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Using sustainable development strategies to increase the competitive advantages of agricultural enterprises

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► **Abstract.** This study aimed to analyse the impact of sustainable development strategies on enhancing the competitiveness of agricultural enterprises in order to achieve economic efficiency under modern market conditions. The research methodology was based on a quantitative analysis of statistical indicators relating to the implementation of the circular economy, the use of renewable energy sources in agriculture, and state support for agricultural research in European Union countries. Key environmental initiatives of the European Union, such as the Common Agricultural Policy and the Circular Economy, and their relevance to agricultural businesses were examined. In the course of the research, the successful experiences of Denmark, Sweden, the Netherlands, Germany, and France in implementing sustainable agricultural practices were analysed. The study investigated the implementation of sustainable development in the agricultural sector of both Ukraine and the European Union, particularly through an analysis of the practices of two companies: Rheinisch-Westfälisches Elektrizitätswerk (Germany) and Astarta-Kyiv (Ukraine). The results of the study indicated that Rheinisch-Westfälisches Elektrizitätswerk invested over 5 billion euros in the expansion of renewable energy sources between 2019 and 2024, particularly in agrovoltaics and bioenergy, enabling the company to reduce carbon dioxide emissions by 50% by 2030. Meanwhile, Astarta-Kyiv invested over 5 million euros in irrigation systems and expanded biogas production in 2023-2024, which contributed to increasing the enterprise's energy independence and enhancing its export potential. Based on the

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findings, recommendations were developed for Ukraine regarding the integration of sustainable development into the agricultural sector, including: increased investment in renewable energy, expansion of bioenergy capacities, digitalisation of agricultural production, improved state support for sustainable initiatives, and the adaptation of legislation to the environmental standards of the European Union

▸ **Keywords:** circular economy; renewable resources; digitalisation; environmental friendliness; international experience

▸ Introduction

In the context of globalisation and heightened competitive pressure, agricultural firms must create effective procedures for achieving sustainable development. A fundamental method to attaining enduring success is the adoption of sustainable development policies that harmonise economic efficiency, environmental protection, and social accountability. These solutions not only mitigate environmental harm but also generate new potential for augmenting the competitive advantages of firms in the agricultural industry. Conventional approaches to agricultural business are becoming progressively inadequate for long-term effectiveness (Khrystenko *et al.*, 2025). The Intergovernmental Panel on Climate Change (n.d.) reports that the average global temperature has risen by roughly 1.5°C since the pre-industrial era, resulting in extreme weather events, droughts, and alterations in precipitation patterns, notably affecting agriculture. Moreover, consumers are progressively preferring items produced with low environmental impact, necessitating agricultural firms to modify their business models. The implementation of sustainable development plans is increasingly essential for environmental and economic reasons, serving as a critical determinant of competitiveness, facilitating access to international markets and "green" finance.

The research topic is that, despite increasing interest in sustainable development, numerous agricultural firms face challenges in its implementation. This results from several issues, including inadequate awareness among managers regarding the advantages of sustainable growth, elevated initial expenses linked to environmental and social efforts, and the absence of effective state support systems. Furthermore, it is essential to tailor worldwide experiences in executing sustainable strategies to the unique circumstances of the Ukrainian agriculture sector.

The subject of sustainable agricultural enterprise development has garnered considerable interest from scholars who have analysed diverse facets of its execution and its influence on competitiveness. J. Murphy & A. Gouldson (2020) shown that companies incorporating environmental management principles into their operations successfully reduced production costs by optimising resource use. Their findings substantiate the assertion that sustainable development functions not only as a mechanism for guaranteeing environmental safety but also as a method for improving economic efficiency. T. Gorokhova *et al.* (2023) examined the European experience in adapting the agriculture sector to sustainable development objectives, identifying state subsidies and preferential lending as critical success factors. They underscored that, without enough governmental assistance, enterprises-especially small and medium-sized ones-cannot execute long-term sustainable development objectives.

Research conducted by J. Clapp & S.L. Ruder (2020) demonstrated that the implementation of precision agriculture and digital technologies can markedly diminish environmental impact while concurrently enhancing enterprise efficiency. The authors noted that investments in novel solutions generally produce returns within a few years due to improved production efficiency. S. Fortunati *et al.* (2020) made a notable contribution to the examination of the social aspect of sustainable development by analysing the influence of corporate social responsibility on the positive perception of agricultural firms. They proved that enterprises involved in social activities get competitive advantages through enhanced trust from consumers and partners.

O. Dovgal *et al.* (2024) examined the correlation between the adoption of sustainable practices and the financial viability of agricultural firms. Their findings suggest that companies employing a systematic method for implementing environmental and social initiatives exhibit greater long-term profitability. A. Sartal *et al.* (2014) noted that consumers are progressively favouring products produced in alignment with environmental responsibility concepts. Their research validated that sustainable development can function as a mechanism for product differentiation in the marketplace.

A. Appolloni *et al.* (2022) examined the challenges associated with organic product certification and its influence on business competitiveness. Companies with worldwide environmental quality certifications markedly increased their export prospects. Y. Majeed *et al.* (2023) investigated the significance of investing in renewable energy sources in the agriculture industry. They determined that businesses utilising biogas facilities or solar panels not only decrease operational expenses but also produce supplementary revenue by selling excess energy.

N. Siebrecht (2020) examined the obstacles to the execution of sustainable development plans in agricultural firms. He observed that the principal impediments comprise a lack of environmental awareness, inadequate finance, and a deficiency of skilled professionals in this domain. M. Habib-Ur-Rahman *et al.* (2022) examined the effects of global climate change on agricultural management and affirmed the imperative of adopting adaptive management systems. Their observation indicates that the implementation of sustainable development principles allows agricultural firms to mitigate risks linked to harsh weather conditions.

Researchers affirm that sustainable development is crucial for improving the competitiveness of agricultural operations; yet, its execution necessitates a comprehensive approach that includes innovative technology, social responsibility, and governmental backing. However, there

is an absence of thorough research regarding the mechanisms for adapting international experiences to Ukrainian contexts, assessing the economic viability of long-term investments in sustainable technologies, and investigating the contribution of small and medium-sized enterprises to the sustainable development of the agricultural sector. A comprehensive review of the mechanisms for governmental promotion of environmental initiatives and the effects of sustainable strategies on business development is required.

This study aimed to evaluate the fundamental mechanisms for executing sustainable development strategies within agricultural firms and their impact on competitive advantages. The study objectives were: to analyse current methods for implementing sustainable development strategies in the European Union's agricultural sector; to evaluate the influence of state support and international investment on sustainable agriculture; and to assess the impact of sustainable development on the competitiveness of agricultural enterprises to formulate practical recommendations for effective integration of these principles.

▸ Materials and methods

The research utilised an extensive integration of quantitative and qualitative studies to evaluate the influence of sustainable development on the agricultural sector's competitiveness. To this end, comparative analysis methodologies and a systems perspective were utilised, enabling a comprehensive evaluation of the integration of environmental and new technology in agriculture. The primary statistical data were sourced from official entities, notably Eurostat (n.d.), which offers insights into critical indicators including the rate of circular material utilisation in European Union nations, the volume of electricity consumption derived from renewable sources in agriculture, and governmental support for agricultural research and development from 2019 to 2023. The data for 2024 had not been released at the time of the study.

A quantitative study was performed to evaluate patterns among EU countries, facilitating the identification of dynamics in the transition to a circular economy, the efficacy of renewable energy deployment, and the extent of public support for research in sustainable development. A comparative analysis of the policies of Denmark, the Netherlands, Germany, France, and Sweden facilitated the identification of the most efficacious public mechanisms for promoting environmental initiatives, notably including the Common Agricultural Policy (CAP) (n.d.), the programme "A New Circular Economy Action Plan" (Communication from the Commission…, 2020), and the European Green Deal (n.d.). These countries were chosen for their prominent roles in advancing sustainable development within the agricultural sector and their integration of cutting-edge environmental technologies. The research examined several EU efforts designed to promote sustainable agricultural development, including the Biodiversity Strategy for 2030 (n.d.), the Farm to Fork Strategy (n.d.), and the Ecophyto Plan II (2015). These programmes are crucial for enforcing environmental standards, enhancing the efficiency of natural resource utilisation, and mitigating the environmental impact of agriculture.

A case study method was utilised to examine the influence of sustainable development on the competitive advantages of enterprises, focussing on the activities of two companies: Rheinisch-Westfälisches Elektrizitätswerk (RWE) (2025) (Germany) and Astarta-Kyiv Agro-Industrial Holding (n.d.) (Ukraine). RWE was identified as a leader in the implementation of agrovoltaics and bioenergy, granting the company access to international financing and strategic collaborations in renewable energy. Astarta-Kyiv is a Ukrainian enterprise that promotes sustainable development by utilising biogas plants, precision agriculture, and efficient water conservation systems, therefore enhancing the company's energy independence and export capacity. The investigation utilised business reports, strategic documents, and environmental activities from 2019 to 2024, facilitating a comparison of ecological transformation strategies in the EU and Ukraine.

A systems approach was employed to evaluate the interconnections among economic, environmental, and social dimensions of sustainable development. The research examined the impact of state regulation, investment policy, and international financing on the efficacy of environmental projects. Special emphasis was placed on the function of international groups and financial initiatives designed to promote the circular economy, advance renewable energy, and facilitate the digitisation of agricultural production. The research included statistical data analysis, comparative assessment of state policies, and scrutiny of corporate strategies, enabling the identification of critical criteria that facilitate the effective implementation of sustainable development in the agricultural sector. This interdisciplinary approach facilitated a thorough comprehension of ecological change processes and allowed for the formulation of pragmatic recommendations for Ukraine.

▸ Results

Modern approaches to implementing sustainable development strategies in the agricultural sector. Sustainable development has arisen worldwide as a fundamental framework for economic progress, seeking to attain a healthy equilibrium of economic efficiency, social equality, and environmental stewardship. The agricultural sector, a major consumer of natural resources and a key contributor to environmental impact, need the immediate incorporation of sustainable development concepts to guarantee long-term food security, economic resilience, and ecological stability. The notion of sustainable development was officially articulated in the Report of the World Commission on Environment and Development (n.d.), which characterised it as development that fulfils the requirements of the current generation without jeopardising the capacity of future generations to satisfy their own needs. In 2015, the United Nations General Assembly ratified the Sustainable Development Goals, encompassing 17 fundamental domains for advancement by 2030 (Tomislav, 2018). The primary objectives for the agricultural sector encompass: eliminating hunger and fostering sustainable agri-food systems; ensuring the judicious utilisation of water resources and mitigating water pollution; incorporating clean energy into agricultural practices; advocating for sustainable consumption and production; and tackling climate change by decreasing greenhouse gas emissions and adapting to evolving climatic conditions.

The agriculture industry encounters various issues that require the implementation of sustainable development concepts. These encompass soil degradation, biodiversity loss, natural resource depletion, climate change, and the environmental repercussions of the war in Ukraine, including land and water contamination from explosives and military waste (Zavhorodnii *et al.*, 2024). A fundamental strategy for integrating sustainability in agriculture is the circular economy, a framework focused on waste reduction, resource reutilisation, and the shift from a linear production model ("production – consumption – disposal") to closed-loop systems, wherein byproducts are perpetually repurposed. The circular economy in agriculture is implemented via composting and biogas technologies that transform organic waste into fertilisers and energy; the use of agricultural residues, such as straw and corn husks, for biofuel production; and efficient water management, facilitated by water collection and reuse technologies (Velasco-Muñoz *et al.*, 2022). The experiences of European nations illustrate the considerable efficacy of this paradigm. The circular material use rate, which quantifies the percentage of reused and recycled resources relative to total material intake, serves as a key indicator of success in this domain (Table 1). This data is crucial for comprehending how various nations are embracing the ideas of the circular economy and utilising renewable resources to alleviate environmental impacts.

Table 1. The rate of use of cyclical material in EU countries for 2019-2023, %

	2019	2020	2021	2022	2023
EU	11.2	11.2	11.1	11.5	11.8
Austria	11.5	11.4	11.3	12.4	14.3
Belgium	20.5	22.9	21.4	18.3	19.7
Denmark	7.6	7.6	8.6	9.3	9.1
Spain	9	9.3	8.8	9.4	8.5
Italy	18.8	20.6	19.7	20.6	20.8
Netherlands	25.6	27.1	28.5	27.2	30.6
Germany	12.4	12.8	12.2	12.5	13.9
Poland	9.2	7.4	7	6.7	7.5
France	17.1	16.2	15.9	17.5	17.6
Sweden	6.4	6.9	9.5	12.1	9.9

Source: created by the authors based on Eurostat (n.d.)

The Netherlands demonstrates the highest figures, with an increase from 25.6% in 2019 to 30.6% in 2023, indicating the effective implementation of circular economy practices. In contrast, Sweden, after a notable rise in 2022, shows a slight decline in 2023 to 9.9%. Other countries, such as Germany, France, and Italy, exhibit a steady upward trend, with Germany increasing from 12.4% in 2019 to 13.9% in 2023. The progress observed across most countries reflects the gradual adoption of more efficient technologies for incorporating recycled materials into production processes. The shift to renewable energy sources signifies a crucial aspect of sustainable agricultural development. Agriculture possesses considerable potential for solar energy utilisation via the installation of solar panels on rooftops of farms and agricultural structures, wind energy through the deployment of wind turbines in climatically appropriate areas, and bioenergy through the transformation of agricultural waste into biofuels. These approaches allow farmers to diminish their dependence on conventional energy sources (Rahman *et al.*, 2022). Table 2 displays information regarding electricity consumption derived from renewable sources within the agricultural sector.

Table 2. Electricity consumption volume from renewable sources in the agricultural sector across EU countries, 2019-2023 (GWh)

	2019	2020	2021	2022	2023
EU	35,377.9	36,487.8	38,797.8	37,847.4	36,064.6
Austria	1,884.2	1,831.2	2,149.8	2,033.7	1,985.0
Belgium	460.6	489.8	407.5	397.4	344.3
Denmark	628.1	610.5	660.2	638.0	638.5
Spain	831.1	829.5	828.9	856.0	833.5
Italy	619.1	611.9	880.7	864.8	795.4
Netherlands	4,008.0	4,418.4	4,718.8	4,631.0	3,548.9
Germany	8,940.0	9,510.4	9,702.4	9,619.1	9,374.4
Poland	5,549.2	5,677.3	6,732.6	5,500.7	5,083.8
France	4,162.7	4,482.9	4,533.3	4,506.0	4,968.3
Sweden	2,605.1	2,542.8	2,319.3	2,951.3	2,545.4

Source: created by the authors based on Eurostat (n.d.)

The total consumption of electricity from renewable sources in the EU demonstrates some fluctuation, decreasing from 38,797.8 GWh in 2021 to 36,064.6 GWh in 2023. However, certain countries exhibit either stable growth or fluctuations within specific ranges. For instance, France shows consistent growth in renewable energy consumption, reaching 4,968.3 GWh in 2023, indicating the active adoption of "clean" energy within the agricultural sector. The Netherlands, despite reporting a high level of renewable electricity consumption in 2021 (4,718.8 GWh), experienced a decline to 3,548.9 GWh in 2023, which may be attributed to structural changes in energy consumption patterns. Meanwhile, countries such as Poland maintain comparatively lower levels of renewable electricity consumption, potentially reflecting a slower integration of renewable technologies in agriculture relative to other EU member states.

Sustainable development includes environmental and economic aspects as well as the social responsibilities of agribusiness, which involve investing in social infrastructure to support local communities, ensuring favourable working conditions for agricultural labourers, promoting food security, and enhancing access to eco-friendly products (Ali, 2023). In EU nations, governments actively endorse responsible agriculture by providing subsidies and grants to farmers who implement ecologically sustainable technologies. Investment in agricultural research and development is essential for fostering innovation that improves productivity, environmental sustainability, and resource efficiency. Government assistance for this study is essential for progressing the agricultural sector, especially for the execution of sustainable development strategies, the circular economy, and technological innovation (Sartas *et al.*, 2020). Each EU nation allocates research funds variably, mirroring their distinct economic capabilities and political approaches to advancing the agro-industrial sector. Table 3 illustrates the magnitude of governmental assistance for agricultural research and development.

Table 3. Government assistance for agricultural research and development in EU nations, 2019-2023 (million EUR)

	2019	2020	2021	2022	2023
EU	2,961.1	3,217.9	3,337.7	3,576.3	3,643.1
Austria	36.1	39.3	51.0	61.9	94.6
Belgium	57.0	58.5	78.7	71.7	86.1
Denmark	101.8	90.5	139.1	160.2	95.4
Spain	449.0	472.6	499.7	519.1	543.3
Italy	141.6	219.0	219.6	364.1	420.7
Netherlands	917.5	1,028.5	1,121.6	1,112.4	1,092.7
Germany	97.3	145.0	4.3	5.3	7.0
Poland	362.2	369.5	354.8	429.8	492.5
France	45.7	49.2	79.6	78.7	49.4
Sweden	2,961.1	3,217.9	3,337.7	3,576.3	3,643.1

Source: created by the authors based on Eurostat (n.d.)

The total amount of support in the EU increased from EUR 2,961.1 million in 2019 to EUR 3,643.1 million in 2023, indicating a growing emphasis on innovation in agriculture. The Netherlands traditionally receives the largest share of funding, with EUR 1,092.7 million allocated in 2023, reflecting the country's highly developed agricultural technology sector. A notable increase in investment is observed in Italy, where funding rose nearly threefold – from EUR 141.6 million in 2019 to EUR 420.7 million in 2023. Conversely, Germany has experienced a sharp decline in funding levels in recent years, which may suggest a re-evaluation of state priorities concerning agricultural research support. Meanwhile, countries such as Poland and Spain demonstrate a steady rise in funding, indicating sustained governmental interest in the long-term development of agriculture through scientific advancement.

Government support and international initiatives in the field of sustainable development. The European Union is a global frontrunner in enacting ecologically sustainable laws and regulations designed to diminish emissions, encourage the judicious use of resources, and foster a circular economy in agriculture. The main aim of these activities is to establish an agricultural sector that integrates high production with low environmental impact, efficient utilisation of natural resources, and enhanced food security (Cifuentes-Faura, 2022). The EU strategy focusses on long-term results, designating agriculture as a crucial sector for climate change mitigation and ecological preservation.

A primary strategic endeavour in this area is the European Green Deal (n.d.), which establishes a cohesive framework for sustainable development across all economic sectors, including the agro-industrial complex. The text delineates a gradual shift towards a climate-neutral economy by decreasing reliance on fossil fuels, minimising greenhouse gas emissions, and fostering the advancement of innovative environmental technologies. The agricultural sector is recognised as a key area necessitating reform to reduce its environmental impact. The Farm to Fork Strategy (n.d.) is a fundamental element of the EU's sustainable development agenda, aiming to reform the food system and reduce the environmental effect of agriculture. It encompasses objectives like a 50% decrease in chemical pesticide usage, a 20% reduction in mineral fertiliser application, and an elevation of organic farming to 25% of the total agricultural land area. The policy prioritises the digitisation of agriculture, incorporating artificial intelligence, satellite surveillance, and blockchain technologies to improve resource efficiency and mitigate environmental impact (MacPherson *et al.*, 2022).

Another key initiative is the Biodiversity Strategy for 2030 (n.d.), which forms part of the European Green Deal and focuses on protecting ecosystems and restoring natural landscapes vital for agricultural productivity. Core measures include the establishment of ecological corridors, the protection of pollinators, and the rehabilitation of degraded land. Particular attention is given to agroforestry – the integration of agricultural land with forest plantations – which helps reduce soil erosion, improve soil fertility, and restore essential ecosystem services.

The EU's CAP (n.d.) is one of the most substantial instruments supporting the agricultural sector, offering financial assistance to agricultural producers and facilitating their transition towards more environmentally responsible business models. In the 2023-2024 period, the CAP underwent significant changes, placing greater emphasis on sustainable development and the adaptation of agriculture to the challenges posed by climate change. An "eco-scheme" mechanism was introduced to provide financial incentives for farmers who comply with enhanced environmental standards. Key requirements include the reduction of agrochemical use, expansion of organic farming areas, implementation of cover crops, and the preservation of natural landscapes. Additionally, stricter requirements have been introduced for efficient water management and the reduction of greenhouse gas emissions.

The EU advocates for resource reutilisation, waste reduction, and the advancement of biotechnologies in agriculture as outlined in the New Circular Economy Action Plan (Communication from the Commission…, 2020). Special emphasis is placed on technologies that transform organic waste into biofuels, fertilisers, and feed additives. There is a focus on facilitating the generation of biogas, bioethanol, and biodiesel, thereby diminishing the agriculture sector's dependence on fossil fuels. These efforts not only bolster the energy autonomy of rural areas but also promote the economic stability of agricultural enterprises.

Successful implementation of these initiatives can be observed in countries such as Denmark, the Netherlands, Germany, France, and Sweden. Denmark serves as a prominent example of effective environmental integration in agriculture. In November 2024, Danish political parties reached an agreement to convert 10% of agricultural land into forests and plant one billion trees. This initiative involves allocating 43 billion Danish kroner (USD 6.1 billion) to purchase land from farmers for project implementation. The objective is to restore natural ecosystems and reduce greenhouse gas emissions, thereby addressing global warming (Pavlyuk, 2024). In addition, Denmark has introduced a unique action plan aimed at transitioning to a more plant-based food system. In 2021, the government allocated approximately USD 200 million to support this transition, of which USD 85 million was directed to plant-based farmers. The remaining funds supported projects such as renovating cafeterias to encourage plant-based consumption and establishing incubators for plant-based start-ups. This approach has gained widespread support due to its emphasis on business opportunities and environmental benefits, rather than imposing restrictions on meat consumption (Torrella, 2024).

The Netherlands is a frontrunner in the implementation of innovative approaches to sustainable agriculture. The country is actively developing vertical farming and precision agriculture, both of which reduce water and chemical fertiliser use while increasing yields. These technologies contribute to the optimisation of land use and the reduction of the agricultural sector's environmental impact. According to the Dutch Biogas Association, the Netherlands produced over 1.5 million m³ of biogas per day in 2023, enabling a reduction in CO_2 emissions by 5.4 million tonnes per year. The country has set an ambitious target to increase biogas production by 30% by 2030 (Platform Groen Gas, n.d.). The Netherlands also actively supports circular economy programmes focused on resource reuse and reducing food waste. As part of the National Circular Economy Plan, the country aims to cut food waste by 50% by 2030 and achieve a complete cycle of organic waste recycling for reuse in agriculture. Statistics from 2022 indicate that approximately 60% of organic waste produced in the agricultural sector was either converted into energy resources or used as fertiliser (Ministry of Infrastructure and Water Management, 2023).

Germany is actively applying circular economy ideas in the agro-industrial sector, facilitating the repurposing of organic waste for the generation of bioethanol, biogas, and biodiesel. In 2024, the German government sanctioned the disbursement of EUR 57.6 billion for "green" initiatives, reflecting a 60.2% increase relative to 2023. Of this amount, EUR 18.9 billion is allocated for reconstruction and new construction subsidies, EUR 12.6 billion for renewable energy sources, and EUR 4.7 billion for the expansion of electric vehicle charging infrastructure. These investments seek to facilitate the nation's objective of attaining carbon neutrality by 2045 (Nynko, 2023). Germany is actively implementing precision farming technologies in agriculture, utilising drones and sensors to assess soil and crop conditions. These advances diminish the need on chemical fertilisers and water while enhancing the efficiency and sustainability of agricultural output.

France ranks among the EU leaders in ecological and sustainable agricultural practices. In 2020, the country launched the Ecophyto Plan II (2015), aimed at reducing pesticide use in agriculture by 50% by 2025. Under this programme, farmers receive subsidies to purchase environmentally friendly plant protection products. France also supports the transition to organic farming, with a target of allocating 15% of all agricultural land to organic production by 2025. In 2024, new standards were introduced to encourage biodiversity preservation and the restoration of degraded lands. France is also heavily investing in sustainable farming technologies, including precision agriculture systems that minimise resource use. Moreover, the country employs innovative food production methods that help reduce food waste and conserve energy resources (Jacquet *et al.*, 2022).

Sweden excels in the adoption of sustainable agricultural techniques, systematically incorporating eco-friendly technologies into its agricultural industry. A significant endeavour is the Farmers for Climate approach, which seeks to diminish greenhouse gas emissions in the sector. Sweden aims to attain net-zero greenhouse gas emissions in agriculture by 2045, in alignment with its national policy for executing the Paris Climate Agreement (Martinsson & Hansson, 2021). In recent years, the nation has

markedly augmented the utilisation of renewable energy sources in agricultural production, especially through the manufacture of biogas, bioethanol, and biodiesel from agricultural waste. In 2020, Sweden attained a 16% contribution of bioenergy to its overall national energy production, encompassing energy sourced from agricultural waste. Moreover, over 40% of Swedish farmers utilise advanced precision agriculture technologies, facilitating reductions in fertiliser application and limiting environmental effect (At a glance…, 2024).

The agricultural sector of Ukraine is a vital element of the national economy, guaranteeing food security, considerably contributing to gross domestic product (GDP), and representing a considerable portion of exports. In 2024, agricultural exports totalled around USD 24.5 billion (Tarasovsky, 2025). Nevertheless, under prevailing circumstances, the industry encounters multiple obstacles that impede sustainable development. The issues encompass the repercussions of warfare, environmental deterioration, inadequate investment in contemporary technology, a little degree of digitalisation, and inefficient governmental regulation concerning green transformation. Ukraine has significant potential to implement sustainable development concepts, which might improve the competitiveness of its agriculture sector in domestic and international markets.

A pivotal element of the present condition of sustainable development in agricultural enterprises is the incremental adoption of environmental practices, including organic farming, the reduction of chemical fertilisers and pesticides, precision farming technologies, and the shift to renewable energy sources. Notwithstanding the increasing interest in sustainable development, the rate of adaptation is sluggish, chiefly attributable to insufficient financial assistance for farmers, a fragile regulatory framework, and an unstable socioeconomic landscape. Numerous Ukrainian firms, especially small and medium-sized ones, lack the requisite resources to adopt environmental innovations, hindering the shift to sustainable production methods (Manushkina *et al.*, 2024).

A major concern is the impact of military activities, resulting in substantial environmental degradation, destruction of agricultural infrastructure, mine contamination, and damage to land reclamation systems. Estimates from the Kyiv School of Economics suggest that Ukraine's agricultural sector may incur indirect losses up to USD 83 billion by the conclusion of 2025. These losses are associated with decreased seeded areas and alterations in production technologies, which adversely impact crop yields. The yield of grains and oilseeds decreased from 107 million tonnes in 2021 to roughly 77 million tonnes in 2024. The conflict has additionally limited farmers' access to contemporary technology, fertilisers, and seeds, hence diminishing yields and product quality (Ukraine farm sector…, 2024). Ukraine is predicted to incur an annual GDP loss of USD 11 billion owing to mine contamination, rendering 2.5% of fertile land unproductive (Harmash, 2024).

Financial assistance and investment in sustainable development are essential. Although several initiatives, including grant programmes from international organisations, are in progress, their magnitude is now inadequate to effectuate a systemic impact on the sector. The inadequate digitisation of agriculture is a challenge. The implementation of digital technology, including satellite monitoring and precision agriculture, has the potential to significantly decrease the consumption of natural resources and alleviate environmental effect. Nonetheless, the execution of such solutions necessitates the requisite skills and technical infrastructure, which are predominantly available to major agricultural enterprises. Conversely, small and medium-sized farmers frequently lack access to these innovations.

Despite the challenges outlined, Ukraine possesses considerable potential for transitioning to a sustainable agricultural model. Engagement in European environmental initiatives, integration into EU funding programmes, and the adaptation of national legislation to align with European environmental standards could become key drivers in accelerating the country's "green" transformation. Furthermore, the promotion of local initiatives focused on expanding organic farming, enhancing energy efficiency, and implementing circular economy principles will be vital to fostering long-term sustainable development.

The influence of sustainable development on the competitiveness of agricultural operations. Sustainable development is a significant factor influencing the competitiveness of the agricultural sector, as demonstrated by the cases of two companies: Rheinisch-Westfälisches Elektrizitätswerk (RWE) (2025) in Germany and the Astarta-Kyiv Agro-Industrial Holding (n.d.) in Ukraine. RWE is actively engaged in the adoption of renewable energy technologies, particularly agrovoltaics – an innovative approach that integrates electricity generation with agricultural production. The company's key financial indicators are presented in Table 4.

Table 4. Key financial indicators of RWE, 2019-2024 (billion EUR)

	2019	2020	2021	2022	2023	2024 (3rd quarter)
Income	13.1	13.7	24.5	38.4	28.6	15.9
Earnings before Interest, Taxes, Depreciation and Amortisation (EBITDA)	2.5	3.3	3.6	6.3	8.4	4
Profit	9.2	1.1	0.8	3	1.6	1.2
Assets	64.2	61.6	142.3	138.5	106.5	98.6
Equity	17.4	17.7	17	29.3	33.1	35.1

Source: created by the authors based on Rheinisch-Westfälisches Elektrizitätswerk (2025)

RWE's sustainable solutions have had a significant impact on its profitability, contributing to an increase in market share, the establishment of new partnerships, and an enhanced corporate image. For instance, following a substantial expansion of its investments in renewable energy, the company's revenue almost doubled – from

EUR 13.7 billion in 2020 to EUR 24.5 billion in 2021 – and reached a record EUR 38.4 billion in 2022. In particular, agrovoltaic and bioenergy projects have not only enhanced the efficiency of land use but also reduced energy costs, which positively influenced the company's EBITDA, rising from EUR 3.3 billion in 2020 to EUR 6.3 billion in 2022. However, in 2023, these figures declined, with profit falling to EUR 1.6 billion, attributed to the high initial costs associated with the implementation of new projects.

Renewable initiatives have become a key factor in reinforcing RWE's reputation as a leader in environmental responsibility, thereby facilitating the attraction of substantial international investments. For example, in 2023, the company secured over EUR 2.5 billion in "green" investments from the European Investment Bank and private partners to finance agrovoltaic projects in Germany, Spain, and Italy. As a result, the company's equity increased from EUR 17.7 billion in 2020 to EUR 33.1 billion in 2023, indicating improved financial stability and heightened investor confidence.

Digital technologies have also significantly enhanced RWE's operational efficiency. The adoption of automated monitoring and management systems for energy networks has enabled the company to reduce operating costs and optimise production. For instance, the application of artificial intelligence in electricity demand forecasting has improved resource management efficiency, which partially explains the growth in the company's EBITDA during 2022-2023. Moreover, the expansion of the agrovoltaic project in Bavaria in 2023 enabled the production of up to 50 MW of electricity, supplying more than 30,000 households. This not only supported decarbonisation efforts but also boosted the company's profitability within the renewable energy sector.

Astarta-Kyiv, a prominent agro-industrial holding in Ukraine, is diligently incorporating sustainable development principles into its operations, emphasising the reduction of environmental impact and the enhancement of agricultural production efficiency. The corporation cultivates grain crops, sugar beets, milk, and various other agricultural products. The primary activities encompass the implementation of novel technology, enhancements in energy efficiency, and the advancement of organic agriculture. Table 5 delineates the company's principal financial metrics.

Table 5. Key financial indicators of Astarta-Kyiv, 2019-2024 (million EUR)

	2019	2020	2021	2022	2023	2024 (3rd quarter)
Income	448	415.6	491.4	510.1	619.9	441.5
EBITDA	77.9	113.4	201.4	154.8	145.4	132.6
Profit	1.7	8.6	122.5	65.2	61.9	75.6
Assets	759.3	511.4	690.6	707.6	710.3	716.7
Equity	438.8	337.3	495.1	489.2	498.8	517.7

Source: created by the authors based on Astarta-Kyiv Agro-Industrial Holding (n.d.)

The implementation of sustainable development by Astarta-Kyiv has significantly influenced the company's financial performance and competitiveness. The transition to organic production, initiated in 2020 with 7,000 hectares and expanded to 11,500 hectares by 2023, enabled the company to enter the organic market, which offers higher added value and stable demand within the EU. This transition positively impacted financial performance: the company's revenue increased from EUR 415.6 million in 2020 to EUR 619.9 million in 2023, demonstrating the success of this strategy. Moreover, profitability improved markedly – with net profit rising to a record EUR 122.5 million in 2021 – driven by cost optimisation and the adoption of sustainable management practices.

A key contributor to the company's enhanced financial stability has been its strategy to increase energy efficiency. The implementation of bioenergy projects, including biogas plants, has significantly lowered energy costs, which is particularly important given the rising prices of conventional energy sources. As a result, the company's EBITDA following the launch of these programmes in 2021 reached EUR 201.4 million, and by 2024 (for the first three quarters) stood at EUR 132.6 million, indicating the effectiveness of this initiative. The use of precision agriculture and digital technologies – such as satellite monitoring and automated systems for managing agricultural processes – has contributed to cost reductions in agrochemical use and optimised fertiliser application. This has not only lessened the environmental impact but also improved agricultural land productivity, thereby enhancing the profitability of crop production. Through these technological advancements, the company has achieved steady asset growth, from EUR 511.4 million in 2020 to EUR 716.7 million in 2024.

The attraction of international grants has also played a vital role in enhancing financial sustainability. For instance, in 2020, Astarta-Kyiv received a EUR 1.5 million grant from the EU for the development of sustainable agricultural technologies. These funds were allocated to the modernisation of production facilities and the implementation of environmental standards in line with contemporary European requirements. Such initiatives not only improved the company's environmental profile but also strengthened its market position, fostered partnership development, and enhanced its reputation as a responsible producer. Table 6 presents a comparative analysis of the approaches used in the implementation of sustainable practices. The differing strategies, investments, technologies, and environmental impacts adopted by these companies offer valuable insights for adapting similar approaches to the context of Ukraine.

Table 6. Comparison of RWE and Astarta-Kyiv in the implementation of sustainable practices

Criterion	RWE (Germany)	Astarta-Kyiv (Ukraine)
Branch	Energy, renewable energy, agrovoltaics	Agricultural production, processing, bioenergy
The main strategy for sustainable development	Investments in renewable energy sources, agrovoltaics, bioenergy	Biogas plants, precision agriculture, water conservation, energy efficiency
Investment in sustainable solutions	5+ billion euros in the period 2019-2023 for renewable energy and agrovoltaics	5+ million euros in irrigation in 2023 and 50 GWh in biogas plants in 2020
Impact on competitive advantage	Increasing access to "green" investments, international partnerships, growing market positions in the EU and abroad	Increasing export potential, improving energy independence and reputation in domestic and international markets
Main market	EU, international agroholdings, investors in "green" technologies	Ukraine, EU, international traders, agricultural companies
Environmental impact	Plans to reduce CO_2 emissions by 50% by 2030, ensuring stable renewable energy production	Use of biogas, reduction of water consumption, minimisation of chemical load on soils
Financial support and subsidies	Benefits of European "green" investment programmes	Support from international financial organisations, subsidies for bioenergy and environmental projects
Digital technologies	Innovative platforms for energy consumption monitoring, process automation	Implementation of precision farming systems, digital monitoring of water and energy use
Future predictions	Continued development of agrovoltaics, bioenergy projects, and environmental initiatives	Development of biogas plants, organic farming, modernisation of irrigation systems

Source: created by the authors based on Rheinisch-Westfälisches Elektrizitätswerk (2025), Astarta-Kyiv Agro-Industrial Holding (n.d.)

Drawing from the experiences of firms like RWE and Astarta-Kyiv, some critical recommendations may be articulated for Ukraine to facilitate the adoption of sustainable practices in the agriculture sector. Ukraine ought to engage more vigorously in renewable energy sources and agrovoltaics. RWE's experience illustrates that the amalgamation of agricultural land with solar panels can effectively diminish CO_2 emissions while concurrently providing supplementary income for farmers. Ukraine has considerable potential for agrovoltaic development, which may simultaneously improve agricultural productivity and decrease reliance on traditional energy sources.

The proactive implementation of bioenergy technology, especially biogas facilities, is crucial. The experience of Astarta-Kyiv demonstrates that biogas is a useful means of reducing energy dependence and alleviating the negative effects of agricultural waste. Ukrainian agricultural firms ought to prioritise bioenergy development by assisting farms in the establishment of such facilities, which would enhance energy efficiency and create additional prospects for reducing greenhouse gas emissions.

An important domain is the implementation of precision agriculture technologies. Systems that provide precise fertiliser delivery and optimal water utilisation can markedly improve production efficiency. Ukraine ought to vigorously advance the evolution of digital technologies in agriculture, particularly through the adoption of Global Positioning System technologies, which facilitate the reduction of natural resource consumption and mitigate environmental impact. This will enhance agricultural yield without intensifying environmental strain.

Successful implementation of sustainable methods in agriculture necessitates support through government programmes, grants, and subsidies. Prioritising the financing of new and environmentally sustainable technologies for small and medium-sized farmers should be a governmental focus. These initiatives will guarantee wider access to emerging technology and promote the adaption of businesses to sustainable development principles. A similarly significant facet is the overhaul of the legislative structure. Ukraine must persist in incorporating environmental efforts into national policy and implement legislative measures to promote sustainable development in the agricultural sector. This encompasses measures aimed at safeguarding water resources, conserving soil, rehabilitating damaged land, and mitigating environmental pollution. Ukraine may attain sustainable agricultural growth that adheres to environmental norms and aids in the conservation of natural resources for future generations just by addressing these concerns.

▸ Discussion

The study's results affirm that incorporating sustainable development principles into agricultural production is a crucial aspect in improving the competitiveness of agricultural firms. The industry currently confronts various issues, including as climate change, soil degradation, rising food consumption, and the necessity for the judicious utilisation of natural resources. Moreover, the implementation of sustainable technology has become imperative, not only for economic efficiency but also in reaction to increased worldwide environmental standards. A.S. Magdalena *et al.* (2025) investigated the influence of the circular economy on the financial performance of agricultural firms. They determined that closed production cycles, waste reutilisation, and other elements of the circular economy can substantially save operating expenses and enhance organisational resilience to market volatility. This study supports these findings and further examines the environmental aspects of the circular economy, namely its impact on diminishing pollution and enhancing resource efficiency. Innovations in agriculture, as evidenced by the research of A. Berxolli *et al.* (2023), can function as tools for economic sustenance and psychological stability for rural communities during crises, particularly among military conflicts.

The adoption of renewable energy is a vital aspect of sustainable agricultural development. Minimising dependence on fossil fuels allows agricultural businesses to reduce energy expenses, diminish greenhouse gas emissions, and adhere to contemporary environmental regulations (Musca & Kara, 2023). The deployment of solar panels, wind farms, and bioenergy facilities not only fosters energy independence for businesses but also bolsters their financial viability via access to assistance programmes and "green" investments. M.B. Pietrzak *et al.* (2021) performed an investigation on the economic feasibility of converting the agriculture industry to renewable energy sources. They determined that solar and wind energy are especially advantageous for substantial agroholdings with adequate cash to invest in the requisite infrastructure. C. Cavicchi *et al.* (2022) contended that these technologies are predominantly unattainable for small and medium-sized firms owing to substantial initial expenses and prolonged return on investment durations. The present study affirms the importance of renewable energy, while emphasising that bioenergy technologies, especially biogas facilities, may be more attainable for medium-sized organisations.

Mitigating the adverse environmental effects of agriculture is attainable through the implementation of resource-efficient technology. Precision farming methods, computerised soil monitoring, and efficient water management reduce chemical inputs and improve agricultural output (Shahini *et al.*, 2023). For instance, minimising the application of synthetic fertilisers and pesticides not only mitigates pollution but also enhances the quality of agricultural products. L. Guo *et al.* (2022) examined the effects of diminished mineral fertiliser application on agriculture and discovered that, in the short term, this results in decreased yields, potentially harming enterprise profitability. Nonetheless, over the long term, enhancements in soil health resulted in heightened production efficiency. The present study acknowledges the significance of reducing chemical fertiliser usage while prioritising the equilibrium between environmental and economic considerations. It promotes the implementation of alternative methods, including precision agriculture and organic production.

J.M. Kwakye *et al.* (2024) examined the economic and environmental efficacy of bioenergy technology in agriculture, focussing specifically on biogas production from agricultural waste. He analysed the effects of biogas plant adoption on agricultural energy autonomy and the mitigation of greenhouse gas emissions. This study corroborates these conclusions, especially with the environmental advantages of bioenergy. Although J.M. Kwakye *et al.* emphasised bioenergy as a promising avenue, his study did not account for regional disparities in the viability of these technologies. The present analysis emphasises the significance of governmental assistance and legislative incentives to facilitate the broader implementation of bioenergy.

The advancement of sustainable farming methods is strongly affected by governmental policies and the level of support offered through national and international programmes. Government incentives, including subsidies for renewable energy, grant funding for scientific research in agro-innovation, and concessional loans for the adoption of environmentally sustainable technologies, promote a more vigorous transition of agricultural producers to sustainable management practices (Bulgakov *et al.*, 2017; 2019). Moreover, international initiatives include the EU CAP (n.d.), the Horizon Europe (n.d.) programme, the Farm to Fork Strategy (n.d.), and the Biodiversity Strategy for 2030 (n.d.) significantly influence the establishment of global norms for sustainable development. These projects can act as standards for the modification of national agricultural policies. C.D. Thompson *et al.* (2022) examined governmental support programmes for environmental activities in agriculture, uncovering significant financial differences between Western and Eastern European nations. Their findings demonstrated that nations with elevated GDP per capita allocate significantly greater resources towards the advancement of the circular economy and green technologies. The present study reiterates the significance of state support while emphasising the efficacy of specific programmes, including Horizon Europe, the CAP, and the European Green Deal. Moreover, the current analysis examined both the magnitude of public investment and its allocation across small, medium, and big firms.

The application of digital technologies in agriculture is essential for advancing environmental sustainability and improving productivity. Automated management systems, artificial intelligence, the Internet of Things, and satellite monitoring provide accurate regulation of soil conditions, yield forecasting, resource optimisation, and the reduction of adverse environmental effects. The adoption of these technologies improves agricultural efficiency, lowers material expenses, and boosts the profitability of farming operations. Research by U. Deichmann *et al.* (2016) similarly revealed that firms that actively implement digital technologies can decrease fertiliser and water consumption, thus enhancing resource efficiency. The findings align with those of the current study; however, this analysis prioritises the environmental advantages of precision agriculture over its economic viability. Access to digital technologies varies markedly between nations.

Compliance with European environmental regulations allow firms to access cutting-edge technologies, funding opportunities, and global alliances (Silagadze *et al.*, 2024). Furthermore, compliance with stringent environmental requirements bolsters consumer confidence and reinforces the worldwide competitiveness of agricultural enterprises. J. Lu *et al.* (2020) examined the influence of compliance with environmental requirements on the export capacity of agricultural firms. Their findings indicated that enterprises aligning their manufacturing processes with European environmental standards experience markedly enhanced access to international markets, advantageous financing circumstances, and increased consumer trust. This study corroborates these conclusions, while also highlighting that international integration requires not just compliance with environmental regulations but also the modernisation of technological processes, frequently necessitating significant financial investment.

Sustainable agricultural growth is a complex process requiring a cohesive strategy and active collaboration among government, industry, and the scientific community. The adoption of renewable energy sources, precision agriculture technology, bioenergy solutions, digitalisation, and efficient resource management enhances firm competitiveness, ensures financial sustainability, and complies

with modern environmental norms. An integrated strategy for adopting sustainable practices is crucial for the long-term advancement of the agriculture sector, enhancing the economic performance of firms while concurrently mitigating the environmental impact of agricultural activities.

▸ Conclusions

The study's findings affirm that incorporating sustainable development into agriculture enhances enterprise competitiveness, economic resilience, and environmental accountability. The implementation of renewable energy sources, the digitisation of manufacturing, and the optimisation of resource utilisation allow enterprises to decrease operational expenses, attract further investment, and penetrate new markets. The adoption of digital technologies, especially satellite monitoring and automated systems, enables businesses to enhance resource efficiency, elevate product quality, and reduce environmental effect. The experience of EU nations illustrates that governmental assistance via grant programmes and tax incentives expedites the implementation of environmental projects.

An examination of RWE's financial metrics indicates that the company has proactively invested in renewable energy, favourably impacting its financial performance. From 2019 to 2023, RWE invested over EUR 5 billion in solar, wind, and bioenergy development, leading to a revenue increase from EUR 13.1 billion in 2019 to EUR 28.6 billion in 2023, and an EBITDA rise from EUR 2.5 billion to EUR 8.4 billion during the same timeframe. Astarta-Kyiv exhibits a beneficial effect from the adoption of bioenergy and precision agriculture. In 2020, the company generated 50 GWh of biogas, thereby diminishing dependence on conventional energy sources. Investments in irrigation systems over EUR 5 million in 2023 facilitated enhanced water resource management, augmented crop production, and diminished environmental effect. These initiatives facilitated the company's profit increase from EUR 448 million in 2019 to EUR 619.9 million in 2023.

The successful execution of sustainable principles necessitates a holistic approach encompassing governmental backing, financial incentives, and innovative technologies. This approach will strengthen the agricultural sector's resilience, promote its integration into global markets, and foster the establishment of efficient and sustainable food systems for the future. A disadvantage of the study is its dependence on accessible statistical data and its failure to consider all elements affecting sustainable agricultural development, including regional particularities and changes in the political landscape. Future research may concentrate on a comprehensive investigation of the effects of particular environmental initiatives on the financial viability of agricultural firms and the efficacy of governmental support systems for sustainable agriculture.

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Використання стратегій сталого розвитку для підвищення конкурентних переваг аграрних підприємств

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► **Анотація.** Робота була направлена на аналіз впливу стратегій сталого розвитку на підвищення конкурентоспроможності аграрних підприємств для досягнення економічної ефективності в умовах сучасного ринку. Методологія дослідження базувалася на кількісному аналізі статистичних показників щодо впровадження циркулярної економіки, використання відновлюваних джерел енергії в сільському господарстві та державної підтримки аграрних досліджень у країнах Європейського Союзу. Було розглянуто ключові екологічні ініціативи Європейського Союзу, такі як Спільна аграрна політика та Циркулярна економіка, і їхнє значення для аграрного бізнесу. У процесі дослідження був проаналізований успішний досвід Данії, Швеції, Нідерландів, Німеччини та Франції щодо впровадження сталих аграрних практик. У роботі досліджено впровадження сталого розвитку в аграрному секторі України та Європейського Союзу, зокрема через аналіз практик двох компаній – Rheinisch-Westfälisches Elektrizitätswerk (Німеччина) та Астарта-Київ (Україна). Результати дослідження показали, що Rheinisch-Westfälisches Elektrizitätswerk інвестувала понад 5 млрд євро у розширення відновлюваних джерел енергії в період 2019-2024 рр., зокрема в агроволтаїку та біоенергетику, що дозволило компанії зменшити викиди вуглекислого газу на 50 % до 2030 року. Водночас Астарта-Київ інвестувала понад 5 млн євро у системи зрошення та розширила біогазове виробництво за 2023-2024 рр., що сприяло підвищенню енергетичної незалежності підприємства та покращенню експортного потенціалу. На основі отриманих результатів розроблено рекомендації для України щодо інтеграції сталого розвитку в аграрний сектор, зокрема: активізація інвестицій у відновлювану енергетику, розширення біоенергетичних потужностей, цифровізація аграрного виробництва, удосконалення державної підтримки сталих ініціатив та адаптація законодавства до екологічних стандартів Європейського Союзу

► **Ключові слова:** циркулярна економіка; відновлювальні ресурси; цифровізація; екологічність; міжнародний досвід