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REDUCING PRODUCTION AND CONSUMPTION WASTE AS A WAY TO INCREASE QUALITY 5.0: MANAGEMENT WITH THE HELP OF SUSTAINABLE INNOVATIONS

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A B S T R A C T

Global technologization and the process of constant expansion of production became a reaction to the quick population growth and an increase in the living standards and needs. They led to the active use of a larger volume of natural resources and the formation of production and consumption waste. Formation of waste is a global problem that affects the environment, economy, and public health. Innovations are a powerful tool for solving this problem since they offer various strategies to minimise the volume of waste. Industry 5.0 emphasises the integration of technologies, environmental sustainability, and cooperation to raise the effectiveness of using resources and minimise waste. Sustainable development practices help countries develop so as to adapt to challenges connected with climate change, which will contribute to the preservation of important natural resources for future generations.

In the modern world, sustainable development, recycling, and environmental solutions are very important. Innovations in waste management provide significant advantages for the preservation of nature and the effective use of resources. Implementing environmentally-friendly methods, such as energy efficiency, waste minimisation, and the use of renewable resources, manufacturers strive towards long-term value and reduction in their environmental footprint. Waste reduction contributes to the efforts on sustainable development and raises the company's reputation. At the same time, in the modern, environmentally conscious society, consumers often demand products and services from companies that prioritise sustainable development.

Quality 5.0, integrated into the Industry 5.0 system, offers many advantages. It allows revealing and solving problems with quality, minimises losses, raises operational effectiveness, and contributes to the culture of constant improvement. Apart from this, it improves transparency of the production processes, which contributes to customers' trust and loyalty (Frick and Grudowski, 2023).

Sustainable innovations are connected with the movement away from the traditional models of growth and development, which were often caused by degradation of the environment and social inequality, towards more sustainable forms of progress, which prioritise the well-being of humans.

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1. INTRODUCTION

From the environmental position, the reduction of waste is vital in the mitigation of the negative consequences of excessive consumption and disposal. Waste production and disposal account for a large share of greenhouse gas emissions, environmental pollution, and depletion of natural resources.

Sustainable innovations aim at satisfying consumers' needs with the smallest possible impact on the environment. This requires all production companies to thoroughly take into account all environmental factors associated with the use of resources in their production, energy consumption, and waste formation (Ghulam & Abushammala, 2023).

Sustainable innovations are a term that covers a wide range of practices, processes, and results aimed at the creation of value for society and the environment, with minimisation of the negative impact of human activities. Innovations in materials are very important for waste reduction. Traditional production processes often generate large volumes of waste through by-products and ineffective use of resources. Innovations in materials and methods of production are supposed to solve this problem. Sustainable innovations could be used in any sector or sphere: energy, agriculture, healthcare, education, transport, etc.

Quality 5.0 is the fifth evolution of the principles of quality management, which reflects the transformational influence of new technologies and quality concepts on industrial processes. This paradigm change emphasises not only the quality of products or services but also the holistic view that covers sustainable development, customer satisfaction, involvement of employees, and social responsibility (Frick and Grudowski, 2023).

Since sustainable development becomes increasingly important for consumers and stakeholders, companies that do not cope with their waste may face reputation damage and lose their market share. Measures on waste reduction conform to environmental goals and increase the brand's image and customer loyalty.

Cooperation of Industry 5.0 innovations can minimise losses of food products, improve by-products recycling and disposal, and support the cycles of sustainable production and consumption (Gaikwad and Anerao, 2025). Principles of lean production put emphasis on constant improvement with the help of employees' involvement. Providing employees with the possibility to reveal and eliminate inefficiencies, organisations contribute to the development of the culture of innovations and problem-solving. Employees become more involved in their work because they actively participate in efforts for waste reduction. This approach, which is a part of Quality 5.0, raises employees' moral spirit and leads to more effective decision-making and growth of operational effectiveness.

Sustainable consumption means more effective and conscious use of resources for satisfying current needs without damaging future generations' ability to satisfy their needs. It involves the facilitation of the use of durable, reusable, and recyclable products to reduce the burden on natural resources and decrease waste (Khajuria et al., 2025).

SDG 12 covers two main directions, which are closely connected: reduction in the economy's resource intensity and support of environmental safety. Effective management of natural resources, as well as methods of disposal of toxic waste and polluting materials, are important target indicators in the achievement of this goal. Stimulation of sectors, companies, and consumers for waste reduction and disposal is equally important compared to the implementation of rational models of consumption.

According to the Quality 5.0 principles, all stakeholders' needs must be met, together with satisfaction of social demands through a sustainable approach to environmental problems. According to Quality 5.0, manufacturers are to use the leading technologies, e.g., artificial intelligence or Big Data analysis, to predict customers' needs and improve the quality of the market offer. Quality 5.0 takes into account customer satisfaction, innovations, social influence, and sustainable development (Skrzypek & Grudowski, 2025).

The purpose of this article is to study the methods of reducing production and consumption waste through sustainable innovations, according to the principles of Quality 5.0.

2. LITERATURE REVIEW

Sustainable products and ideas aim to create a positive effect on all stakeholders, including society, environment, and economy, without threatening the ability of future generations to satisfy their demands. This means the replacement of traditional models of development with more sustainable and just forms of development.

The problems of production and consumption waste, waste management, sustainable innovations, and Quality 5.0 were researched in many scholarly and analytical works. They were analysed for the purpose of this work. Clancy et al. (2023) aimed to determine the approach managers could use to digitilise their operations, which would allow them to manage the quality of their production operations in supply chains, as well as to provide a methodology of digitilisation for managers to achieve improved operations management and quality management through decision-making based on data.

Ghulam and Abushammala (2023) elaborated on the main aspects of e-waste, including its definition, structure, and influence of e-waste disposal on human health, and focused on practical sustainable solutions and strategies of effective management of e-waste.

Altenburger et al. (2024) studied innovations in eco-friendly packaging materials made of renewable sources and by-products and pointed to the significant potential to reduce waste, especially in the value creation chain of food products. Von Braun et al. (2023) dwelt on scientific evidence on ways to reduce food waste and losses and provided recommendations for actions at the global and national levels, including the actions of civil society, government and private investments. Bazaz et al. (2024) performed an overview of the existing combinations of the technologies of lean manufacturing and Industry 4.0 and discussed the potential of digital twins in lean manufacturing.

Alaghemandi (2024) analysed the current state and prospects of the innovative technologies of plastic waste recycling in the conditions of the circular economy. According to the scholars, innovations in chemical recycling and sorting systems based on AI demonstrate a significant increase in the effectiveness of recycling, scaling, and quality of recycled products, which contributes to a reduction in environmental pollution.
Onur et al. (2024) demonstrated how digital transformation of waste recycling had been developing in recent years and established the problems that had been neglected, revealing types of waste that created the largest problems and digital technologies that were used for waste recycling. The issues of production and consumption waste reduction and waste recycling were also studied by Orlova et al. (2024), Torosyan et al. (2011), and Carvajal et al. (2025).

Skare et al. (2024) dwelt on the influence of innovations in industry and infrastructure on sustainable production and consumption within the circular economy in the EU countries and established a connection between the level of circular materials applications and innovations in industry and infrastructure. Hegab et al. (2023) elaborated on the guidelines on implementing the systems of sustainable production and offered effective strategies on dealing with problems, ensuring a valuable resource for a more sustainable industrial future.

Popkova et al. (2024) disclosed social cause-and-effect relationships of the agrarian economy development with artificial intelligence and identified the perspectives of change management for its sustainable development. The authors came to the conclusion that the sustainable development of the agrarian economy with artificial intelligence is based on its flexibility, which is achieved through change management.

3. RESULTS

The Quality 5.0 concept is an important foundation for effectiveness and competitiveness, which is extrapolated from the operational level to the level of the management of value creation chains. It is one of the manifestations of Industry 5.0 (Zizic et al., 2022) and includes all features of this concept, including the use of basic digital technologies, focus on the important role of humans in the interaction with technologies, and attention to equality and environment. Quality 5.0 aims at dealing with limitations of the traditional methods of optimisation of production processes and prevention of defects and focuses on compliance with the principles of sustainability, human-centrism, and inclusion.

The fundamental principles of Quality 5.0 are manifested through compliance with ethical norms, support of transparency, and focus on sustainable development. According to this, the current values in quality management are principles of ethical production, socially-responsible marketing, fair interactive interaction with consumers, and compliance with the demands of sustainable development, in particular, the use of sustainable materials, application of eco-design in development of products, tracking and reduction of the carbon footprint, and other actions aimed at the reduction of anthropogenic impact on environment during the processes of production and consumption (KPMG, 2022). Thus, from the position of Industry 5.0, quality is no longer viewed as the totality of purely technical parameters, which is characterised from the position of products' correspondence to standard demands; instead, it transforms into a complex notion, which takes into account conformity to ethical principles, support of the transparent information support, compliance with the conditions of inclusion, personalisation, and tracking of sustainable footprint of the company in the system of the value creation chain.

Innovative methods of reuse of waste are an effective tool for the sustainable development of business and society. Implementation of these technologies ensures environmental safety and substantial economic profit, allowing companies to reduce costs, receive additional profit, and strengthen their positions in the market (Sergeev, 2025). Support of responsible consumption is of utmost importance for mitigating the influence of products on the environment. The key elements of these efforts are an increase in the products' life cycle: actions and measures that reduce the general environmental footprint. Prioritising longevity, consumers less frequently purchase new products – thus, they preserve valuable resources required for production. It is very important to develop products with long-term attractiveness and adaptability, so that consumers desire to use them and not follow the trends of one-time use.
Sustainable consumption involves the use of services and products which satisfy the main needs and improve the quality of life, minimising the application of natural

resources, toxic materials, waste, and polluting emissions during the life cycle, to avert the threats to future generations' needs. Sustainable consumption requires a change in consumers' behaviour, urging individuals and communities to make more environmentally conscious decisions (Khajuria et al., 2025).

To achieve and support balance in the ecosystem, the concept of sustainable development was developed and is promoted. It includes three directions for action: economic, social, and environmental. One of the conditions for the achievement of sustainable development is the transition to more responsible production and consumption, which is the goal of a circular economy. The basis of the circular economy is formation of new business models which are oriented towards a decrease in the number of resources used, implementation of reuse or closed cycle production (planning the production's need for materials) and recycling in productions, which allows ensuring the protection of environment and reduces the initial need of industrial companies for external resources.

Innovations and innovative activities influence all components of sustainable development – social, economic, and environmental – at all levels. At the macroeconomic level, an increase in innovative activities leads to the growth of gross domestic product, the emergence of new sectors in the national economy, the growth of the budget, etc. At the company level, intensification of innovative activities will help raise labour productivity, reduce product cost, or improve the company's profitability, which, in turn, will lead to the growth of profits.

The following types of waste are distinguished: municipal waste (household waste and city infrastructure waste); hazardous waste (e.g., used oil products, waste with CO3); production/industry waste (mining industry waste); medical waste; agricultural waste; construction and demolition waste; packaging waste; waste of electric and electronic equipment; used batteries; old vehicles; wastewater from municipal treatment facilities. Hazardousness of waste is determined based on the presence of one or several hazardous qualities, e.g., ability to self-ignite or infect, corrosivity, toxicity, or ecotoxicity.

It is possible to distinguish the following innovations in production and consumption waste management:

- Intellectual systems of waste management. Traditional methods of waste management are often based on manual processes, which might require a lot of time and be ineffective. However, the appearance of smart systems of waste management can automatize different aspects of waste disposal. These systems use sensors and the Internet of Things technology to monitor the level of waste in dumpsters in real time.
- Data analytics to track waste. By gathering and analysing data associated with the formation and disposal of waste, companies can receive valuable information about their waste management practices. For example, they can detect regularities or trends in waste formation, which enables them to determine spheres with a high level of waste.
- Innovations in recycling. Technologies caused a revolution in the recycling processes, implementing innovative methods which make recycling more effective and economically profitable. For example, achievements in sorting technologies allowed for more precise division of different types of secondary raw materials.
- Systems of stock management.

Waste management falls within Sustainable Development Goal 12, which covers various tasks of responsible production and consumption. In the context of achieving this goal, waste reduction is based on the application of sustainable innovations, which contribute to the growth of Quality 5.0, as one of the principles of the sustainable development concept. Analysing the structure of the components of SDG 12, we can note that sustainable innovations ensuring its achievement could be associated with the application of the following:

- Circular economy, which allows reducing the volume of waste due to recycling (Table 1). This sector also involves the creation of products with a high level of circularity.
- Sustainable materials science, which involves the production and application of innovative materials. The main advantage of these materials is their ability to raise the material intensity of the product, without any damage to its consumer qualities. This also applies to innovative solutions in the semiconductor industry and packaging materials.

The modern system of waste management must be oriented towards high-tech production based on the Industry 5.0 concept: automated or robotised modules of waste management, with the centre of production management. Innovativeness is based on different digital technologies, such as artificial intelligence, the Internet of Things, robotisation, adaptive technologies, unmanned and mobile technologies, biometric and quantum technologies, technologies of identification, blockchain, etc. Blockchain is a technology that can guarantee preservation in an endless cycle and support the activities in a closed cycle. AI technologies offer alternative computation approaches to solving the problems of the waste management system.

Table 1. Classification of the selected sustainable innovations aimed at waste reduction

	Sustainable innovation	Description
1	Two-process innovations (sorting and recycling)	Example: Innovative wasteless recycling of plastic into mixed fraction, used for additive production (3D printing, plastic materials used in various production niches). It is implemented by Cogersa SAU (Spain). Sorting and recycling consist of the following stages: - Smart sorter (robot connected to the management system) selects plastic from plastic waste supplied from city collection points, which fits, according to the characteristics, a 3D print of certain plastic materials. Parameters of selection are set with the help of a machine learning algorithm. The selection process is performed with the use of machine vision and augmented reality (the operator performs remote monitoring of the quality of waste sorting). Robots used by Cogersa SAU achieved a 97 % precision result, which distinguishes them from the robots of rival companies in this sector; - Sorted plastic waste of the same type (materials of the given specification) is moved to the production line. During this process, a mixed fraction of recycled plastic of the same type is produced. This production is also robotised, and the quality and functioning of equipment are assessed with the help of the Internet of Things (digital sensors and video cameras). The data are transferred into the corporate system of production management, and operators deal with the monitoring of the indicators of the manufacturer's material quality. The obtained material is supplied to customers who work in the 3D printing of plastic materials. The demand for these products in Spain and other EU countries is high. Indicators of the effectiveness of sustainable innovations in Cogersa SAU: - Investments EUR 1,095 million. Investors: the EU, municipal authorities, and private investors; - Investment return period: 01.11.2024 - 31.10.2027; - Factual payback period: 2025. This is due to high demand and the growth of the volumes of mixed faction production; - Environmental impact. Reduction in plastic waste in Asturia, Spain; decrease in CO2 emissions due to the use of eco-friendly technologies of recycling and production.
2	Continuous digital monitoring of the dumpster's capacity	Example: RecycleSmart (Australia) created and started in 2021 a digital app Pello (management of sensors and a multispectral camera, which assesses the level of the dumpster's capacity). This system also determines the homogeneity of waste (on the territory of residential apartments, campuses, offices, etc.). In 2023, this digital application was sold to Recycle Track Systems (British Columbia, Canada), which works in the waste management market in Canada. Pello has the following advantages: - Support of the territory's safety (automatic informing in case of the presence of hazardous items and materials in dumpsters serviced by the company). Operators make a decision: whether to extract such items or materials independently (if they are identified) or attract specialists from the corresponding services. This allows supporting safety as an element of Quality 5.0 management; - Support of the high level of dumpsters' sanitation, which influences the quality of life of citizens and is a component of Quality 5.0 management. If the management system receives information about the pollution of a certain dumpster, the company replaces it with a clean one and takes away the old dumpster for the corresponding procedures; - Ecologization of process management. Dumpsters are cleaned with materials that are not dangerous to the environment. Company cars that take garbage away and transport dumpsters work on eco-friendly fuel (biofuel, which also contributes to environmental protection. Recycle Track Systems participates in the implementation of territorial goals of waste reduction in Canada. Dumpsters conform to the modern trend of sorting, which allows setting an algorithm for garbage recognition. Waste sorting allows the waste management system to set sorting centres' cars' routes. Recycle Track Systems has agreements with companies to transfer waste for recycling, which is conducted with the application of eco-friendly methods and technologies. This contributes to the reduction in greenhouse gas emissions into the environment.
3	Innovative packaging	Various innovative solutions, which ensure direct and indirect waste reduction in packaging development: 1) Direct influence (application of waste in production); manufacturing of packaging for various types of products from recycled plastic and cardboard (including application of eco-oriented technologies). Leading companies in 2025: DS Smith (UK) (eco-friendly recycling of cardboard and production of sustainable packaging materials from paper and cardboard); Smurfit Kappa (Ireland) (wastepaper recycling and production of corrugated packaging products with a high level of CO2 emissions control); Mondi Group (UK) (purchase and outsource of eco-friendly recycling of wastepaper, production of packaging and paper products using eco-friendly technologies); Amcor Limited (Australia) (plastic and wastepaper recycling and production of green packaging for various sectors); Tetra Pak (Sweden-Switzerland) (cardboard recycling using green technologies and production of packaging products). 2) Indirect influence (reduction of the volumes of materials consumption for the production of packaging). Here innovations are aimed at the creation of minimalistic packaging using digital twins, which model the minimum size of packaging for certain types of products (according to their characteristics); packaging that can be dissolved in water without damage to the environment and human health (with necessary sustainability and reliability during transportation; it is made of organic waste of agricultural production)

Source: Prepared by the authors based on (Amditis, 2025; Cogersa SAU, 2025; Matuszak, 2025; Polaris Market Research & Consulting, Inc., 2025; Romuno, 2024)

The leading methods of recycling expand traditional methods, restoring and recycling different materials, in particular, plastic, electronic waste, and textiles. Such methods as chemical recycling, improved systems of sorting, and mechanical processes of division help to recover valuable resources. These methods solve problems connected with materials that are difficult to recycle, creating new opportunities for reuse. Splitting complex materials, leading technologies make their reuse simpler and minimise the influence on the environment. Reducing the need for primary materials and decreasing energy consumption, these methods contribute to the development of the circular economy and sustainable management of waste.

From the position of employees, active participation in waste management can be very motivating. When employees realise the influence of their actions on waste formation and disposal, they will more likely use sustainable methods. Providing complex training programmes, which teach the employees the methods of waste reduction, recycling procedures, and correct methods of recycling, companies can expand their employees' capabilities to make justified decisions, which conform to the company's goals in the context of waste reduction and management. This is a part of the Quality 5.0 principles.

4. DISCUSSION

The sustainable development concept means effective and well-balanced usage of the existing resources without any damage to future generations' needs. Recycling is one of the foundations of sustainable development. Waste recycling and the use of waste as resources prevent the depletion of natural resources and save energy. New methods and technologies of materials resources recycling, reuse of resources, disposal of industrial and municipal waste, production of composite materials, wastewater treatment, and environmental engineering of dirty industries are the key components of environmental innovations and a necessary condition for ecologization of the reproductive process on the whole.

Sustainable innovations play a decisive role in solving environmental and social problems. It is necessary to create goods and services that meet the demands of the current generation and ensure the well-being of future generations and the planet as a whole. Implementation of innovative methods of reuse of industrial waste is a necessary condition for transitioning to sustainable development. Creation of a circular economy will allow reducing the negative impact on the environment, preserving natural resources, and ensuring a sustainable future for generations to come (Sergeev, 2025).

At the same time, monitoring and analysis of data from different sources, including sensors, cameras, and other connected devices, Quality 5.0 can detect potential defects or problems with quality before their emergence, allowing manufacturers to take the proper actions (Frick and Grudowski, 2023). Involvement of employees in the initiatives on waste management could lead to innovative ideas and solutions.

The modern consumer pays attention to such aspects as conditions of production and manufacturers' compliance with the sustainable development policy, which includes the production's impact on the environment, social responsibility of manufacturers, proper labour conditions of employees, compliance with business ethics, etc.

5. CONCLUSIONS

Industry 5.0 integrates human-oriented production with artificial intelligence, the Internet of Things, and data analytics in real-time to raise the effectiveness of using resources and practices of the circular economy. Industry 5.0 uses leading technologies to improve effectiveness, minimise waste, and increase transparency, contributing to more sustainable development of the food system (Gaikwad and Anerao, 2025).

Production and consumption waste reduction is a vital and beneficial strategy for businesses and the environment. By undertaking measures for waste reduction, companies can raise their productivity and profitability, as well as contribute to the global programme of sustainable development and the well-being of our planet and people. Innovations in the sphere of waste recycling offer substantial advantages from the perspective of sustainable development and environmental solutions. Saving energy, reduction in the carbon footprint, economic benefits, and environmental solutions are a part of the positive effects in many spheres. Support and dissemination of these innovations are important steps that need to be taken for a sustainable future.

Integration of sustainable and responsible consumption, quality education, and the circular economy is a powerful strategy for the achievement of effective waste management and implementation of the UN Sustainable Development Goals (Khajuria et al., 2025).

Sustainable production offers serious environmental benefits, including a decrease in consumption of resources and minimisation of waste and greenhouse gas emissions. Manufacturers can reduce their impact on the environment through the application of energy-efficient methods, renewable materials, and principles of the circular economy.

Implementation of sustainable development in the organisational culture is very important for the long-term success in waste reduction and management. This could be achieved through recognition of employees who actively participate in the efforts on the reduction of waste, promotion of open communication channels for the exchange of ideas, and integration of the Sustainable

Development Goals into the assessment of effectiveness. This is an example of improvement of Quality 5.0.
Sustainable development closes the cycle of waste management, transforming approaches to recycling. Using the models of the circular economy and leading technologies of recycling, as well as solutions for turning waste into energy, these innovations reduce the influence on the environment and create economic value from disposable materials.

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