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STRATEGIC INTEGRATION OF SUSTAINABILITY, CIRCULAR ECONOMY, AND BLOCKCHAIN IN SLOVENIAN URBAN GOVERNANCE

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Abstract Slovenia has 12 urban municipalities, each with a sustainable development strategy aligned with the Agenda 2030 framework and valid through 2030. This paper examines how these strategies incorporate emerging technologies, particularly blockchain, and innovative sustainability concepts such as the circular economy. Achieving the goals of Agenda 2030, especially transitioning to a circular economy, requires doubling energy efficiency by 2030. While blockchain and the circular economy have often been studied separately, this research explores their intersection within the context of urban sustainability. The study applies qualitative content analysis to the official development strategies of all 12 urban municipalities. This analysis is complemented by semi-structured interviews with senior officials from the Ministry of the Environment, Climate and Energy, and the Vice Mayor of Ljubljana, providing institutional perspectives on strategic priorities and implementation logic. This is the first comprehensive analysis of how Slovenian urban municipalities address the interconnected themes of sustainability, circular economy, and blockchain technology. The findings contribute to academic discussions and offer practical recommendations to enhance innovation in urban sustainability planning.

Keywords
Blockchain,
Circular economy,
Energy efficiency,
Agenda 2030,
Urban Municipality

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1 Introduction

Slovenia is composed of 212 municipalities, of which only 12 hold the status of *urban municipalities* (Republic of Slovenia, 2025). In accordance with the United Nations' Agenda 2030 (UN, 2015) and Slovenia's National Development Strategy 2030 (Government of the Republic of Slovenia, 2017), these urban municipalities are required to develop sustainable development strategies that address key environmental, economic, and social challenges. These strategies serve as foundational planning documents and are prerequisites for accessing European Union funding instruments such as the European Regional Development Fund (ERDF) and the Just Transition Fund (JTF).

This paper examines the strategic documents of all 12 urban municipalities in Slovenia from three interrelated perspectives:

- ✓ the degree to which sustainability is emphasised as a guiding policy principle;
- ✓ the extent to which emerging technologies, specifically blockchain, are integrated as tools for sustainability; and
- ✓ the incorporation of circular economy principles into long-term planning.

These perspectives were selected based on their strategic relevance to both European and national policy agendas. Sustainability represents the overarching normative goal; the circular economy serves as a practical and systemic framework for achieving it; and blockchain technology is explored as an enabler that can enhance implementation through transparency, traceability, and operational efficiency (European Commission, 2020; OECD, 2022).

In this study, sustainability primarily refers to *ecological sustainability*—the responsible use and protection of the natural environment through conservation and sustainable practices—in line with Goal 12 of the UN Sustainable Development Goals: *Responsible Consumption and Production*. However, the analysis also considers the social and economic dimensions of sustainability, as defined in the Brundtland Report (1987) and reflected in Slovenia's national strategy.

Understanding the link between sustainability and the circular economy is essential. While sustainability articulates normative objectives such as ecosystem preservation, emissions reduction, and intergenerational equity, the circular economy provides a systemic means of achieving these goals by closing material and energy loops,

minimising waste, and regenerating natural systems (Ellen MacArthur Foundation, 2013; Kirchherr et al., 2017).

Urban municipalities are the focus of this study because they are Slovenia's most densely populated and economically dynamic areas. They are key sites for policy innovation and are major recipients of EU funding under the green and digital transitions. If these municipalities fail to incorporate advanced tools such as blockchain or circular economy frameworks into their strategic documents, it may signal broader systemic barriers to innovation adoption across the country.

To explore this issue, we conducted a qualitative content analysis of the sustainable development strategies of all 12 urban municipalities. This document analysis was complemented by semi-structured interviews with senior officials at the Ministry of the Environment, Climate and Energy, who oversee urban development policy, and with the Vice Mayor of Ljubljana, who is responsible for digital transition. These interviews yielded insights into the motivations, institutional dynamics, and perceived barriers to adopting innovative technologies and sustainability frameworks at the municipal level.

Although academic literature has addressed blockchain and the circular economy as separate topics, few studies examine their intersection within the context of urban sustainability. This paper seeks to address this gap by offering the first in-depth analysis of how Slovenia's urban municipalities conceptualise and operationalise the relationships among sustainability, the circular economy, and blockchain technology. The paper concludes with policy recommendations tailored to local government contexts and identifies priority areas for future research and innovation.

2 Methodology

This study adopts a qualitative research design, combining document-based content analysis with semi-structured expert interviews to explore how the principles of sustainability, circular economy, and blockchain technology are reflected in the strategic development documents of Slovenia's 12 urban municipalities.

2.1 Data Sources

The primary data source consists of the officially published Sustainable Urban Strategies (Trajnostne urbane strategije, TUS) and related development plans of all

12 urban municipalities, available on their official websites.[1] These documents are foundational planning tools required under Slovenia's national development framework and the European Union's integrated territorial investment (ITI) policy. In total, 12 strategic documents were systematically reviewed, ensuring full coverage of the urban municipal landscape.

To complement the document analysis, semi-structured interviews were conducted in early 2025 with senior officials from the Ministry of the Environment, Climate and Energy,[2] and the Vice Mayor of Ljubljana,[3] who oversees digital and circular economy initiatives in the capital city. These interviews provided institutional insights into policy design logic, implementation practices, and the reasons behind the (non)adoption of specific concepts.

2.2 Analytical Approach

- ✓ A directed qualitative content analysis approach was applied (Hsieh & Shannon, 2005). This method begins with predetermined coding categories, "sustainability," "circular economy," and "blockchain technology", based on concepts defined in the literature. Within each strategic document, these keywords were identified, their frequency recorded, and their contextual usage examined.
- ✓ Keyword frequency was used as a proxy for conceptual emphasis. The assumption is that strategic priorities are reflected in the visibility and recurrence of key terms.
- ✓ Where terms appeared frequently, their surrounding text was analysed to assess how they were operationalised (e.g., linked to specific goals, measures, funding instruments).
- ✓ Where terms were absent, municipal strategies were cross-referenced with sectoral documents or interview data to account for potential terminological or institutional misalignment.

[1] The Association of Urban Municipalities of Slovenia, available at: https://zmos.si/ctn/ctn-tus-21-27/ (accessed 28.5.2025)

[2] The answers were provided by senior officials at the Ministry of the Environment, Climate and Energy, Sector for Strategic Spatial Development: Mag. Ines Lupše, Mag. Mojca Piry, and Mag. Lenća Humerca Šolar."

[3] The answers were provided by Vice Mayor of Ljubljana, Boštjan Koritnik and Nataša Jazbinšek Seršen, Head of the Environmental protection at the City Administration of Ljubljana.

To ensure comparability across documents of varying lengths and styles, raw keyword counts were interpreted qualitatively, not statistically. Documents were reviewed holistically to avoid overinterpreting superficial mentions.

2.3 Limitations

This study acknowledges that keyword frequency alone cannot fully capture the depth or quality of strategic commitment. Some municipalities may engage in circular economy or blockchain initiatives under different terminology or outside the primary strategic framework. To mitigate this, the study triangulated findings with expert interviews, which helped contextualise document gaps and provided deeper institutional understanding.

Future research should include case studies of implementation, interviews with local stakeholders (e.g., civil society or business actors), and analysis of funded projects to provide a more comprehensive assessment of actual practice versus strategic framing.

3 Sustainability as a Guiding Principle in Urban Development

Sustainability has become a central normative principle in urban planning and development, encompassing far more than environmental protection. As defined by the World Commission on Environment and Development (commonly known as the Brundtland Report, 1987), sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Contemporary understandings of sustainability incorporate three interconnected dimensions: environmental, economic, and social (UN, 2015; OECD, 2021).

In urban contexts, the significance of sustainability is amplified. Cities are the primary consumers of resources, major emitters of greenhouse gases, and simultaneously hubs of innovation and policy experimentation. They are also the settings in which many of the world's most pressing challenges, climate change, energy transitions, social inequality, must be addressed (European Environment Agency, 2020). Consequently, sustainability has become a foundational concept in the formulation of municipal development strategies, as reflected in the European Green Deal (European Commission, 2019) and the United Nations' Sustainable

Development Goals (SDGs), particularly Goals 11 (Sustainable Cities and Communities) and 13 (Climate Action).

Urban sustainability strategies often aim to (IPCC, 2022):

- ✓ Reduce greenhouse gas emissions through renewable energy use, green infrastructure, and sustainable mobility;
- ✓ Promote resource efficiency, especially in energy, water, land, and materials;
- ✓ Protect natural ecosystems and biodiversity within and around urban areas;
- ✓ Ensure social equity, access to services, and public participation;
- ✓ Build climate resilience, enhancing cities' ability to adapt to environmental stresses.

While the normative framework for sustainability is well-established, implementation remains challenging due to institutional, financial, and technological barriers (Meadowcroft, 2007; Bulkeley & Betsill, 2013). Understanding how local governments operationalise sustainability, by translating abstract principles into concrete strategies and actions, is therefore critical.

In Slovenia, the National Development Strategy 2030 explicitly positions sustainability as the overarching development paradigm. It advocates a comprehensive approach that balances environmental responsibility with economic competitiveness and social inclusion (Government of the Republic of Slovenia, 2017). However, the degree to which this strategic vision is embedded in municipal-level planning remains an open empirical question.

This paper addresses this gap by analysing how sustainability is conceptualised and embedded in the strategic development documents of Slovenia's 12 urban municipalities. It evaluates both the breadth of sustainability goals and the specificity of proposed actions, thereby shedding light on the actual alignment between national policy visions and local implementation.

4 Blockchain Technology and Its Potential for Sustainability

Blockchain technology entered public consciousness through its first application: the cryptocurrency Bitcoin (Nakamoto, 2008). Since its introduction in 2009, blockchain has evolved significantly, giving rise to flexible, distributed platforms such as Ethereum and Hyperledger Fabric (Lockl et al., 2020). These developments have expanded blockchain's utility well beyond cryptocurrencies, drawing growing attention from researchers and practitioners for its transformative potential in various domains (Beck, 2018).

At its core, blockchain is a distributed ledger system that uses consensus mechanisms to validate transactions without relying on a central authority. The most established consensus algorithm, Proof of Work (PoW), requires participants (miners) to solve complex mathematical problems, a process that consumes substantial amounts of energy. For example, the Bitcoin network consumes more electricity than many countries, largely due to its reliance on PoW. However, alternative mechanisms such as Proof of Stake (PoS) have emerged, offering more energy-efficient solutions. PoS enables validators to confirm transactions based on the amount of cryptocurrency they "stake," thereby reducing energy intensity.

Blockchain's decentralised nature, where all participating nodes maintain synchronised replicas of the ledger, removes the need for intermediaries such as banks or notaries (Crosby et al., 2016). This attribute has made blockchain attractive for applications where trust, transparency, and tamper-resistance are essential.

The energy implications of blockchain have been a major focus of scholarly analysis. Sedlmeier et al. (2020), building on studies by Vranken (2017) and Krause & Tolaymat (2018), estimated the energy consumption of five leading cryptocurrencies. Their findings suggest that PoW-based blockchain energy use correlates strongly with market capitalisation, due to incentives such as block rewards. Despite concerns over energy use, the authors conclude that blockchain technologies do not constitute a critical threat to the climate and highlight their broader potential for supporting sustainable innovation.

In the energy sector, blockchain is increasingly viewed as an enabler of eco-efficiency. Schletz et al. (2020) examined blockchain's application in peer-to-peer energy trading, white certificate schemes, and energy service companies. Their findings illustrate how blockchain's functionality varies across implementation models, but consistently contributes to improved resource management. Shrier et al. (2016) argue that blockchain's capacity for secure, decentralised data exchange aligns with broader data-driven transformations in sustainable development.

From a public sector perspective, blockchain's relevance is twofold. First, governments are both regulators and beneficiaries of energy efficiency initiatives. Second, public management reforms, such as the New Public Management movement, have encouraged performance-based governance and cost-efficiency through structures like Shared Service Centres (SSCs) (Dorrel, 1993; Kukovič & Justinek, 2020). SSCs, which centralise services such as finance, IT, and legal functions, exemplify efficiency-oriented reforms. For instance, the joint SSC established by the City of Wodonga and the Rural City of Wangaratta in Australia

used blockchain-supported systems to conduct municipal energy audits (City of Wodonga, 2020).

The renewable energy sector plays a central role in the global transition to sustainability (Alsunaidi & Khan, 2022). Renewable sources such as solar, wind, hydro, geothermal, and biomass offer low-emission alternatives to fossil fuels and are essential for mitigating climate change (Lohani et al., 2023). According to the International Energy Agency (IEA, 2023), global investment in clean energy has grown by 40% since 2020, and one in five vehicles sold in 2023 was electric (Muir & Campbell, 2023). However, challenges remain, including energy intermittency, high capital costs, and the complexity of integrating renewables into existing grid infrastructure (Guo et al., 2021; Enescu et al., 2020; Junaidi et al., 2023).

Blockchain has emerged as a promising technology to address these challenges (Aman et al., 2024). Its immutable and transparent data management capabilities can streamline peer-to-peer energy trading, certify green energy sources, and enhance demand-side flexibility (Abdella, 2018; Barcelo, 2023; Wu et al., 2021). As Rejeb & Zailani (2023) note, blockchain is gaining traction across multiple sectors, and its role in energy markets is expanding rapidly. The global blockchain-in-energy market was valued at USD 278 million in 2019 and is projected to reach USD 81.2 billion by 2032, growing at a compound annual growth rate (CAGR) of 56.1% (Emergen Research, 2023).

5 Circular Economy: A Framework for Sustainable Energy Transition

The global energy crisis is among the most pressing challenges of the 21st century. Rising energy prices, increasing dependence on imported fossil fuels, and escalating greenhouse gas emissions threaten environmental sustainability, economic stability, and geopolitical security. As certain fossil fuel resources become scarcer and costlier to extract, urgent and systemic action is required to reduce emissions and accelerate the transition toward sustainable energy systems (World Experience, 2024). One promising avenue for addressing these challenges is the adoption of circular economy principles.

Growing environmental awareness has brought attention to an array of global issues, including climate change, air and water pollution, biodiversity loss, and the depletion of natural resources. These issues affect all regions, irrespective of their level of development, reinforcing the urgency of environmental sustainability as a universal priority. Solutions increasingly focus on leveraging advanced technologies and

renewable energy systems to decouple economic growth from environmental degradation.

In the current international policy landscape, the 2030 Agenda for Sustainable Development (Korhonen et al., 2018) and the United Nations Sustainable Development Goals (UN SDGs) (Smith et al., 2018) provide the normative foundation for sustainability action. At the European level, the European Green Deal (European Commission, 2019) sets a bold objective: transforming the European Union into a fair and prosperous society with a resource-efficient, competitive economy that achieves net-zero greenhouse gas emissions by 2050. The Green Deal further aims to protect natural capital, promote public health, and ensure a just transition for all citizens (Skousen, 2007).

The circular economy has gained global traction as a strategic model for achieving sustainable development. Unlike the traditional linear model, based on "take, make, dispose", the circular economy seeks to design out waste and pollution, keep products and materials in use for as long as possible, and regenerate natural systems. This systemic shift not only enhances resource efficiency but also reduces the environmental footprint of production and consumption activities.

The integration of circular economy principles with energy efficiency represents a critical intersection in the pursuit of sustainability. A circular approach promotes reduced energy consumption throughout the entire product lifecycle, from design and manufacturing to reuse, recycling, and remanufacturing. These strategies contribute to lower greenhouse gas emissions, reduced dependency on finite resources, and more sustainable production-consumption patterns.

One area where this convergence is particularly evident is industrial process optimisation. Advances in recycling technologies, including high-precision material separation and low-energy reprocessing, enable the recovery of high-quality materials with far less energy than required for primary resource extraction. Similarly, extending product lifespans through reuse, refurbishment, and remanufacturing reduces the frequency of energy-intensive manufacturing cycles. Emerging technologies such as energy-efficient 3D printing and modular product design support circularity by facilitating easy maintenance, part replacement, and component reuse.

Together, these innovations help build resilient and sustainable production systems. As the global community intensifies efforts to address the climate crisis, circular economy strategies, particularly when coupled with energy efficiency and

technological innovation, offer a transformative pathway toward a low-carbon, resource-resilient future.

6 Circular Economy and Blockchain Technology: Synergies for Sustainable Innovation

Blockchain technology holds significant promise at the intersection of the circular economy and energy efficiency. Its core attributes, decentralisation, transparency, and immutability, offer innovative solutions for managing resource flows more effectively. By providing secure platforms to track material and energy use across product lifecycles, blockchain enhances accountability and supports the implementation of circular practices. For instance, blockchain-based systems can authenticate the origin, composition, and recycling history of materials, ensuring compliance with sustainability standards and enabling circular supply chains.

In the energy sector, blockchain enables peer-to-peer energy trading within decentralised microgrids, thereby facilitating renewable energy integration and localised, energy-efficient solutions. Smart contracts, self-executing agreements coded on the blockchain, can further optimise reverse logistics and recycling systems by automating transactions, reducing administrative overhead, and improving the efficiency of material recovery processes.

The integration of renewable energy into circular economy strategies amplifies the benefits of both approaches. Material recovery facilities powered by renewable energy or decentralised clean energy solutions at the community level can significantly reduce emissions. Emerging circular practices such as urban mining and bio-based material loops provide opportunities to align resource recovery efforts with sustainable energy transitions. By addressing energy, material, and data flows holistically, the convergence of circular economy principles, energy efficiency, and blockchain technology accelerates the transition to net-zero emissions while enhancing resilience and resource stewardship.

The alignment of blockchain with circular economy objectives supports the development of sustainable, efficient, and transparent business models. Blockchain's traceability and automation capabilities reinforce core circular economy strategies, narrowing, slowing, and closing material and energy loops (Pieroni et al., 2019). Despite existing integration challenges, its potential to drive environmental sustainability and resource optimisation underscores the importance of continued technological advancement.

As global material consumption and waste production are projected to double by 2050, there is growing urgency to decouple economic growth from environmental degradation (European Commission, 2020). The circular economy is increasingly recognised as a viable framework for this transition, emphasising systemic change across production and consumption cycles (Franzo et al., 2021). This transformation is further reinforced by the emergence of digital technologies under the banner of Industry 4.0.

Technologies such as the Internet of Things (IoT), big data analytics (BDA), artificial intelligence (AI), and additive manufacturing (e.g., 3D printing) are reshaping industrial processes, supply chains, and consumer behaviour (Lasi et al., 2014; Vaidya et al., 2018). These digital tools enable automated production, smart resource management, and real-time decision-making, key enablers of circularity (Whitmore et al., 2015). In manufacturing, they support equipment retrofitting, smart factories, and the design of closed-loop production systems (Stock & Seliger, 2016).

The synergy between digitalisation and circular economy practices is receiving growing attention. Studies have shown that digital technologies not only support existing circular economy strategies but also create new business models and value creation pathways (Awan et al., 2021; Rosa et al., 2020). Liu et al. (2022) highlight how such technologies systematically enhance the design and implementation of circular systems, especially in terms of lifecycle tracking, resource efficiency, and stakeholder collaboration.

Blockchain, in particular, plays a critical role in enabling multi-lifecycle tracking and facilitating trust among diverse actors in circular value networks. For example, blockchain-supported platforms can monitor product reuse, enable predictive maintenance, and foster new models such as cooperative competition (coopetition) and prosumer-based economies. As circular economy ecosystems expand, blockchain offers a means to simplify verification processes and strengthen information exchange across increasingly complex stakeholder networks.

However, several challenges remain. Future research should investigate the scalability, interoperability, and cost-efficiency of blockchain solutions in circular contexts. It is also essential to design blockchain architectures that meet the specific needs of circular economy applications, particularly in terms of privacy, security, and usability. Exploring how blockchain can support repairability and long-term product stewardship remains a key research gap with practical implications for reducing environmental impact.

7 Sustainability, Blockchain, and the Circular Economy in Urban Municipalities of Slovenia

This study, conducted in 2024, analysed the sustainable development strategies of all 12 urban municipalities in Slovenia to evaluate the integration of three critical components: sustainability, blockchain technology, and the circular economy. In addition to document analysis, the research was enriched by semi-structured interviews with senior officials at the Ministry of the Environment, Climate and Energy and the Vice Mayor of Ljubljana, offering valuable insight into both national policy alignment and local strategic approaches.

7.1 Strategic Alignment and Context

All 12 urban municipalities have adopted sustainable development strategies. This consistency is largely driven by regulatory frameworks requiring such strategies as a condition for participation in EU funding mechanisms, such as Integrated Territorial Investments (ITI) and Cohesion Policy funds. According to the Ministry, the strategies, particularly those developed or updated after 2020, are aligned with Slovenia's Spatial Development Strategy 2050 (ReSPRS50) and the EU's Territorial Agenda 2030.

"Municipalities are legally obliged to ensure that local development strategies are not in conflict with national strategic frameworks. The ReSPRS50 incorporates the goals of Slovenia's 2030 Development Strategy and integrates the Territorial Agenda of the EU," explained ministry officials.

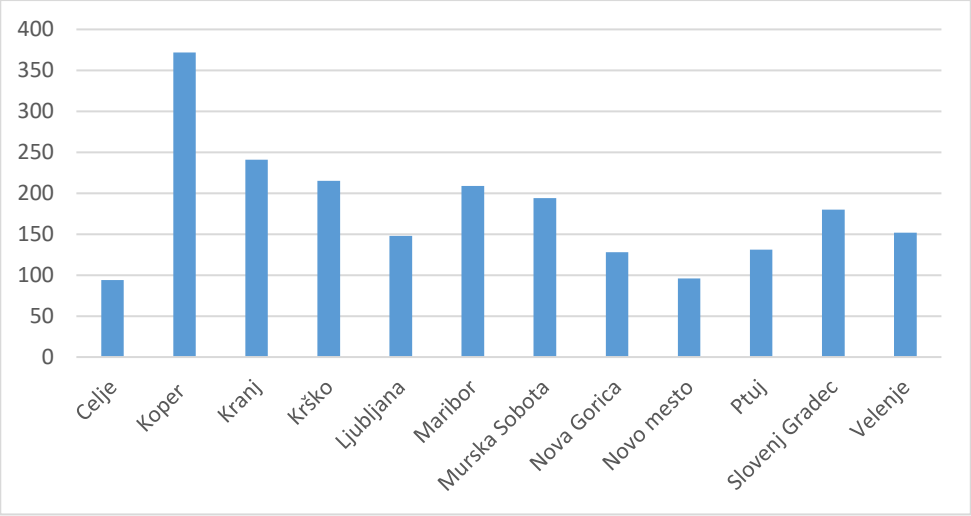
However, the format and depth of these strategies vary considerably. While some municipalities produced lengthy, professionally designed documents, others published more concise and basic versions. Despite differences in presentation, the presence or absence of key concepts such as blockchain and circular economy is telling and indicates broader institutional priorities.

7.2 Sustainability: Strong Declarative Commitment

As expected, sustainability features prominently across all documents. The term appears at least 100 times in each strategy, with Koper leading at over 350 mentions. Krško (215 mentions) and Velenje (150 mentions) also score high, which aligns with

their significance as sites of Slovenia's nuclear and coal power plants. This indicates a widespread declarative commitment to sustainability principles.

Figure 1: Frequency of the term "Sustainability" in Strategic Development Strategies of Slovenian Urban Municipalities



Source: Own data based on municipal strategy documents

This emphasis is in line with Slovenia's national commitment to the UN 2030 Agenda for Sustainable Development, as well as its participation in EU programs such as the 100 Climate-Neutral and Smart Cities Mission, which includes Ljubljana, Kranj, and Velenje.

7.3 Circular Economy: Terminological Gaps and Strategic Nuances

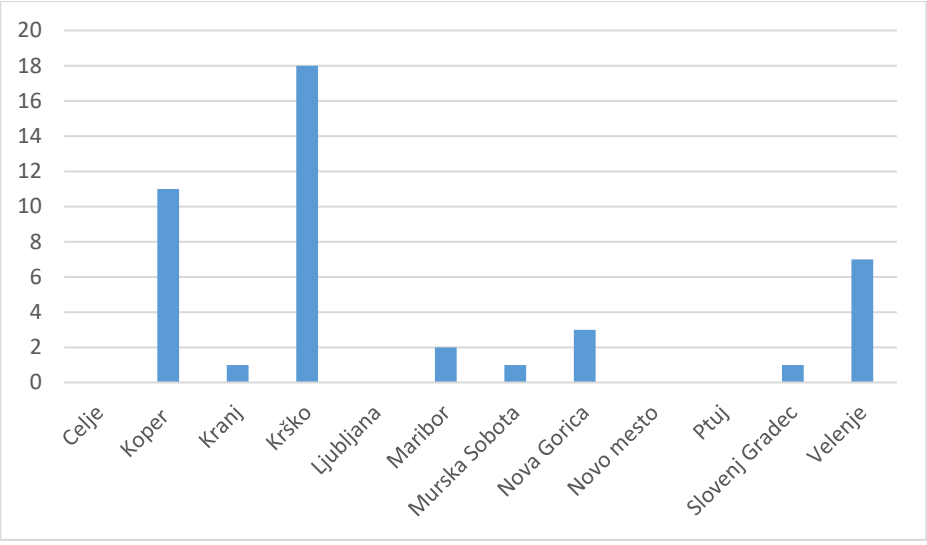
In contrast, the circular economy appears far less frequently. The term is mentioned most in Krško (18), followed by Koper (11) and Velenje (7), with only brief mentions in most other municipalities. Four cities, including Ljubljana, Celje, Novo Mesto, and Ptuj, make no mention of the circular economy at all in their sustainable development strategies.

However, this apparent absence must be interpreted with caution. According to the Vice Mayor of Ljubljana, the city has a long-standing commitment to circular practices:

"Ljubljana has been working on circular economy initiatives for many years. We adopted the Circular Potentials Strategy 2021–2027 and aim for 'Ljubljana, Circular City 2045'. Earlier, we implemented the 2014–2035 Zero Waste Strategy. The term may not appear in the TUS, but it is reflected in our implementation plan and sectoral strategies."

The Vice Mayor also highlighted Ljubljana's international engagement, participation in the Circular Cities initiative, EUROCITIES, Waste Wise Cities, and signing of the New Plastics Economy Global Commitment.

Figure 2: Frequency of the term "Circular Economy" in Strategic Development Strategies of Slovenian Urban Municipalities



Source: Own data based on municipal strategy documents

The Ministry confirmed that while the term "circular economy" may be underused, many municipalities are incorporating its principles through the lens of spatial development, particularly within the Strategic Plan for Circular Spatial Management 2024–2030:

"Circular spatial management prioritises urban renewal, brownfield redevelopment, and land-use efficiency. These principles may not be labelled as 'circular economy' in municipal strategies but are present in planning practice."

This distinction highlights a critical methodological point: conceptual integration may occur under different terminologies, necessitating a layered reading of policy texts.

7.4 Blockchain Technology: An Overlooked Enabler

Of the 12 strategies analysed, only one municipality Velenje mentions blockchain, and even then only in passing. This lack of reference is striking, given the documented potential of blockchain for enhancing transparency, traceability, and process efficiency in sustainability and circular economy systems. This points to a broader systemic gap: while blockchain is widely recognised in the academic literature as a transformative enabler of sustainable innovation, its uptake in Slovenian urban governance remains negligible.

8 Policy Recommendations

The findings of this study reveal that while all Slovenian urban municipalities have adopted sustainable development strategies, the concepts of the circular economy and blockchain technology remain largely underrepresented or absent. To bridge the gap between strategic commitment and innovative implementation, several policy interventions are recommended at the municipal, national, and European levels.

At the municipal level, it is essential that cities revise and update their strategic frameworks to more explicitly incorporate emerging policy concepts such as the circular economy and digital technologies, particularly blockchain. This can be achieved by embedding these concepts in revised versions of Sustainable Urban Strategies (TUS) and accompanying implementation plans. Additionally, municipalities should develop dedicated local action plans that operationalise circular economy goals through measurable activities, such as urban mining, sustainable public procurement, and the establishment of decentralised reuse centres.

In parallel, it is recommended that municipalities explore concrete pilot applications of blockchain technology, for example, in areas such as peer-to-peer energy trading, decentralised waste tracking systems, and smart contracts to enhance transparency in procurement. Collaboration with academic institutions and technology providers will be crucial to advancing these initiatives in a practical and cost-effective manner.

At the national level, ministries and public agencies can play a vital enabling role. First, there is a need to harmonise terminology and improve conceptual clarity across policy documents. This would entail distinguishing clearly between "circular economy," "circular spatial management," and "sustainable development," and

providing guidance to municipalities on how to meaningfully integrate these terms into their strategies. In addition, ministries should consider introducing dedicated thematic calls, within existing cohesion, digitalisation, or climate funding streams, to support blockchain-enabled circular economy projects at the local level.

Providing targeted technical and advisory support is equally important. National authorities should invest in capacity-building initiatives to familiarise municipal staff with the principles and practical applications of blockchain and circular economy metrics. These efforts could be complemented by the creation of innovation hubs or public-sector advisory services that help municipalities test and implement innovative solutions.

Taken together, these recommendations aim to support Slovenian urban municipalities in moving beyond compliance-based sustainability planning toward more integrated, innovative, and transformative urban governance. By embedding circular economy principles and emerging technologies like blockchain into local development strategies, municipalities can enhance their resilience, attract funding, and contribute meaningfully to Slovenia's broader climate and sustainability goals.

9 Conclusion

This chapter has explored the degree to which Slovenia's 12 urban municipalities have integrated sustainability, circular economy principles, and blockchain technology into their strategic planning. It combined document analysis with expert insights from the Ministry of the Environment, Climate and Energy and the Vice Mayor of Ljubljana to contextualise findings within both national policy frameworks and municipal practices.

The analysis confirmed that all municipalities had formally adopted sustainable development strategies, reflecting alignment with EU and national mandates. The prominence of sustainability across all strategic documents, often appearing over 100 times, demonstrates a strong declarative commitment. However, the depth of this commitment varies, and frequent mentions do not necessarily equate to strategic prioritisation in implementation. As observed, cities like Koper, with a major port, and Krško or Velenje, with substantial energy infrastructure, showed notable emphasis.

The circular economy, though widely recognised at the EU level as a core pillar of the green transition, was inconsistently referenced. While Krško and Koper led with 18 and 11 mentions respectively, four municipalities, including the capital Ljubljana,

did not mention it at all in their sustainable development strategies. This was surprising given Ljubljana's international reputation as a sustainability leader. However, the Vice Mayor of Ljubljana clarified that circular principles are addressed in complementary sectoral strategies and implementation plans, and that the omission from the TUS may stem from terminology used in European Commission guidance documents.

The situation is even more critical with regard to blockchain technology. Referenced only once, in Velenje, and only in passing, blockchain appears to have little to no presence in municipal planning. This finding is notable given the substantial body of academic and technical literature identifying blockchain as a powerful enabler of sustainable and circular systems. The literature review suggests that blockchain can improve transparency, traceability, and operational efficiency across sectors through applications such as peer-to-peer energy trading, material lifecycle tracking, and smart contracts. Yet, barriers related to energy consumption, scalability, and institutional awareness continue to hinder adoption.

The Ministry candidly acknowledged that blockchain is currently not a focus within national-level urban planning, nor are municipalities provided with specific financial or advisory instruments to support its integration. This signals a broader institutional gap between innovation potential and implementation capacity.

Looking forward, unlocking the benefits of digital innovation and circularity in Slovenian municipalities will require deliberate action:

- ✓ Strategic revision of municipal plans to include circular economy frameworks and digital technologies;
- ✓ Capacity-building and knowledge transfer, particularly around blockchain and Industry 4.0 tools;
- ✓ Clarification of terminology and better visibility of sectoral strategies within overarching development frameworks;
- ✓ Improved coordination between municipalities and national ministries to align strategic goals with practical tools and funding mechanisms.

The chapter ultimately reveals a twofold reality: while Slovenian municipalities are largely compliant in adopting sustainability strategies, they have yet to leverage the full spectrum of technological and conceptual tools available to drive transformative change. Integrating blockchain and circular economy models could help bridge this

gap, accelerating the transition to climate neutrality, enhancing economic resilience, and positioning municipalities for greater innovation leadership and EU funding competitiveness.

The convergence of sustainability goals, digital transformation, and circular thinking offers not only a policy imperative but a profound opportunity, one that Slovenia's urban centres must now seize.

Further research should explore the implementation side of these strategies, assessing whether the presence or absence of key terms corresponds to actual municipal investments or projects in the field. Comparative studies with other EU regions could also reveal best practices in integrating blockchain and circular economy approaches into urban sustainability. Moreover, there is a need to examine citizen engagement, public-private partnerships, and regulatory innovation as critical enablers for operationalising smart and circular transitions at the local level.

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Povzetek članka v slovenskem jeziku (abstract in Slovene language):

Slovenija ima 12 mestnih občin, vsaka z lastno strategijo trajnostnega razvoja, ki je usklajena z okvirom Agende 2030. Prispevek preučuje, kako te strategije vključujejo nove tehnologije, zlasti tehnologijo veriženja blokov (blockchain), ter inovativne trajnostne koncepte, kot je krožno gospodarstvo. Za dosego ciljev Agende 2030, predvsem pri prehodu na krožno gospodarstvo, je treba do leta 2030 podvojiti energetsko učinkovitost. Medtem ko sta blockchain in krožno gospodarstvo pogosto raziskana ločeno, ta raziskava proučuje njuno presečišče v kontekstu trajnosti mest. Študija uporablja kvalitativno analizo vsebine uradnih razvojnih strategij vseh 12 mestnih občin. Analizo dopolnjujejo polstrukturirani intervjuji z visokimi uradniki Ministrstva za okolje, podnebje in energijo ter s podžupanom Mestne občine Ljubljana, ki podajo institucionalne poglede na strateške prioritete. To je prva celovita analiza, kako slovenske mestne občine obravnavajo medsebojno povezane teme trajnosti, krožnega gospodarstva in tehnologije veriženja blokov. Ugotovitve prispevajo k akademskim razpravam in ponujajo praktična priporočila za krepitev inovativnosti pri načrtovanju trajnostnega razvoja mest.