to emerge in forms that are technologically moderate or simple yet closely aligned with local resource loops and production practices (Daniloska and Boshkovska, 2025). This context provides a relevant empirical setting for exploring how circular business models operate under structural constraints.

Accordingly, this paper adopts an inductive and exploratory comparative approach to examine selected domestic and international examples of circular business models in agriculture. The selection deliberately combines simpler, locally embedded initiatives from North Macedonia with more technologically advanced and system-integrated models from other countries. This heterogeneity is intentional and designed to illuminate differences in technological characteristics, economic viability, environmental effects, and scalability potential across diverse contexts. By comparing these models, the paper seeks to identify recurring patterns and trade-offs rather than to prescribe a single optimal pathway for circular agriculture.

The paper proceeds with the methodological framework and selection criteria, followed by a comparative analysis of the selected examples and a synthesis of the main findings.

2. MATERIAL AND METHODS

This paper adopts an inductive and exploratory comparative case-study approach to examine selected circular business models in agriculture across different contexts. The analysis relies on illustrative cases in order to identify recurring patterns and trade-offs across different contexts rather than to test predefined hypotheses (Yin, 2018). The objective is analytical generalization through structured comparison, not statistical representativeness.

The study draws on six selected examples: three domestic cases from the Republic of North Macedonia and three international models. The cases were deliberately chosen to reflect variation in technological configuration, scale of operation, and business orientation. This heterogeneity is methodologically intentional, as it allows for comparison across different levels of complexity and development conditions (Ridder, 2017).

In selecting the cases, attention was given to their relevance for comparative analysis rather than to representativeness. The domestic examples illustrate locally embedded and structurally constrained circular initiatives, while the international cases reflect more technologically integrated and system-level configurations. Together, they enable cross-contextual examination of circular business models under diverse structural conditions.

The analytical framework combines descriptive case attributes and four formal analytical dimensions. Descriptive attributes include the type of business model, resource inputs, and final outputs, which provide contextual understanding of each case. Comparative assessment is structured around four key dimensions:

(1) Technological characteristics, referring to the degree of technological integration and process complexity; (2) Economic viability, including value creation logic, revenue streams, and cost-efficiency; (3) Environmental effects, encompassing resource efficiency, waste reduction, and ecological impact; (4) Scalability potential, referring to the capacity for replication, adaptation, or expansion in comparable agricultural contexts. These dimensions are adapted from established circular economy evaluation frameworks (Kirchherr et al., 2017; Ellen MacArthur Foundation, 2019) and provide a consistent basis for systematic comparison across cases.

The analysis relies primarily on secondary data derived from publicly available sources, including official company documentation, organizational reports, media coverage, project materials, and relevant academic literature. All case descriptions are based on verifiable sources, which are cited accordingly in the text and listed in the reference section. While the depth of available information varies across cases, particularly for smaller domestic initiatives, triangulation of sources was applied where possible to enhance analytical reliability and consistency.

3. RESULTS AND DISCUSSION

3.1 Case Descriptions and Analytical Framing

This section presents six selected case studies that illustrate diverse configurations of circular business models (CBMs) in agriculture. Three cases originate from the Republic of North Macedonia and represent locally embedded initiatives operating under structural constraints, while three international examples reflect more technologically advanced and system-integrated models. The cases are intentionally heterogeneous in order to enable comparative analysis across different levels of technological complexity, economic structure, environmental impact, and scalability potential.

Veze Shari-Tetovo, North Macedonia. Veze Shari represents a biogas-based circular model built on the conversion of poultry manure into renewable energy and organic fertilizer (Veze Shari, 2024; ETF UGD, 2021). Through anaerobic digestion, organic waste is transformed into biogas used for electricity generation, while digestate is processed into value-added fertilizer. The model demonstrates moderate technological integration, relying on automated fermentation systems and energy conversion infrastructure. Economically, it benefits from diversified revenue streams, including energy production and fertilizer sales (Club Economy, 2022). Environmentally, it contributes to methane reduction and improved nutrient cycling. Its scalability is contingent on access to feedstock and capital investment but remains viable in contexts with concentrated livestock production.

Kompostara Resen-North Macedonia. Kompostara Resen illustrates a low-technology municipal composting initiative based on the recycling of apple-processing waste into agricultural compost (Prespa Razbudi Se, 2020; Prizma, 2019). The model operates through basic composting techniques with limited mechanization, reflecting low technological complexity. Its economic viability is moderate, primarily linked to reduced waste management costs and potential compost distribution. Environmental effects are significant at the local level, particularly in terms of organic waste reduction and nutrient recovery. Due to its modest investment requirements, the model demonstrates strong replication potential in small municipalities with similar biomass availability. The facility ceased operations around 2017-2018, primarily due to institutional and financing constraints rather than technical infeasibility. This trajectory illustrates a recurring challenge for low-technology circular initiatives in structurally constrained contexts: technical viability does not guarantee operational continuity in the absence of sustained institutional support.

Orizova Bratimka-Cheshinovo-Obleshevo, North Macedonia. Orizova Bratimka represents a hybrid circular model combining resource-efficient rice production with eco-oriented market positioning (ARNO, 2019; Faktor, 2020). The model relies on rational water use, reduced chemical inputs, and environmentally conscious packaging. Technological complexity remains relatively low, centered on agronomic knowledge

and irrigation management rather than advanced automation. Economic viability stems from differentiated market access and eco-branding strategies. Environmental benefits are moderate, particularly in biodiversity preservation and input reduction. The model shows considerable scalability potential within rural regions oriented towards sustainable or organic production.

Ÿnsect-Amiens, France. Ÿnsect exemplifies a high-technology circular model based on insect-based bioconversion of agricultural by-products into protein feed and organic fertilizer (Ÿnsect, 2022). The company operates vertically integrated facilities utilizing automation, robotics, and AI-based monitoring systems. Technological complexity is high, reflecting advanced process optimization and industrial-scale production. Economic viability is supported by substantial investment and access to premium feed markets. Environmental benefits include waste valorization and reduced reliance on conventional protein sources such as fishmeal and soy. The modular design of production units enhances scalability across suitable regulatory and market environments.

Hengelo Integrated Anaerobic Digestion-Composting Plant, Netherlands. This composting plant represents a hybrid circular model combining anaerobic digestion and composting within a decentralized regional framework (BioCycle, 2014). The model integrates farmers, energy producers, and local stakeholders in the conversion of biomass into renewable energy and soil-enhancing fertilizer products. Technologically, it reflects a medium-to-high level of integration, incorporating digestion tanks, energy recovery systems, and compost stabilization processes typical of advanced anaerobic treatment systems in Europe (Baere and Mattheeuws, 2012). Economically, the model relies on diversified revenue streams, including renewable energy production, fertilizer sales, and policy-supported green incentives. Environmentally, it contributes to greenhouse gas mitigation, improved manure management, and reduced dependency on fossil-based inputs. Its scalability is supported by modular infrastructure and regional coordination mechanisms, allowing gradual expansion within comparable agricultural systems.

Kalundborg Symbiosis-Denmark. Kalundborg Symbiosis represents an advanced example of industrial symbiosis, where multiple actors exchange waste streams, heat, and by-products to optimize resource use (Kalundborg Symbiosis, 2020; European Circular Economy Stakeholder Platform, 2025). Although not limited to agriculture, the model includes agricultural resource loops within a broader industrial ecosystem. Technological complexity is high, supported by integrated logistics and coordinated process management. Economic viability arises from cost savings and secondary revenue streams. Environmental benefits are substantial due to systematic waste reuse and heat recovery. Scalability depends on coordination capacity and spatial proximity among participating actors but has demonstrated replicability in similar industrial clusters.

Table 1. Key characteristics of the selected case studies across four analytical dimensions

Model	Technological Characteristics	Economic Viability	Environmental Effects	Scalability Potential
Veze Shari (MK)	Moderate	High	Significant	Strong
Kompostara Resen (MK)	Low	Moderate	High	Strong
Orizova Bratimka (MK)	Low	Moderate to High	Moderate	High
Ÿnsect (FR)	High	High	High	Very High
Hengelo Anaerobic Digestion (NL)	Medium to High	Moderate to High	Significant	High
Kalundborg Symbiosis (DK)	High	High	Very High	High

Source: Authors' own elaboration based on case study analysis.

The table provides a structured overview of the relative positioning of the selected models across the four analytical dimensions. While the domestic cases are generally characterized by lower technological intensity, they demonstrate notable environmental and replication potential within constrained contexts. The

international examples reflect higher technological integration and capital intensity, combined with broader system-level scalability. This structured differentiation provides the empirical basis for the comparative analysis developed in the following section.

3.2 Comparative Analysis Across Analytical Dimensions

Technological Characteristics and System Configuration. Comparison across the selected cases confirms that technological intensity significantly shapes the operational configuration of circular business models, but does not determine their circular effectiveness per se. The Macedonian cases are characterized by low to moderate technological integration. Kompostara Resen and Orizova Bratimka rely primarily on basic infrastructure, agronomic expertise, and incremental process optimization. Circularity in these models emerges through improved resource management and the reintegration of organic flows rather than through advanced digitalization or automation.

In contrast, Ýnsect and Kalundborg Symbiosis represent high-technology and system-integrated configurations. Ýnsect's model depends on controlled production environments, automation, and vertically integrated processing chains, enabling high material throughput and process standardization. Kalundborg operates through coordinated exchanges of energy and by-products among multiple actors, relying on advanced logistics and infrastructure. In these cases, technology functions as an enabler of systemic circularity across broader production networks.

Configurations characterized by moderate technological integration, including the Hengelo integrated anaerobic digestion-composting plant and the Veze Shari biogas system, illustrate a transitional technological profile. These models incorporate technical infrastructure for energy recovery and nutrient management while remaining operationally manageable. The comparison indicates that technological complexity should be interpreted as a configuration variable that influences scale and integration, rather than as a normative benchmark of circularity.

Economic Viability and Value Creation Logic. Economic viability across the examined cases is achieved through diverse value creation mechanisms. The domestic models rely primarily on hybrid and context-sensitive economic logics. Kompostara Resen generates economic value largely through cost avoidance and internal resource recovery, while Orizova Bratimka leverages product differentiation and eco-market positioning to enhance revenue stability. In both cases, circularity supports economic sustainability through incremental efficiency gains and niche market access rather than through scale expansion.

The international high-technology models exhibit more capital-intensive and market-integrated economic structures. Ýnsect operates within premium protein markets, where technological efficiency and product standardization underpin revenue generation. Kalundborg Symbiosis creates economic gains through resource efficiency and cost-sharing mechanisms across interconnected actors. In these cases, circularity strengthens competitiveness by reducing dependency on virgin inputs and improving system-wide efficiency.

Intermediate models combine energy production, input substitution, and diversified outputs, which enhances resilience against market volatility. A central insight emerging from the comparison is that economic stability depends more on diversification of value streams than on operational scale alone. Models integrating multiple forms of economic benefit (energy recovery, waste reduction, premium pricing) or cost savings, demonstrate greater adaptive capacity across different agricultural contexts.

Environmental Effects and Regenerative Potential. All analyzed models generate positive environmental outcomes, though the scope and intensity of these effects vary considerably. The Macedonian low-technology initiatives demonstrate strong localized regenerative impacts. Composting enhances nutrient cycling and soil organic matter, while eco-oriented crop production reduces chemical inputs and supports biodiversity

preservation. These environmental benefits are embedded within local agroecosystems and contribute to cumulative improvements in resource efficiency.

High-technology models extend environmental effects beyond immediate production sites. Ľnsect contributes to reduced reliance on conventional protein sources, thereby lowering pressure on land and marine ecosystems. Kalundborg achieves substantial waste reuse and emission reductions through integrated material exchanges across sectors. These configurations illustrate how advanced coordination can amplify environmental gains at regional or cross-sectoral levels.

However, the comparison also highlights trade-offs. High-technology systems require significant infrastructure and energy inputs, whereas low-technology initiatives operate with smaller ecological footprints but generate more localized impacts. Intermediate models, such as biogas systems, combine emission reduction with nutrient recovery, illustrating how mitigation and regeneration can be jointly achieved. Environmental performance therefore varies along a continuum shaped by system boundaries, resource inputs, and operational scale.

Scalability and Context Compatibility. Scalability emerges as a context-dependent characteristic rather than an inherent property of any specific model. Low-technology initiatives display strong horizontal replication potential due to modest capital requirements and reliance on locally available resources. Their simplicity facilitates adaptation in small-scale agricultural systems and supports incremental expansion.

High-technology models demonstrate vertical scalability through capacity expansion and system integration, yet their transferability depends on financial resources, infrastructural readiness, and stable operational conditions. While replicable in suitable environments, such models are not universally transferable as standardized solutions.

Intermediate systems benefit from modular design principles that allow gradual capacity expansion and integration into existing agricultural structures. Across cases, scalability is most effective when models align with prevailing production structures, resource availability, and market conditions. The findings indicate that compatibility with structural conditions is more decisive for scaling than technological sophistication alone.

Cross-Case Synthesis. The cross-case comparison reveals patterns that extend beyond the individual case descriptions. First, neither technological sophistication nor simplicity guarantees operational sustainability. Kompostara Resen ceased operations despite low investment requirements, while Ľnsect encountered significant financial difficulties notwithstanding advanced technological integration and substantial capital backing. This parallel suggests that circular effectiveness depends less on technological tier and more on the alignment between model design and the structural conditions in which it operates.

Second, a tension emerges between environmental ambition and economic resilience. Models generating the broadest environmental benefits such as Kalundborg Symbiosis and Ľnsect, are also the most capital-intensive and context-dependent, limiting their transferability. Conversely, the most replicable models tend to generate more localized and modest environmental impacts. This trade-off is not a deficiency but a structural feature of circular agriculture that policy frameworks should explicitly account for.

Third, scalability and sustainability do not necessarily align. Several cases demonstrate strong replication potential in theory while facing practical constraints in implementation. Taken together, the evidence suggests that circular business models should be evaluated not only on their performance within favorable conditions but on their resilience under structural and market pressures.

Table 2. Comparative patterns across analytical dimensions

Dimension	Low-Technology configurations	Intermediate configurations	High-Technology configurations
Technological characteristics	Basic infrastructure; knowledge-driven processes	Integrated energy and nutrient recovery systems	Automated, digitally managed, system-integrated operations
Economic logic	Cost avoidance; niche differentiation	Diversified revenue streams; energy and input substitution	Capital-intensive; premium markets; system efficiency gains
Environmental effects	Localized nutrient cycling; soil regeneration	Combined mitigation and regeneration	Broad system-level emission reduction and material efficiency
Scalability	Horizontal replication in small-scale systems	Modular expansion under stable conditions	Vertical scaling in capital-intensive environments

Source: Authors' own elaboration based on comparative analysis.

Table 2 systematizes the comparative patterns identified across the four analytical dimensions and highlights structural differences between low, intermediate, and high-technology configurations. The differentiation does not imply a linear hierarchy of performance, but rather illustrates distinct circular strategies shaped by resource conditions, operational scale, and value creation logic. Importantly, the table also reflects a cross-cutting finding that no technological tier is inherently immune to sustainability challenges, that is operational failure and financial vulnerability are distributed across configurations, suggesting that structural alignment rather than technological choice is the primary determinant of circular model resilience.

4. CONCLUSION

This paper examined selected circular business models in agriculture through a structured comparative analysis across four analytical dimensions: technological characteristics, economic viability, environmental effects, and scalability potential. The findings demonstrate that circularity in agriculture does not follow a single technological or organizational pathway. Instead, circular business models function as context-dependent configurations shaped by resource availability, production structures, and market conditions. A structured cross-context comparison of domestic and international cases provides empirical grounding for these conclusions.

The comparative analysis indicates that technological sophistication is neither a prerequisite nor a guarantee of circular effectiveness. Low-technology models can generate meaningful local environmental and economic benefits when aligned with existing resource flows, while high-technology systems enable broader integration and increased material throughput. Similarly, economic resilience depends more on diversified value creation than on scale alone, and environmental performance varies in scope according to system boundaries and operational intensity. Scalability emerges as a function of structural compatibility rather than technological advancement.

Taken together, these findings reinforce the argument that circular business models should not be approached as universally transferable templates. Their effectiveness depends on the coherence between technological design, value creation logic, environmental objectives, and operational scale within specific agricultural contexts.

Several limitations must be acknowledged. The analysis relies on a limited number of illustrative cases and on secondary data sources, which constrains the depth of empirical verification and quantitative assessment. Differences in data availability across cases introduce asymmetry in the level of detail. Moreover, the study focuses on qualitative comparative patterns rather than on measurable performance indicators.

Future research could expand the empirical base through quantitative evaluation of environmental and economic outcomes, longitudinal analysis of model performance, and broader comparative studies across additional regional contexts. Further investigation into performance metrics and impact measurement would strengthen the analytical foundations of circular agriculture research.

The findings carry practical implications for rural development policy in the Republic of North Macedonia. Given the structural constraints of the domestic agricultural sector, fragmented farm structures, limited mechanization, and constrained investment capacity, low-technology circular models such as composting and eco-oriented production represent the most immediately replicable pathways. Scaling such initiatives require targeted public support in the form of advisory services, co-financing mechanisms, and simplified access to rural development funds. Intermediate models, such as biogas systems, offer viable upgrading pathways where livestock concentration provides adequate feedstock. Policy frameworks should therefore prioritize structural compatibility over technological ambition, supporting circular transitions that align with existing resource endowments and local production conditions.

Overall, the paper contributes to a differentiated understanding of circular business models in agriculture as adaptable configurations whose success depends on strategic alignment with contextual conditions rather than on replication of technologically advanced examples.

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CIRCULAR ECONOMY AND SUSTAINABLE GROWTH - EVIDENCE FROM NORTH MACEDONIA

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Abstract: *Sustainable economic growth has become a central priority for countries striving to balance economic development with environmental protection and social well-being. The concept of the circular economy (CE), which emphasizes resource efficiency, waste reduction and innovation is increasingly recognized as a pathway to achieving long-term sustainability. Estimating an extended Cobb–Douglas production function that incorporates traditional growth drivers (capital, labour) alongside sustainability-related variables (resource productivity, renewable energy,), the paper tests the hypothesis whether the higher resource productivity and renewable energy use, contributes positively to GDP growth while reducing environmental pressures (decreasing CO₂ emissions). The estimation is made with ARDL model and use annual time-series data for North Macedonia (NM) covering the period from 2000 – 2023.*

*The research findings**** reveal that economic growth in North Macedonia is driven by the traditional factors, especially labour. Also, a 1% increase in resource productivity is associated with a 0.75% increase in GDP is a strong and direct validation of the circular economy concept. It shows that North Macedonia can achieve economic growth not just by extracting and using more resources, but by using them more efficiently. This finding directly supports the idea of "decoupling" economic growth from environmental degradation.*

Key words: circular economy, economic growth, resource productivity, renewable energy, CO₂ emissions, North Macedonia

JEL classification: Q0, Q56, O440, E23,

INTRODUCTION

In response to growing environmental degradation, resource scarcity and climate change, the CE has emerged as a transformative model for achieving sustainable economic

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growth. Unlike the traditional linear model of "take-make-dispose" the CE emphasizes resource efficiency, waste minimization and the continual reuse of materials. This model is particularly relevant for developing economies like North Macedonia, where the need to balance economic development with environmental sustainability is increasingly urgent.

North Macedonia has recently taken significant steps toward embracing CE principles. In 2024, the country adopted the OECD Roadmap towards a Circular Economy, aligning with the European Union's Green Agenda and the Sofia Declaration for the Western Balkans. This roadmap outlines over 40 policy recommendations across five priority sectors—SMEs, construction, biomass and food, textiles and mining aimed at improving resource productivity, promoting renewable energy and reducing environmental impact. These policy efforts reflect a growing recognition that CE strategies can serve as a catalyst for long-term sustainable growth. However, the transition remains slow due to weak policy coordination, limited financial support and a continued reliance on fossil fuels. (Daniloska, Boshkovska 2025).

This study investigates the impact of CE indicators on economic growth in North Macedonia from 2000 to 2023. Using an extended Cobb-Douglas production function and the Autoregressive Distributed Lag (ARDL) model, the analysis incorporates GDP as the dependent variable and capital, gross capital formation, labour, resource productivity, renewable energy use and CO₂ emissions as explanatory variables. The goal is to estimate both short and long-run effects of CE practices on economic performance.

By integrating recent policy developments and empirical evidence, this paper aims to provide a comprehensive understanding of how CE influence growth based on estimation on selected variables and will suggest recommendation for successful transition toward sustainable growth in North Macedonia.

1. The importance of CE in the transformation toward sustainable growth in North Macedonia

The CE has emerged as a transformative framework for achieving sustainable growth, particularly in economies facing structural limitations and environmental pressures. In North Macedonia, where productivity remains low and economic growth is largely driven by labour and capital intensification (Djambaska et al., 2022), the CE offers a strategic pathway to decouple growth from resource depletion and environmental degradation. By promoting resource efficiency, waste minimization and regenerative production models, CE can enhance long-term competitiveness and resilience.

North Macedonia's economic structure, dominated by traditional sectors such as agriculture, retail and low-tech manufacturing limits its capacity for innovation and high-value output. The integration of CE principles into these sectors, especially through small and medium-sized enterprises (SMEs), is critical. As Hadzi Naumova-Mihajlovska et al. (2022) emphasize, government policies targeting green economy development in SMEs are essential for fostering environmental sustainability and economic modernization.

The literature underscores the importance of CE in driving sustainable development. Angelova et al. (2022) link CE with ESG (Environmental, Social, and Governance) frameworks, arguing that circular practices reinforce sustainability by reducing emissions, conserving resources and promoting social inclusion. Globally, CE is recognized as a key mechanism for achieving climate goals and mitigating biodiversity loss (Khanna et al., 2022). Moreover, CE contributes to employment generation and innovation, particularly in labour-intensive sectors (Shaheera & Imala, 2024).

Despite policy alignment with EU sustainability directives, North Macedonia's CE transition is hindered by low enterprise productivity, limited green investment and weak institutional capacity. The World Bank's Enterprise Surveys reveal negative productivity growth across key sectors, highlighting the urgency for structural reform (Djambaska et al., 2022). Strengthening governance, stimulating green innovation and enhancing human capital are vital for embedding CE into the national development agenda.

Together, these studies reveal that while North Macedonia has begun aligning with CE principles, significant gaps remain in policy integration, institutional capacity and enterprise-level adoption. The literature consistently calls for coordinated reforms, stakeholder engagement and investment in human capital to unlock CE's full potential for sustainable growth.

Existing literature highlights that CE practices, particularly circular material use (CMU) play a pivotal role in enhancing resource productivity across EU member states. Islam and Afolabi (2025) demonstrate that higher CMU significantly increases a country's likelihood of belonging to a high-resource productivity cluster, underscoring its impact on economic efficiency and sustainability. Similarly, Nowak-Marchewka et al. (2025) emphasize that national strategies aligned with EU CE policies contribute to improved waste management, energy efficiency and long-term competitiveness in countries like Poland, Netherlands and Romania.

While there has been extensive research on the role of resource productivity and CE practices in EU member states, there is still a lack of empirical evidence for small, transition economies like North Macedonia. Most existing studies focus on advanced economies where institutional frameworks and circular infrastructures are already well-developed, leaving a gap in understanding how resource productivity affects growth sustainability in candidate countries with weaker systems. This paper addresses these gaps by providing a country-specific econometric analysis of North Macedonia, thereby contributing to both the academic literature and policy dialogue on sustainable convergence with the EU.

2. CE and sustainable growth in North Macedonia: Evidence from ARDL Estimation

This paper uses an extended Cobb–Douglas production function to estimate the impact of CE determinants on sustainable economic growth in North Macedonia. The model expands beyond traditional inputs of capital and labour by incorporating resource productivity,

renewable energy and CO₂ emissions as additional explanatory variables. This extension allows the analysis to capture both economic and environmental dimensions of growth. The functional form is expressed in log-linear terms as:

$$\ln \text{GDP}_t = \beta_0 + \beta_1 \ln K_t + \beta_2 \ln L_t + \beta_3 \ln \text{RP}_t + \beta_4 \ln \text{REN}_t + \beta_5 \ln \text{CO}_2_t + \varepsilon$$

The changes in the GDP, as a depended variable, it is assumed to be explained with the capital, labour, resource productivity, renewable energy and CO₂ as independent variable of the model. The independent variables were selected based on established economic growth theory and their relevance to CE frameworks, while also reflecting the availability of consistent annual data for North Macedonia. This combination ensures the variables provide both theoretical validity and practical suitability, making them the best fit for the extended Cobb–Douglas model. Therefore, the explanation of the independent variables is:

- Capital (GFC) – expressed as the gross capital formation (GFC) as a% of GDP, measures a country's investment in fixed assets like buildings and machinery. It is a key indicator of investment in the economy. An increase in physical capital stock leads to increased productivity and economic expansion. Hence, it is expected positive influence on economic growth (+).
- Labour (EMP) – represents the level of employment, which is the number of people who are working. According to Okun's Law, there is a strong relationship between employment and economic growth. An increase in employment increases the amount of labour in the production process, which in turn increases economic output (+).
- Resource productivity (RES) - refers to the efficiency with which a country uses its natural resources to generate economic output. An increase in resource productivity means that an economy can produce more goods and services with the same or fewer natural resources, leading to more sustainable and efficient economic activity. This is a key component of green growth theories (+).
- Renewable energy (RENEN) - represents the consumption of energy from renewable sources such as solar, wind and hydropower. The use of renewable energy is linked to sustainable economic growth as it reduces a country's reliance on limited fossil fuels and minimizes environmental pollution (+).
- Carbon dioxide emissions (CO₂) - measures the level of carbon dioxide emissions, which is a common indicator of environmental degradation. The relationship between CO₂ emissions and economic growth is complex. The Environmental Kuznets Curve (EKC) hypothesis suggests that environmental degradation initially rises with

economic development and then declines. Therefore, the influence can be either positive or negative depending on the stage of economic development (+/-).

Table 1 Variables in the mode

Variable	Proxy / Measure	Source
GDP	Gross Domestic Product (constant US\$)	World Bank WDI
K (Capital)	Gross Capital Formation (% of GDP)	World Bank WDI
L (Labour)	Employment / Number of employees	World Bank WDI
RP (Resource Productivity)	GDP per unit of Domestic Material Consumption	Eurostat / State Statistical Office of North Macedonia
REN (Renewable Energy)	Share of renewable energy in total final energy consumption (%)	Eurostat / IEA
CO₂	Carbon dioxide emissions (metric tons per capita)	World Bank / IEA

Note: All variables are transformed into natural logarithms for estimation.

Source: <https://databank.worldbank.org/reports.aspx?source=worldwide-governance-indicators>;
<https://ec.europa.eu/eurostat/data/database>; <https://www.iea.org/data-and-statistics>;

Annual data from the World Bank, Eurostat, the International Energy Agency (IEA), and the State Statistical Office of North Macedonia from 2000 to 2023 were collected. All series were transformed into natural logarithms, enabling the interpretation of coefficients as elasticities.

The analysis applies the Autoregressive Distributed Lag (ARDL) approach, which is particularly suited for small sample sizes and mixed integration orders of variables. Prior to estimation, unit root tests (ADF, PP, KPSS) were conducted to determine the stationarity properties of the data. The ARDL bounds testing procedure was then applied to assess the existence of long-run relationships among the variables.

The ARDL framework provides both short-run dynamics and long-run equilibrium estimates, making it ideal for assessing the sustainability of growth. An error correction mechanism (ECM) was included to capture the speed of adjustment toward equilibrium. Diagnostic tests for serial correlation, heteroskedasticity, normality and model stability were performed to ensure robustness of results.

This methodological framework ensures that the study not only quantifies the contributions of traditional factors but also evaluates the role of CE practices in shaping long-run sustainable growth in North Macedonia.

Table 2 ARDL Estimation Results (Dependent Variable: LNGDP)

Variable	Coefficient	Std. Error	t-Statistic	p-Value
LNGDP(-1)	0.2593	0.0817	3.1734	0.0247**
LNGCF (Capital)	-0.3785	0.1126	-3.3621	0.0201**
LNEMP (Labor)	1.2781	0.2769	4.6160	0.0058***
LNCO₂	0.1349	0.0810	1.6651	0.1568
LNRENEN (Renewable energy)	-0.2601	0.0574	-4.5313	0.0062***
LNRES (Resource productivity)	0.7537	0.0911	8.2752	0.0004***
C (Constant)	-7.4531	2.9439	-2.5317	0.0524*

$R^2 = 0.999$; $Adj. R^2 = 0.998$; F -statistic = 792.72 ($p = 0.0000$).

Source: own estimations using E-views statistical packages

The empirical findings (table 2) partly confirm theoretical expectations, while also revealing notable deviations. Estimated coefficient of the GDP evident positive and statistically significant effects (0.26), that suggest that around 26% of previous year's GDP carries over to current year. This confirms growth inertia in the economy, meaning that past performance strongly influences at current output.

In alliance with the growth theory, labour emerges as a strong positive contributor to GDP, with an elasticity greater than one (1.278, $p = 0.0058$). So, a 1% increase in employment contributes to about 1.28% increase in GDP. This confirms the strong role of human capital and labour input as a driver of growth and economic performance in North Macedonia. Also, the model confirms the positive and a highly significant influence of resource productivity on growth (0.7537, $p = 0.0004$), aligns with CE theory. This confirms that efficiency in material use directly enhances competitiveness and sustainability, highlighting resource productivity as a key policy lever for achieving both economic and environmental goals.

By contrast, the results for capital formation, renewable energy, and CO₂ emissions diverge from theoretical predictions. Capital, expected to positively affect GDP, shows a significant negative impact, suggesting inefficiencies and potential misallocation of investments into less productive or resource-intensive sectors. Renewable energy also displays a negative relationship with growth, contrary to its theoretical role as a driver of sustainable development. This likely reflects the short-run costs of transitioning to renewables and the country's structural dependence on fossil fuels. Finally, CO₂ emissions, expected to reduce growth through environmental degradation, appear positive but statistically insignificant, indicating that growth remains only partially decoupled from emissions.

Table 3 Short – run coefficient (Bound test)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP(-1)*	-0.740638	0.080831	-9.162847	0.0003
LNGCF**	-0.378549	0.103464	-3.658766	0.0146
LNEMP**	1.278087	0.224997	5.680475	0.0024
LNCO2**	0.134885	0.082148	1.641976	0.1615
LNRENEN**	-0.260059	0.065023	-3.999529	0.0103
LNRES**	0.753662	0.086781	8.684685	0.0003
C	-7.453127	2.271358	-3.281353	0.0219

Source: own estimations using E-views statistical packages

The short-run coefficients represent the immediate impact of a change in an independent variable on the dependent variable. The coefficient from the Bound test (table 3) shows that GCF, EMPL and RES are statistically significant. Therefore, short-run coefficients that are statistically significant: labour coefficient of 1.278087 (Prob. 0.0024) indicates that a 1% increase in the change of employment leads to a 1.28 % increase in the change of GDP in the short term, resource productivity 0.753662 (Prob. 0.0003), where 1% increase of the resource productivity leads to a 0.75 % increase in GDP in short term (table 3).

Table 4 Long-Run Cointegration Results

Variable *	Coefficient	Std. Error	t-Statistic	Prob.
LNGCF	-0.511112	0.111596	-4.580026	0.0025
LNEMP	1.725657	0.213947	8.065823	0.0001
LNCO2	0.182121	0.107570	1.693038	0.1343
LNRENEN	-0.351129	0.077123	-4.552843	0.0026
LNRES	1.017585	0.035357	28.78056	0.0000

*Notes: ***, *, * denote significance at the 1%, 5%, and 10% levels, respectively.

The results confirm a stable long-run equilibrium relationship between GDP, capital, labour, CO₂ emissions, renewable energy, and resource productivity.

Source: own estimations using E-views statistical packages

Based on the cointegrating results (table 4) in the long run, GCF, EMP RENEN and RES all have a statistically significant relationship with the dependent variable. A positive long-run relationship was found for employment and non-renewable energy consumption, while, a negative one was found for capital formation and renewable energy consumption. However, the effect of carbon emissions was not statistically significant.

The Breusch-Pagan-Godfrey test is used to check for heteroskedasticity. The results are F-statistic - 3.876592 with a probability of 0.0793 and R^2 is 9.876824 with a probability of 0.1299. Since the p-values for both the F-statistic and the R^2 are greater than the conventional significance level of 0.05, we fail to reject the null hypothesis of homoskedasticity. This means that the model's residuals do not show evidence of heteroskedasticity. The use of Huber-White-Hinkley (HC1) heteroskedasticity consistent standard errors in regression further ensures the reliability of t-statistics and probabilities, even if heteroskedasticity were present. The Ramsey RESET test evident the F-statistic that is 6.627767 with a p-value of 0.0617. Results suggest that there is no statistically significant evidence of a model specification error. This Ramsey RESET test confirms that the linear functional form of the model is appropriate for the data and that there no major omitted variables or non-linear relationships that need to be addressed.

3. Policy recommendation

The empirical results of the extended Cobb–Douglas model highlighted the critical role of labour and resource productivity in driving sustainable economic growth in North Macedonia. To capitalize on these findings, policymakers should prioritize strategies that enhance human capital and promote efficient resource use.

Strengthen labour market policies - Given the strong elasticity of employment (1.278), investments in education, vocational training, and labour mobility should be intensified. These measures will not only boost productivity but also ensure inclusive growth by integrating more citizens into the formal economy.

North Macedonia's commitment to human capital development is firmly established in the Strategy for Human Capital Development 2022-2030, which outlines a long-term vision for improving education, workforce skills and labour market inclusion. The strategy prioritizes modernizing vocational education and training (VET), promoting lifelong learning and enhancing labour mobility especially for youth, women and vulnerable groups. These goals are reinforced by the Employment and Social Policy Reform Programme (ESRP) and the Economic Reform Programme (ERP) 2023-2026, which emphasize targeted training, adult education and activation measures. Strengthen labour market policies and investment in vocational training directly supports these national priorities, aligning with the broader objective of building a competitive, inclusive and workforce ready for future. (Roadmap North Macedonia, 2024)

Promote resource efficiency - Resource productivity shows a robust positive impact on GDP (0.7537), affirming its centrality to CE success. Policies should support eco-innovation, industrial symbiosis and waste-to-resource initiatives. Tax benefits or subsidies for firms adopting resource-efficient technologies can accelerate this transition. The OECD's Roadmap towards Circular Economy of North Macedonia (OECD, 2024) identifies resource efficiency as a cornerstone of sustainable growth. The recommendation to stimulate eco-innovation and industrial symbiosis directly supports this roadmap, which promotes circular business models and better material use across sectors like construction, textiles and food.

Reform capital allocation - The negative impact of capital formation suggests inefficiencies in investment targeting. A national investment audit should be conducted to redirect funds toward high-productivity and low-carbon sectors. Public-private partnerships in green infrastructure and digital transformation can enhance capital effectiveness. This aligns with OECD concerns about misallocated resources and the need for better investment targeting. Investment audit and redirection toward green infrastructure fills a critical gap in current policy execution.

Accelerate renewable energy transition – Use of renewable energy currently shows a negative growth correlation, likely due to transitional costs. To reverse this, the government should implement phased subsidy schemes, grid modernization and local capacity-building to reduce dependency on fossil fuels and improve renewable integration. North Macedonia has committed to the Green Agenda for the Western Balkans and EU climate goals, including expanding renewable energy. However, the recommendation address transitional costs and grid modernization reflects the OECD's observation that infrastructure limitations and financial constraints are slowing progress.

Decouple growth from emissions - the weak link between GDP and CO₂ emissions highlights the need for stronger decarbonization policies. Introducing carbon pricing, enhancing emissions monitoring and supporting low-emission technologies will help align economic growth with environmental sustainability (Daniloska et.al 2025). Emphasizing the carbon pricing and emissions monitoring echoes the roadmap's call for stronger environmental governance. While CO₂ emissions are acknowledged in national strategies, this recommendation adds urgency and specificity to the decoupling challenge that remains unresolved.

By aligning policy with these findings, North Macedonia can foster a resilient, inclusive and green economy that meets both present and future sustainable development goals.

CONCLUSION

This study aims to analyze the relationship between CE determinants and economic growth in North Macedonia using an extended Cobb–Douglas production function and the ARDL methodology. The findings provide important insights into how traditional and sustainability-related factors shape the country's growth trajectory. The results highlight labour and resource productivity as the strongest positive contributors to GDP. Labour elasticity exceeds unity, indicating that employment expansion has a substantial effect on growth, while resource productivity has a robust and highly significant impact. This confirms the theoretical argument that greater efficiency in resource use directly supports competitiveness and sustainable expansion. For North Macedonia, policies that enhance skills, human capital and resource efficiency will be critical to aligning growth with EU sustainability objectives. Conversely, gross capital formation exerts a negative effect on growth. This suggests inefficiencies in investment allocation, with capital directed toward sectors that do not generate sufficient productivity gains. Similarly, the share of renewable energy shows a negative impact

on GDP. While counterintuitive, this may reflect the high transition costs of renewable deployment and structural reliance on fossil fuels. These findings point to the need for better integration of renewables and more strategic, productivity-oriented investment. The effect of CO₂ emissions is positive but insignificant, implying that growth in North Macedonia remains only partially coupled to environmental pressures. The significant error correction term indicates that the system is stable and converges quickly to long-run equilibrium, confirming the presence of a durable relationship between GDP and the included variables.

Overall, the results of the ARDL model suggest that sustainable growth in North Macedonia will depend less on traditional capital accumulation and more on labour productivity, resource efficiency and effective energy transition policies. Strengthening these areas will be essential for meeting EU accession goals and achieving long-run sustainable convergence.

To ensure sustainable economic growth, North Macedonia must prioritize labour market development through strategic investments in education, vocational training and workforce mobility. Advancing resource efficiency by promoting eco-innovation and CE practices is essential for aligning productivity with environmental goals. Capital allocation reforms should redirect investment toward high-productivity and low-carbon sectors, while the renewable energy transition requires phased subsidies and infrastructure modernization. Finally, implementing robust decarbonization measures such as carbon pricing and emissions monitoring will help decouple growth from environmental degradation, positioning the country toward a resilient and inclusive future.

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