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Using the Czech Experience of Innovations in Mechanical Engineering and Energy Saving to Train Engineering Personnel in the Agricultural Sector

Abstract: The article provides a thorough analysis of the experience of the Czech Republic in innovative development of Mechanical Engineering and energy saving, considering the needs of modern agricultural engineering. The key directions of modernisation of technical means for agriculture are considered in detail, in particular the use of digital platforms for monitoring production processes, the introduction of automated and robotic systems in animal husbandry and crop production, as well as the integration of precision farming technologies. The importance of the transition of the Czech agricultural sector to the concept of "smart" production, combining machine-building innovations, digital tools and energy-efficient solutions, was noted. Special attention is paid to the state policy of the Czech Republic on energy saving and improving energy efficiency in industry and the agricultural sector. The author analyses measures for developing renewable energy, in particular the use of biogas plants, solar panels and wind farms, as well as the introduction of energy management systems that provide comprehensive control and rational use of energy resources. The article highlights the experience of integrating energy-saving technologies into the production processes of machine-building enterprises that produce equipment for agricultural needs. The article substantiates the prospects for adapting the Czech experience in Ukraine, in particular in the process of training engineering personnel for the agricultural sector. The necessity of modernizing educational programs that should focus on developing competencies in digitalization, automation and energy saving is emphasised. It focuses on the importance of international internships, participation of students and teachers in research projects, as well as the development of inter-university cooperation between Ukraine and the Czech Republic. It is noted that it is the exchange of experience and the implementation of European educational standards that can provide training for competitive specialists who can effectively apply innovative technologies in the context of sustainable development of the agricultural sector of Ukraine.

Keywords: innovation, mechanical engineering, energy saving, Agricultural Engineering, Czech Republic, international experience, engineer training.

Introduction

The modern development of Ukraine's agricultural sector is taking place under conditions of intense global competition and increasing challenges related to resource conservation, energy security and environmental sustainability (*Innovation in Agriculture and Rural Development, 2023*;

Innovation, Productivity and Sustainability…, 2022). These factors create the need to adapt the agricultural sector to new realities, where technological innovation and the efficient use of resources play a key role. In such circumstances, the training of a new generation of engineers becomes a strategically important task, as these specialists are responsible for the introduction of modern technologies, the optimisation of production processes and the sustainable development of the agricultural sector. One of the most important factors determining the quality of such training is the use of advanced international experience, particularly that of the European Union countries, which have already achieved significant progress in innovative technologies, digitalisation and energy efficiency.

The Czech Republic is a vivid example of a country that successfully combines rich traditions in mechanical engineering with modern innovative approaches. The country actively implements digitalisation, automation and renewable energy technologies, which enables it to remain competitive on the global market. Czech experience demonstrates effective models of integrating science, education and industry, ensuring a rapid transition from theoretical developments to practical applications. In particular, the Czech Republic has created a well-developed ecosystem that includes cooperation between universities, research centres and industrial enterprises. This approach facilitates the training of highly qualified engineers who possess both theoretical knowledge and the practical skills necessary to work with modern technologies.

The Czech model of engineering education is based on several key principles. Firstly, there is an emphasis on interdisciplinarity, which enables engineers to combine knowledge from mechanical engineering, information technology and energy saving. Secondly, considerable attention is given to practical training through internships at enterprises, participation in real projects and the use of simulation technologies. Thirdly, Czech universities actively cooperate with business, ensuring that curricula meet the needs of the labour market. For example, dual education programmes are widely applied in the Czech Republic, allowing students to study and work at enterprises simultaneously, thereby gaining practical experience.

The purpose of this article is to conduct a systematic analysis of the innovative development of mechanical engineering and energy saving in the Czech Republic to identify opportunities for applying this experience to improve engineering training in Ukraine. The research focuses particularly on Czech approaches to the introduction of digital technologies, automation and energy-efficient solutions in mechanical engineering, as well as on the analysis of the engineering training system that prepares graduates for work in modern agricultural production. Applying Czech experience may contribute to the development in Ukraine of engineers' professional competences, including knowledge of modern technologies, the ability to work with automated systems, and skills in implementing energy-efficient and environmentally sustainable solutions.

To achieve this aim, Czech practices must be adapted to Ukrainian realities, considering the characteristics of the national agricultural sector and economic constraints. For example, Ukraine could develop dual education programmes, establish technology transfer centres at universities, and strengthen cooperation between universities and agricultural enterprises. Moreover, it is important to invest in the digitalisation of education, particularly in the development of simulation platforms and virtual laboratories, which would allow students to acquire practical skills without incurring significant material costs. Thus, the use of Czech experience may form

the basis for modernising Ukraine's system of engineering training, contributing to increased competitiveness of the agricultural sector on the global market.

Materials and Methods

Mechanical engineering in the Czech Republic has a centuries-long history; however, it is the most recent decades that have marked its transformation into a high-tech industry oriented towards the needs of modern production (*Hromádka & Novák, 2021*). Agricultural engineering in this country is characterised by the integration of digital technologies, robotic systems and "smart" management tools.

One of the leading trends is the introduction of digital monitoring and machinery control systems. Machines are equipped with sensors that transmit real-time data, enabling the optimisation of fuel consumption, load control and equipment condition monitoring. This reduces the risk of breakdowns and increases the efficiency of resource use.

A prominent place is occupied by developing precision farming, based on the precise application of fertilisers, crop protection agents and water. Czech companies employ software systems that analyse field maps and weather data, ensuring the rational use of materials and the reduction of negative environmental impacts.

A significant direction in the modernisation of mechanical engineering is the use of new materials and production technologies. Thanks to the application of lightweight alloys and composites, it has been possible to reduce the weight of machinery, contributing to energy savings during operation. Such solutions are especially important for the agricultural sector, where machinery operates under heavy loads.

Thus, Czech mechanical engineering demonstrates a comprehensive approach to creating modern technical systems that are focused on efficiency, environmental sustainability and integration with digital technologies.

Literature Review

The analysis of recent scientific publications demonstrates that the innovative experience of the Czech Republic in mechanical engineering and energy saving forms an essential reference point for countries striving to modernise their agricultural sectors. According to Hromádka and Novák (*2021*), Czech agricultural engineering has undergone rapid transformation due to the integration of digital technologies, robotics and automation. The researchers note that digitalisation of production, precision agriculture and smart control systems constitute the main drivers of technological advancement, contributing to both productivity growth and sustainability. Their conclusions are consistent with the findings of Palková et al. (*2022*), who highlight the necessity of preparing specialists in accordance with the principles of Agriculture 4.0, based on digital competencies, interdisciplinary education and strong links between academia and industry.

The importance of innovation and sustainability in the agricultural economy is further emphasised in the OECD report Innovation, Productivity and Sustainability in Food and Agriculture (*2022*), which stresses that long-term competitiveness of agricultural production is directly linked to the implementation of resource-efficient technologies. The document outlines that the most successful European countries in this regard, including the Czech Republic, have

achieved significant progress through national strategies focused on energy efficiency, renewable energy and digital transformation. A similar perspective is shared by the European Commission (*Innovation…, 2023*), which associates rural development with the diffusion of innovation and smart specialisations across regions, ensuring an integrated approach to technological and educational reforms.

An essential component of Czech innovation policy is the government's commitment to energy efficiency and renewable energy. The Energy Efficiency and Renewable Energy Strategy 2030 (*2022*) developed by the Ministry of Industry and Trade of the Czech Republic defines key priorities in reducing energy consumption and expanding renewable sources. Durčanský (*2023*) analyses the evolution of green energy in the Czech Republic and identifies a dynamic increase in biogas, solar and wind energy use. These developments, according to the author, not only reduce dependence on imported energy resources but also promote environmental sustainability and create new opportunities for engineering innovation. Honchar (*2023*) supports this view, pointing out that similar approaches could be successfully implemented in Ukraine to improve energy security and agricultural efficiency.

The integration of energy-saving technologies into educational and industrial systems is another recurring theme in the literature. Gródek-Szostak et al. (*2021*) show that awareness and behavioural factors play a critical role in promoting energy conservation, particularly among students and young specialists. The authors' comparative analysis of Polish, Czech and Ukrainian students demonstrates that the level of energy-saving awareness correlates with the effectiveness of national educational strategies. Therefore, the inclusion of sustainability issues and energy efficiency in higher education curricula becomes a prerequisite for successful implementation of innovative technologies.

From the standpoint of industrial innovation, Kozyrskyi and Sydorenko (*2022*) emphasise that the experience of EU countries, especially the Czech Republic, proves the effectiveness of integrating innovative engineering technologies into the agricultural machinery sector. Their study notes that the combination of automation, sensor-based monitoring and lightweight materials ensures energy savings and enhances the ecological efficiency of agricultural production. Similar conclusions are drawn by Kowalska and Kovárník (*2019*), who examine smart specialisations in Poland and the Czech Republic, arguing that the synergy between innovation policy and education reform generates sustainable competitive advantages for the regional economy.

Collectively, these studies underline that Czech innovation in mechanical engineering and energy saving is not limited to technical progress alone but extends to the broader transformation of educational and institutional frameworks. The formation of a coherent innovation ecosystem that unites research institutions, industrial enterprises and educational establishments has allowed the Czech Republic to build an advanced model of knowledge transfer and practical training. Such integration ensures that engineers are equipped not only with theoretical knowledge but also with practical skills in energy management, digital technologies and ecological design (*Palková et al., 2022*; *Hromádka & Novák, 2021*). Consequently, the Czech model can serve as an exemplary case for Ukraine, where the modernisation of engineering education is considered a strategic component of agricultural innovation and sustainable development (*Honchar, 2023*; *Innovation…, 2023*).

In summary, the reviewed literature reveals that the Czech Republic's success in mechanical engineering and energy efficiency is based on the interconnection between state policy, academic research and industrial practice. The integration of digital tools, energy-saving technologies and interdisciplinary education forms the foundation of this system. Adapting these principles to Ukrainian realities could facilitate the creation of a new generation of engineers capable of ensuring technological modernisation, energy independence and sustainable growth of the national agricultural sector.

Results

Energy saving is one of the key priorities of state policy in the Czech Republic, reflected in a comprehensive approach to reducing energy consumption and increasing energy efficiency across various sectors of the economy, including agriculture. The country actively implements incentive mechanisms aimed at enterprises and households to reduce energy consumption—an issue of particular importance in agriculture, where energy costs constitute a substantial share of production expenses. This approach combines financial incentives with regulatory mechanisms that encourage technological modernisation and the adoption of energy-efficient solutions.

One of the leading areas of energy saving in the Czech agricultural sector is the widespread use of renewable energy sources. Biogas plants have become an important tool that simultaneously addresses both energy and environmental challenges. These plants operate on the processing of livestock and crop residues such as manure, straw and harvest waste. The resulting biogas is used to generate electricity and heat, meeting the needs of agricultural enterprises. In addition, waste processing helps reduce greenhouse gas emissions and enhances the environmental safety of production. For instance, biogas plants can utilise up to 90% of organic waste, significantly reducing negative environmental impacts.

Alongside biogas technologies, solar energy is also actively developing in the Czech Republic. Solar power plants are installed on both large agricultural enterprises and small farms. This ensures a stable electricity supply while reducing dependence on traditional energy sources. State support programmes, such as subsidies and preferential loans, promote the rapid spread of solar panels in rural areas. For example, farms can receive up to 50% compensation for the cost of equipment for solar power plants, making such investments economically viable.

Considerable attention in the Czech Republic is devoted to the energy-efficient design of agricultural buildings and facilities. New complexes for storage, processing or production of agricultural goods are constructed using modern thermal insulation materials such as polystyrene or mineral wool, which reduce heat loss by 20–30%. Ventilation, heating and cooling systems are equipped with automated control mechanisms that optimise energy consumption depending on weather conditions and production requirements. For example, the use of heat pumps in combination with automated control systems allows energy costs for heating livestock facilities to be reduced by up to 40%. Furthermore, passive energy-saving principles are widely applied in the design of new buildings. These include the correct orientation of buildings relative to the sun to maximise natural light, as well as the installation of low-emission glazing to minimise heat loss. Such solutions not only reduce energy consumption but also improve comfort for workers and animals in agricultural complexes.

The Czech Republic is also actively developing energy management systems based on digital technologies and real-time monitoring of energy consumption. The use of "smart meters" allows agricultural enterprises to track energy use at various stages of production, identify inefficient processes and optimise them. Specialised software integrated with these meters provides a detailed analysis of energy consumption structures, helping to identify potential savings. For example, farms using such systems can cut electricity consumption for lighting and equipment operation by 15–25%. Moreover, energy management systems allow for predictive energy planning. With the help of artificial intelligence algorithms, enterprises can forecast peak loads and optimise equipment operation to avoid excessive energy use. Such solutions are especially significant for large agroholdings, where even minor reductions in consumption may result in substantial financial savings.

In the Czech Republic, energy saving is viewed not merely as a tool for conserving resources but also as a strategic foundation for sustainable development. The combination of economic benefits, environmental safety and social responsibility is a key principle of Czech policy in this field. The introduction of energy-efficient technologies enables agricultural enterprises to reduce production costs, thereby increasing their competitiveness on European and global markets. At the same time, reducing greenhouse gas emissions and recycling waste contribute to environmental protection. The Czech experience demonstrates that successful implementation of energy-saving projects requires a comprehensive approach that includes state support, private investment and cooperation with research institutions. For instance, the country operates specialised funds that finance research in energy efficiency, as well as training programmes for specialists capable of applying modern technologies in practice.

Czech experience in energy saving can be adapted to the needs of Ukraine's agricultural sector. For example, the introduction of biogas plants on Ukrainian farms could resolve the issue of organic waste disposal while providing an additional energy source. Solar power plants, which are already emerging in Ukraine, could expand further with state support and affordable loan programmes. Moreover, the adoption of energy management systems and energy-efficient building design could significantly reduce agricultural enterprises' energy costs. To realise such initiatives in Ukraine, favourable conditions must be created, including a legislative framework, financial incentives and specialist training programmes. The Czech model demonstrates that cooperation between the state, business and research institutions is a crucial success factor. Therefore, adapting Czech experience could contribute to modernising Ukraine's agricultural sector, increasing its energy efficiency and strengthening its competitiveness.

Discussion

The experience of the Czech Republic in the field of innovation is of exceptional value to Ukraine, faced with the need to update its approaches to the training of engineering personnel for the agricultural sector. This experience may serve as the foundation for creating a modern education system that meets the challenges of the global market and fosters the sustainable development of agriculture. Above all, it concerns the formation of professional competences that correspond to current labour market demands, international standards, and technological trends. This involves not only technical knowledge, but also the ability to adapt to rapidly changing conditions, apply innovative solutions, and work with advanced technologies. Such an

approach is key to ensuring the competitiveness of Ukraine's agricultural sector in conditions of intense global competition.

Firstly, an important priority is the strengthening of attention to digital technologies in the training of engineers. Future specialists must acquire strong skills in using software for modelling technical processes, data analysis, managing automated systems, and introducing digital solutions into production (*Hromádka & Novák, 2021*; *Innovation, Productivity and Sustainability…, 2022*). This includes the use of programmes for equipment design, optimisation of production processes, as well as big data analysis for forecasting needs and increasing efficiency. Such skills enable engineers to develop innovative solutions that improve agricultural productivity, reduce resource costs, and optimise the use of equipment. For example, digital platforms for managing agricultural processes can reduce the time needed for operations and lower fuel and other material expenses, which is critically important for Ukraine's energy-intensive agricultural sector.

Secondly, it is extremely important to familiarise students with energy-saving and renewable energy technologies. High energy consumption, which creates significant financial and environmental challenges, characterises Ukrainian agricultural production. The implementation of innovative energy solutions, such as biogas plants, solar panels, or energy-efficient heating systems, is one of the key tasks of modern engineering. Engineers must be prepared to design and operate such systems, as well as to integrate them into agricultural production. Training should include studying the principles of renewable energy sources, methods of reducing energy consumption, and technologies that minimise environmental impact. This will not only increase production efficiency but also contribute to ecological stability, which is a vital aspect of modern agriculture.

Thirdly, attention is worth drawing to international internships and academic mobility, which provide future engineers with the opportunity to become directly acquainted with advanced practices and technologies. Participation in such programmes allows students to gain experience in operating modern equipment, studying new methods of energy systems management, and learning innovative approaches to production organisation (*Innovation in Agriculture and Rural Development, 2023*). For instance, Czech student exchange programmes provide practical training at enterprises where future engineers can become familiar with automated systems, modern management methods, and energy-efficient technologies. Such experience is invaluable for developing professional skills that can be applied in Ukraine. Furthermore, international cooperation fosters knowledge exchange and the creation of professional networks, which may be beneficial for the further development of the agricultural sector.

Thus, the adaptation of Czech experience within the Ukrainian education system will contribute to forming a new generation of engineers capable of ensuring the technological modernisation of the agricultural sector. These specialists will possess the necessary knowledge and skills for implementing digital technologies, energy-efficient solutions, and modern management methods, thereby increasing the productivity and competitiveness of Ukrainian agriculture. Moreover, an emphasis on environmental sustainability will help reduce the impact of agricultural production on the environment, in line with global trends in sustainable development. Implementing such changes requires a comprehensive approach, including the reform of educational programmes, the creation of conditions for international cooperation, and

support from both the state and business. Nevertheless, the results of these efforts will have a long-term positive effect on Ukraine's economy.

Conclusion

The Czech Republic's experience in mechanical engineering and energy saving in agriculture illustrates an effective model of technological modernisation, combining economic, environmental and social aspects. The introduction of biogas plants, solar power systems, energy-efficient buildings and digital energy management demonstrates that sustainable development is achievable through a comprehensive approach and interaction between all stakeholders.

For Ukraine, this experience may serve as a practical guide to enhancing the efficiency of its agricultural sector. The adaptation of Czech practices could reduce production costs, strengthen the competitiveness of Ukrainian products and contribute to environmental protection. The main condition for success lies in developing a legislative framework, financial incentive mechanisms and the promotion of cooperation between the state, business and scientific institutions.

Thus, the Czech Republic represents a successful example of the transition to sustainable agriculture based on innovation, energy saving and environmental responsibility. Its experience provides valuable insights that could be effectively applied in Ukraine, promoting the modernisation of agriculture and its integration into European and global markets.

Conflict of Interest

The author declares that there is no conflict of interest.

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