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DIGITALIZATION AS A DRIVER OF THE DEVELOPMENT OF THE CIRCULAR ECONOMY: A COMPARATIVE ANALYSIS OF THE EXPERIENCE OF THE EU AND UKRAINE
ЦИФРОВІЗАЦІЯ ЯК ДРАЙВЕР РОЗВИТКУ ЦИРКУЛЯРНОЇ ЕКОНОМІКИ: ПОРІВНЯЛЬНИЙ АНАЛІЗ ДОСВІДУ ЄС ТА УКРАЇНИ

Степаненко Н. О., Литвиненко А.В. Цифровізація як драйвер розвитку циркулярної економіки: порівняльний аналіз досвіду ЄС та України. *Український журнал прикладної економіки та техніки*. 2026. Том 11. № 1. С. 366 – 369.

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The article examines digitization processes as a key driver of the circular economy, drawing on a comparative analysis of the European Union and Ukraine to identify opportunities for its adaptation within the national economy. The purpose of the article is to provide a comprehensive study of digitalization as a key factor in the development of the circular economy by analyzing existing practices in the European Union and Ukraine. The methodological framework includes analysis and synthesis, comparative analysis, the structural–logical method, and case analysis of practices implemented by leading countries in the field of circularity. The study summarizes theoretical approaches to defining the essence of the circular economy and digitalization; analyzes the impact of digital technologies on the development of circular processes; examines the main directions and instruments for the development of the circular economy in EU countries; and conducts a comparative analysis of the EU and Ukrainian experience in the field of digital circular transformation. The scientific novelty of the research lies in substantiating the possibilities for adapting European experience in the use of digital technologies to ensure the circularity of economic processes under Ukrainian conditions. The practical significance of the study consists of substantiating the role of digitalization in the development of the circular economy and the prospects for its application in Ukraine, as well as in identifying barriers to the implementation of digital circular solutions in the country. The article also emphasizes the relationship between digital innovations and the economy's increasing resource efficiency. The development of digital infrastructure plays a special role in implementing circular business models. The obtained results can be used to develop public policy in the fields of sustainable development and digital transformation.
***Keywords**: circular economy; digitalization; waste management; digital markets; digital technologies.*

У статті досліджено процес цифровізації як ключового драйвера розвитку циркулярної економіки на основі порівняльного аналізу досвіду Європейського Союзу та України з визначенням можливостей його адаптації в умовах національної економіки. Метою статті є комплексне дослідження цифровізації ролі як одного з основних факторів розвитку циркулярної економіки за допомогою аналізу існуючого досвіду Європейського Союзу та України. Методологічну основу становлять аналіз і синтез, порівняльний аналіз, структурно-логічний метод та кейс-аналіз практичних держав-лідерів у сфері циркулярності. За результатами дослідження узагальнено теоретичні підходи щодо визначення сутності циркулярної економіки та цифровізації; проаналізовано вплив цифрових технологій на розвиток циркулярних процесів; досліджено основні напрями та інструменти розвитку циркулярної економіки в країнах ЄС; здійснено порівняльний аналіз досвіду ЄС та України у сфері цифрової циркулярної трансформації. Наукова новина суперечить обґрунтуванню можливостей адаптації європейського досвіду використання цифрових технологій у забезпеченні циклічності економічних процесів в українських умовах. Практична значущість сталася в обґрунтуванні ролі цифровізації у розвитку циркулярної економіки та перспективі її застосування в Україні, а також визначені бар'єри впровадження цифрових циркулярних рішень в Україні. У статті також акцентовано увагу на взаємозв'язку між цифровими інноваціями та підвищенням ресурсоефективності економіки. Особливу роль відіграє формування цифрової інфраструктури як основи для впровадження циркулярних бізнес-моделей. Отримані результати можуть бути використані для розробки державної політики у сфері сталого розвитку та цифрової трансформації.
***Ключові слова**: циркулярна економіка, цифровізація, управління відходами, цифрові ринки, цифрові технології.*

Statement of the problem

The current phase of global economic development is marked by the intensification of environmental, resource-related, and socio-economic challenges, necessitating a reconsideration of traditional production and consumption models. The linear paradigm of economic growth, grounded in extensive resource extraction and the continuous accumulation of waste, increasingly demonstrates its structural inefficiency and inability to ensure long-term systemic sustainability. In this context, the circular economy is widely regarded as a viable alternative model aimed at enhancing resource efficiency, preserving material flows, and reducing adverse environmental impacts.

At the same time, the advancement of the circular economy unfolds amid rapid digital transformation, which significantly shapes economic dynamics, governance mechanisms, and interactions among market participants. The application of digital technologies – including big data analytics, the Internet of Things, artificial intelligence, blockchain solutions, and digital platforms – creates new opportunities to embed circular principles throughout the product life cycle, from design and manufacturing to consumption, reuse, and recycling. Nevertheless, the insufficient integration of digital tools into circular transformation processes remains a considerable obstacle for many countries.

In this regard, the European Union's experience is particularly illustrative. Within the framework of the European Green Deal and related strategic initiatives, digitalization is recognized as a foundational instrument for implementing circular economy policies. The EU's approach reflects a comprehensive integration of digital and environmental transitions, contributing to tangible progress in resource efficiency, innovation capacity, and sustainable development.

For Ukraine, the development of a circular economy amid digitalization has acquired heightened relevance considering European integration processes, the need for structural economic modernization, and the challenges of post-war recovery. On the one hand, financial and resource constraints limit transformation capacity; on the other, reconstruction

efforts require alignment with sustainability principles. These circumstances underscore the importance of adapting effective European digital-circular practices to national conditions. At the same time, the absence of a systematic comparative assessment of the European Union and Ukraine's experiences in this domain hampers evidence-based policymaking and the effective implementation of digital circular business models.

Accordingly, a significant research problem emerges: the need for a comprehensive examination of digitalization as a key driver of the circular economy, based on a comparative analysis of the European Union and Ukraine, with the aim of identifying opportunities for its adaptation within the national economic framework.

Analysis of recent research and publications. In recent years, global academic discourse has shown growing interest in examining digital technologies as a pivotal driver of the circular economy. For instance, Michel Scholtysik, Anja Rasor, and Lisa Petzke, in their systematic review, argue that digital solutions – particularly the Internet of Things, artificial intelligence, and big data analytics – fundamentally reshape production systems by improving resource optimization and embedding closed-loop strategies (slowing resource flows, narrowing resource use, and closing material loops) into corporate governance structures [1].

An integrative review by Luca Bianchi and Jason Lambert further emphasizes that digital technologies not only enhance supply chain transparency and extend product life cycles but also create opportunities for innovative business models that can scale circular practices across diverse economic sectors [2].

Reinforcing the transformative potential of digital tools, I. Dimov, Yu. Bielousov, and their co-authors investigate the impact of digitalization on the sustainable development of Ukraine's agricultural sector. Their findings suggest that the convergence of digital technologies and circular principles can significantly improve resource efficiency and strengthen the resilience of regional economies [3].

In Ukrainian scholarship, particular attention has been devoted to the development of digital infrastructure supporting the circular economy. Notably, Yu. Orlovska and A. Zhushman analyze the evolution of policy approaches within the European Union concerning the digital dimension of the circular model. They conclude that the establishment of digital platforms and material registries constitutes a critical mechanism for ensuring transparency and effective management of resource flows [4]. Additionally, studies such as Yu's. Perehuda explores the application of digital tools for advancing circular economy practices in specific sectors – such as green tourism – highlighting the interdisciplinary nature of digital–circular transformation processes [5].

I. Zvarych, Y. Petrushenko, and A. Vorontsova focus on the development of the circular economy in Ukraine, identifying its principal challenges and outlining potential pathways for addressing them [6].

Among Ukrainian sources, analytical contributions examining strategic governance trends in the circular economy – particularly the works of O. Melnyk and M. Zlotnik – also deserve attention, as do studies addressing practical barriers faced by domestic enterprises in implementing circular practices [7].

Overall, the contemporary body of research reflects the emergence of a multidimensional understanding of digitalization as a catalyst for transforming the circular economy. This perspective encompasses both technological and institutional dimensions and increasingly incorporates the European Union's experience into its analytical framework.

The purpose of the research

The purpose of this article is to provide a comprehensive study of digitalization as a key driver of the circular economy, based on a comparative analysis of the European Union and Ukraine. Particular attention is paid to the generalization of theoretical approaches to defining the essence of the circular economy and digitalization; analysis of the impact of digital technologies on the development of circular business models; research of the main directions and tools for the development of the circular economy in the EU countries; comparative analysis of the experience of the EU and Ukraine in the field of digital circular transformation; justification of the possibility of adapting European experience in Ukrainian conditions.

Presentation of the main research material

The European Union's policy on the circular economy is an integral component of the European Green Deal – the EU's overarching strategic framework to achieve climate neutrality by 2050. At its core lies the transition from the traditional linear «take–make–dispose» model to a closed-loop system in which products and materials retain their value for as long as possible, while waste generation is reintegrated and residual resources are minimized within production cycles.

Through the Circular Economy Action Plan (CEAP, 2020), the EU has introduced a comprehensive set of measures covering the entire product life cycle. These include:

Eco-design requirements – the establishment of standards for durability, reparability, and recyclability, including the introduction of digital product passports.

Extended Producer Responsibility (EPR) – the obligation of producers to assume responsibility for the full life cycle of their products, including take-back schemes and post-consumer waste management.

Digital tools and monitoring systems – the deployment of IoT technologies, big data analytics, blockchain solutions, and digital platforms to enable real-time tracking of material flows.

Support for secondary raw material markets – the development of a unified market for secondary resources, accompanied by quality standards and certification mechanisms.

These initiatives pursue not only environmental objectives but also aim to enhance the competitiveness and innovative capacity of the European economy [8].

In particular, the Ecodesign for Sustainable Products Regulation (ESPR) introduces the concept of a digital product passport containing information on material composition, reparability, recycled content, and environmental performance indicators. This instrument is designed to increase transparency in both production and consumption processes.

Digital technologies serve as a critical enabler of circular economy implementation, exerting influence at multiple levels:

Internet of Things (IoT) and sensor technologies enable real-time monitoring of the condition of products, materials, and equipment, thereby reducing resource losses and improving maintenance efficiency.

Blockchain-based platforms enhance supply chain transparency and strengthen trust in secondary materials by ensuring data integrity and preventing manipulation.

Big data analytics and artificial intelligence (AI) facilitate the optimization of logistics, recycling routes, and the matching of supply and demand for reusable materials.

Digital marketplaces for secondary resources connect suppliers and users of recycled materials, supporting efficient material redistribution and minimizing waste generation.

Collectively, these digital instruments reinforce the systemic transition toward circularity by integrating technological innovation with environmental governance mechanisms.

It is appropriate to consider specific examples of the deployment of digital solutions within the European Union.

1. Digital Product Passports (DPPs).

The introduction of DPPs under the Ecodesign for Sustainable Products Regulation (ESPR) enables systematic tracking of product composition, environmental characteristics, and the products' reparability and recyclability. This instrument establishes a data-driven foundation for resource optimization across value chains at all stages—from manufacturing to end-of-life management—thereby strengthening circular performance and transparency.

2. Platforms for secondary resource exchange.

In countries such as the Netherlands and Belgium, digital marketplaces have been developed to facilitate the trading or exchange of surplus materials between enterprises. These platforms reduce dependence on primary raw materials and stimulate the development of secondary material markets by improving information flows and market accessibility.

3. IoT-based waste management systems.

Municipalities across the EU increasingly deploy IoT-enabled waste bins equipped with fill-level sensors. These technologies allow for real-time monitoring and route optimization for waste collection services, leading to lower logistical costs and reduced CO_2 emissions.

Collectively, these practices demonstrate that digital instruments not only provide technical support for circular strategies but also foster the emergence of innovative business models aligned with circular transformation objectives.

One of the main indicators used to assess circular economy performance is the Circular Material Use Rate (CMUR), which measures the share of secondary (recycled) materials in total material consumption. The overall dynamics of CMUR in the EU are presented in Table 1. The table illustrates a gradual increase in the Circular Material Use Rate (CMUR) across the European Union from 2010 to 2024, indicating slow yet steady progress toward the development of the circular economy. In particular, the figures for 2023–2024 (11.8–12.2%) reflect a renewed growth trajectory and a new peak. This trend can be attributed to the intensification of production digitalization, the broader adoption of smart technologies, and the expansion of secondary material markets.

Although CMUR growth remains moderate, the upward trend signals increasing resource efficiency within EU member states. However, the 12.2% level recorded in 2024 remains below the targets set under the Circular Economy Action Plan (approximately 23–24% by 2030). This gap underscores the necessity of further digital integration and the accelerated implementation of circular solutions.

Table 1. Dynamics of Circular Material Use Rate (CMUR) in the EU (2010–2024)

Year	Circular Material Use Rate	Comments
2010	~10.7	Baseline
2021	11.7	Slight increase
2022	11.5	Slight decrease
2023	11.8	Increase compared to 2022
2024	12.2	New high

Data: Eurostat/EEA. Circular material use rate

In Ukraine, the circular economy is increasingly viewed as a strategic component of economic transformation and sustainable development, aimed at improving resource efficiency, minimizing waste generation, and strengthening integration into the European economic space. This issue has gained particular urgency in light of contemporary challenges, including the severe economic consequences of the war and the large-scale need for infrastructure reconstruction.

Academic studies emphasize that the implementation of circular economy principles in Ukraine lags significantly behind the EU, both in regulatory frameworks and in practical application. For instance, only around 5% of municipal waste in Ukraine is recycled – partly due to insufficient infrastructure and limited waste-sorting practices – whereas the corresponding indicator in the EU is substantially higher.

The digital transformation of Ukraine's economy is progressing incrementally, primarily in public administration, e-government services, and e-commerce. However, the deployment of digital technologies in the industrial sector and resource management systems remains considerably less advanced compared to the European Union, where digital infrastructures are integrated into supply chains, waste management systems, and resource monitoring mechanisms. Standardized digital product passports, IoT-based monitoring tools, and blockchain solutions are still in their early stages of development in Ukraine.

Due to the limited availability of CMUR statistics for Ukraine – unlike the systematic reporting framework established in the EU – assessing circularity performance requires using alternative indicators, such as overall recycling rates, the share of secondary materials in production, and resource productivity metrics.

Table 2 summarizes the key indicators used to assess the level of circular economy development in Ukraine and compares them with the EU average values [9], [10].

Table 2. Comparative analysis of key indicators of the circular economy of Ukraine and the EU

Indicator	Ukraine (as of 2024)	EU-27 (as of 2024)
Recycling of household waste, %	≈ 5%	45–50%
Share of secondary materials (estimate)	Unknown official	~12.2% CMUR
Material intensity of the economy (ton/capita)	11.2	Significantly lower
Share of renewable energy, %	≈ 5%	~45%
Share of waste in landfills	~90%	~10%

The presented data reveal substantial gaps between Ukraine and the European Union across key indicators of resource management and circular practices. For example, the share of municipal waste that is recycled or otherwise recovered in Ukraine amounts to only about 5%, whereas in EU member states this figure is several times higher – exceeding 45% on average.

Particularly critical is the indicator reflecting the use of secondary materials. In the EU, the Circular Material Use Rate (CMUR) has already surpassed 12% (as of 2024), while in Ukraine this metric is not officially calculated, complicating any systematic assessment of progress. At the same time, the proportion of recycled and secondary materials used in Ukrainian production processes remains extremely low.

Accordingly, several key barriers to the implementation of digital circular solutions in Ukraine can be identified:

insufficient digital infrastructure in industrial production and waste management systems;

limited competencies and technical expertise among enterprises, constraining the adoption of IoT technologies, big data analytics, and digital resource-monitoring platforms;

an underdeveloped regulatory framework governing digital solutions in the circular economy, including the absence of standardized digital product passport requirements;

restricted access to financing for innovative technologies, which is particularly crucial for enterprise modernization and post-war infrastructure reconstruction.

Conclusions and prospects for further research

The conducted study allows for several major conclusions regarding the role of digitalization in advancing the circular economy and its prospects in Ukraine.

First, digital technologies function not merely as technical instruments but as catalysts for structural transformation in production and broader socio-economic systems. They enable the emergence of new business models, enhance transparency and control over material flows, and stimulate the development of secondary resource markets.

Second, effective circular transformation requires a systemic approach that integrates technological, organizational, and regulatory dimensions. In this context, digitalization acts as a connecting mechanism between sustainable development strategies and practical resource management solutions, facilitating the integration of closed-loop principles into economic systems.

Third, the advancement of a digital circular economy depends significantly on the state's capacity to create an enabling innovation environment. This includes coherent regulatory support, improved access to finance, workforce development, and incentives for digital initiatives. For Ukraine, the adaptation of European practices to national conditions is particularly relevant, given the country's economic structure, resource base, and ongoing post-war reconstruction.

Finally, the digitalization of the circular economy should be viewed as a strategic instrument not only to improve production efficiency and reduce environmental pressures but also to strengthen national economic competitiveness. Its integration creates the foundation for sustainable growth, enhanced economic resilience, and more rational use of available resources. Thus, further progress in the development of the circular economy in Ukraine is impossible without the systematic implementation of digital solutions, combined with institutional reforms and national-level strategic initiatives. Such an integrated approach will ensure the long-term sustainability of the economic system, more efficient resource utilization, and the deeper integration of Ukraine into the European and global sustainable development framework.

Література

1. Scholtysik M., Rasor A., Petzke L., Koldewey C., Dumitrescu R. An integrative perspective on digital technologies and circular economy: a systematic literature review. *Proceedings of the Design Society*. 2025. № 5. P. 541–550. DOI: https://doi.org/10.1017/pds.2025.10068.
2. Bianchi L., Lambert J. Digital Transformation and the Circular Economy: An Integrated Review of Technologies, Challenges, and Opportunities. *International Interdisciplinary Business Economics Advancement Journal*. 2025. № 6(08). P. 1–8. URL: https://www.iibajournal.org/index.php/iibeaj/article/view/70.
3. Dimov I., Bielousov Y., Kravtsov A., Shakhovets A., Tluchkevych N. Circular economy and digital technologies as drivers of sustainable development of the agricultural sector of the region in Ukraine. *Cadernos De Educação Tecnologia E Sociedade*. 2024. № 17(se3). P. 287–297. DOI: https://doi.org/10.14571/brajets.v17.nse3.287-297.
4. Орловська Ю., Жушман А. Цифрова інфраструктура циркулярної економіки в ЄС. *Економічний простір*. 2024. № 2. С. 46-53.
5. Перегуда Ю.А. Цифрові рішення для розвитку зеленого туризму та циркулярної економіки. *Acta Academiae Beregsasiensis: Geographica Et Recreatio*. 2025. № 3. С. 157–168. DOI: https://doi.org/10.32782/2786-5843/2025-3-14.
6. Zvarych I., Petrushenko Y., Vorontsova A. Circular economy development in Ukraine: Challenges and opportunities. *Problems and Perspectives in Management*. 2021. № 19(2). С. 310–322.
7. Melnyk O.H., Zlotnik M.L. Analyzing the Status and Tendencies of Circular Economy Development in Lviv Region. *Business Inform*. 2020. № 2(505). P. 125–133. DOI: https://doi.org/10.32983/2222-4459-2020-2-125-133.
8. European Commission. A New Circular Economy Action Plan: For a Cleaner and More Competitive Europe. Brussels. 2020. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0098.
9. UNIDO. Baseline Analysis of Circular Economy in Ukraine: Final Report. Vienna, UNIDO. 2024. URL: http://www.recpc.org/circular-economy/.
10. Shpak N., Kuzmin O., Melnyk O., Ruda M., Sroka W. Implementation of a Circular Economy in Ukraine: The Context of European Integration. *Resources*. 2020. № 9(96). URL: https://www.mdpi.com/798866.
11. EU Reporter. Deal on new EU rules to make sustainable products the norm. 2023. URL: https://uk.eureporter.co/environment/2023/12/06/deal-on-new-eu-rules-to-make-sustainable-products-the-norm/.
12. Berlin Circular Economy Lab. Berlin Innovation Hub for Circularity. URL: https://circular.berlin/.
13. Міністерство захисту довкілля та природних ресурсів України. Концепція реалізації державної політики у сфері розвитку циркулярної економіки. Київ, 2023.

References

1. Scholtysik, M., Rasor, A., Petzke, L., Koldewey, C., Dumitrescu, R. (2025). «An integrative perspective on digital technologies and circular economy: a systematic literature review». *Proceedings of the Design Society*. № 5. pp. 541–550. DOI: https://doi.org/10.1017/pds.2025.10068.
2. Bianchi, L., Lambert, J. (2025). «Digital Transformation and the Circular Economy: An Integrated Review of Technologies, Challenges, and Opportunities». *International Interdisciplinary Business Economics Advancement Journal*. № 6(08). pp. 1–8. Available at: https://www.iibajournal.org/index.php/iibeaj/article/view/70.
3. Dimov, I., Bielousov, Y., Kravtsov, A., Shakhovets, A., Tluchkevych, N. (2024). «Circular economy and digital technologies as drivers of sustainable development of the agricultural sector of the region in Ukraine». *Cadernos De Educação Tecnologia E Sociedade*. № 17(se3). pp. 287–297. DOI: https://doi.org/10.14571/brajets.v17.nse3.287-297.
4. Orlovs'ka, Yu., Zhushman, A. (2024). «Digital infrastructure of the circular economy in the EU». *Ekonomichnyj prostir*. № 2. pp. 46-53.
5. Perehuda, Yu.A. (2025). «Digital solutions for the development of green tourism and the circular economy». *Acta Academiae Beregsasiensis: Geographica Et Recreatio*. № 3. pp. 157–168. DOI: https://doi.org/10.32782/2786-5843/2025-3-14.
6. Zvarych, I., Petrushenko, Y., Vorontsova, A. (2021). «Circular economy development in Ukraine: Challenges and opportunities». *Problems and Perspectives in Management*. № 19(2). pp. 310–322.
7. Melnyk, O.H., Zlotnik, M.L. (2020). «Analyzing the Status and Tendencies of Circular Economy Development in Lviv Region». *Business Inform*. № 2(505). pp. 125–133. DOI: https://doi.org/10.32983/2222-4459-2020-2-125-133.
8. (2020). European Commission. A New Circular Economy Action Plan: For a Cleaner and More Competitive Europe. Brussels. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0098.
9. (2024). UNIDO. Baseline Analysis of Circular Economy in Ukraine: Final Report. Vienna, UNIDO. Available at: http://www.recpc.org/circular-economy/.
10. Shpak, N., Kuzmin, O., Melnyk, O., Ruda, M., Sroka, W. (2020). «Implementation of a Circular Economy in Ukraine: The Context of European Integration». *Resources*. № 9(96). Available at: https://www.mdpi.com/798866.
11. (2023). EU Reporter. Deal on new EU rules to make sustainable products the norm. Available at: https://uk.eureporter.co/environment/2023/12/06/deal-on-new-eu-rules-to-make-sustainable-products-the-norm/.
12. Berlin Circular Economy Lab. Berlin Innovation Hub for Circularity. Available at: https://circular.berlin/.
13. Ministerstvo zakhystu dovkillia ta pryrodnykh resursiv Ukrainy. Kontseptsiia realizatsii derzhavnoi polityky u sferi rozvytku tsyrkuliarnoi ekonomiky. (2023). [Ministry of Environmental Protection and Natural Resources of Ukraine. Concept of implementation of state policy in the sphere of circular economy development]. Kyiv. Ukraine.

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