УДК 339.13:[629.33-67:621.313.13](4-6ЄС)
DOI: https://doi.org/10.30838/EP.201.288-296

Honcharov Oleksii
V.N. Karazin Kharkiv National University
Гончаров О.О.
Харківський національний університет імені В.Н. Каразіна
https://orcid.org/0009-0005-1952-6904

Goncharenko Nataliia
PhD in Economic Sc.
V.N. Karazin Kharkiv National University
Гончаренко Н.І.
кaкдидат економічних наук
Харківський національний університет імені В.Н. Каразіна
https://orcid.org/0000-0003-4148-5369

GREEN ENERGY TECHNOLOGIES IMPLEMENTATION IN THE EU ELECTRIC VEHICLE MARKET IN THE CONTEXT OF THE GREEN SMART TRANSPORT CONCEPT

In this article, the features of implementing green energy technologies in the European Union's electric vehicle market are explored in the context of realizing the concept of green smart transport. The article identifies key technological innovation directions that contribute to emissions reduction and improved energy efficiency, such as the implementation of fuel cells, supercapacitors, and intelligent energy management systems, which optimize the operation of electric and hybrid vehicles.

The aim of the article is to investigate current trends in the implementation of green energy technologies in the EU electric vehicle market and to develop scientific and practical recommendations for intensifying the digital transformation of the transport sector within the framework of the green intelligent transport concept.

The methodological framework of the study is based on qualitative analysis, which includes comparative and structural research of key aspects of implementing green energy technologies in the EU's transport system. The study uses methods of system and contextual analysis to explore their integration into transport infrastructure and EU policies.

Particular attention is given to strategic directions for the implementation of digital technologies in the EU's transport infrastructure, including the Internet of Things, artificial intelligence, cybersecurity, and the interoperability of charging infrastructure. The importance of coordinating digital solutions at the European level to ensure the integration of vehicles, infrastructure, and energy systems is emphasized. Scientific and practical recommendations are proposed to accelerate the implementation of digital solutions in the European electric vehicle market aimed at creating a unified, environmentally clean, and efficient transport environment within the EU.

The findings can be useful for developing policies on energy transformation, shaping strategic directions for the sustainable development of transport systems, and integrating cutting-edge technologies at the level of European countries.

Keywords: *green energy technologies, electric vehicles, green smart transport concept, sustainable development, energy efficiency, mobility.*

JEL classification: *L98, O33, Q42, Q48.*

ВПРОВАДЖЕННЯ ЗЕЛЕНИХ ЕНЕРГЕТИЧНИХ ТЕХНОЛОГІЙ НА РИНКУ ЕЛЕКТРОМОБІЛІВ ЄС У КОНТЕКСТІ РЕАЛІЗАЦІЇ КОНЦЕПЦІЇ ЗЕЛЕНОГО РОЗУМНОГО ТРАНСПОРТУ

У статті досліджуються особливості впровадження технологій зеленої енергетики на ринку електричних транспортних засобів Європейського Союзу в контексті реалізації концепції зеленого розумного транспорту. У ході дослідження ідентифіковано ключові напрями технологічних інновацій, які сприяють зменшенню викидів та підвищенню енергоефективності, зокрема впровадження паливних елементів, суперконденсаторів та інтелектуальних систем енергоменеджменту, що оптимізують роботу електричних і гібридних транспортних засобів.

Метою статті є визначення сучасних тенденцій у впровадженні технологій зеленої енергетики на ринку електромобілів ЄС та розробка науково-практичних рекомендацій щодо інтенсифікації цифрової трансформації транспортного сектору в рамках концепції зеленого розумного транспорту.

Методологічною основою дослідження є якісний аналіз, що включає порівняльне та структурне дослідження ключових аспектів впровадження технологій зеленої енергетики у транспортну систему ЄС, застосовуються методи системного та контекстуального аналізу для вивчення інтеграції зазначених технологій у транспортну інфраструктуру та політику ЄС.

У статті окреслено основні виклики та можливості, пов'язані з інтеграцією зелених енергетичних технологій у транспортну систему ЄС, а також їхній вплив на формування сталого майбутнього мобільності. Особливу увагу приділено стратегічним напрямам впровадження цифрових технологій у транспортну інфраструктуру ЄС, включаючи інтернет речей, штучний інтелект, кібербезпеку та інтероперабельність зарядної інфраструктури. Наголошується на важливості координації цифрових рішень на європейському рівні для забезпечення інтеграції транспортних засобів, інфраструктури та енергетичних систем. У ході дослідження запропоновано науково-практичні рекомендації щодо прискорення впровадження цифрових рішень на європейському ринку електромобілів, спрямовані на створення єдиного, екологічно чистого та ефективного транспортного середовища в межах ЄС.

Результати можуть бути корисними для формування політик енергетичної трансформації, визначення стратегічних напрямів сталого розвитку транспортних систем та інтеграції передових технологій на рівні європейських країн.

***Ключові слова**: зелені енергетичні технології, електромобілі, концепція зеленого розумного транспорту, сталий розвиток, енергоефективність, мобільність.*

Problem Statement. The implementation of green energy technologies in the electric vehicle (EV) market of the European Union is a key element of the sustainable development strategy and the objective of achieving climate neutrality by 2050. In the context of global climate change and rising greenhouse gas emissions, the modernization of the transport sector through the adoption of environmentally friendly technologies has become particularly relevant. According to the European Commission [1], the transport sector is responsible for approximately 25% of all CO_2 emissions in the EU, casting doubt on the feasibility of reaching climate neutrality by 2050 without radical transformations in this sector.

The EU's commitment to sustainable transport development is enshrined in the European Green Deal, which aims to make Europe the first climate-neutral continent by 2050. This ambitious plan involves reducing greenhouse gas emissions, investing in green technologies, and supporting industrial innovation. The Green Deal is reinforced by the "Fit for 55" package, which sets legally binding emissions reduction targets and outlines measures for achieving them [2].

The European Battery Alliance (EBA) plays a critical role in expanding battery manufacturing capabilities across Europe, aiming to reduce reliance on non-EU suppliers and to secure a sustainable supply chain for electric vehicles [3].

Electric vehicles, as a key component of the transport decarbonization strategy, offer the potential for a significant reduction in harmful emissions. At the same time, their efficiency and environmental viability largely depend on the integration of green technologies such as energy-efficient power components, regenerative braking systems, fuel cells, supercapacitors, and artificial intelligence systems for energy consumption optimization.

The integration of these technologies not only enhances the energy efficiency of vehicles but also contributes to reducing dependence on fossil fuels, fostering the development of innovative infrastructure, and supporting the growth of the green economy. Furthermore, the shift to electromobility is a vital element in achieving the United Nations Sustainable Development Goals, particularly in terms of access to clean energy, infrastructure development, sustainable urbanization, and climate action.

In this context, the study of green technology implementation in the EU electric vehicle market is of critical importance and holds substantial value for building an environmentally safe, energy-efficient, and climate-neutral future for Europe.

Analysis of Recent Studies and Publications. Environmental challenges and the urgent need to achieve net-zero carbon emissions have prompted active research into effective and sustainable solutions for automotive technologies.

Scientific investigations in this field focus on policy, technology, infrastructure, and consumer behavior within the framework of transitioning toward the concept of «smart green transport».

One of the main factors influencing the adoption of environmental technologies is public policy. Research by Woerter M., Stucki T., Arvanitis S., Rammer C., Peneder M., and Goncharenko N. [4] demonstrates that instruments such as subsidies, tax incentives, and demand stimulation significantly affect the diffusion of green technologies in Germany, Austria, and Switzerland. However, their effectiveness depends on specific national conditions and implementation contexts.

In turn, Martins H., Henriques C.O., Figueira J.R., Silva C.S., Costa A.S. and others [5] analyze policy interventions at the EU level and emphasize that targeted, coordinated measures are crucial for accelerating the transition to electric transportation.

An important area of research is the technological integration of electric vehicles into the energy infrastructure.

Kostenko G. [6] emphasizes that the growing number of electric vehicles requires the development of smart grids and energy storage systems capable of balancing peak loads. This view is supported by Gunkel P.A., Bergaentzlé C., Jensen I.G., and Scheller F. [7], who examine various charging strategies – from passive to bidirectional (V2G, «vehicle-to-grid») – and conclude that intelligent charging enhances the flexibility of power grids.

The study by Preuß S., Kunze R., Zwirnmann J., Meier J., Plötz P., Wietschel M. [8] confirms that the share of renewable electricity used to charge electric vehicles in Europe is higher than the average share of green energy in the general power grid. This indicates the additional environmental efficiency of electric transport when integrated with renewable energy sources (RES).

Special attention in the literature is also devoted to digitalization and market dynamics. Goncharenko N. [9] compares the development of electric vehicle markets across different regions, highlighting that combining environmental and digital solutions increases infrastructure efficiency, reduces costs, and improves the user experience.

Regarding infrastructure issues, Kostenko G. and coauthors [10] analyze the economic feasibility of highway electrification. They emphasize that large-scale deployment of charging stations requires strategic investments and coordination between the private and public sectors.

Scientific literature indicates that the successful implementation of green energy technologies in the EU transport sector demands a comprehensive approach that integrates policy, technology, infrastructure, and consumer motivation. Such synergy is essential to fully realize the concept of «smart green transport» within the European Union.

Although recent years have seen growing academic interest in studying the electric mobility transition in the context of sustainable development and digital transformation, there remains a lack of comprehensive interdisciplinary approaches that systematically combine economic, institutional, and technological aspects of digital solution implementation in the EU electric vehicle market. In particular, existing research has not sufficiently addressed the effective synergy between digitalization policies and energy transition strategies, which limits the potential for shaping a coherent sustainable transport policy. This gap highlights a scientific niche for future research focused on developing practical tools to intensify digital innovation as a key driver of green mobility development amid today's global economic and climate dynamics.

The aim of the article is to investigate current trends in the deployment of green energy technologies in the EU electric vehicle market and to develop scientific and practical recommendations for intensifying the digital transformation of the transport sector within the framework of implementing the concept of smart green mobility.

Presentation of the main research results. The automotive sector in the EU is undergoing a significant transformation, primarily driven by the adoption of green fuel technologies. Among the most promising innovations are technologies for environmentally friendly vehicles and the integration of alternative energy sources, including advanced high-energy-density batteries, fuel cells capable of generating energy over long distances with water as the only byproduct, and supercapacitors characterized by extremely fast charging and discharging capabilities [11–14].

One of the key drivers of the electric vehicle market is the activity of leading automakers, which actively implement innovative technologies and shape global trends. To analyze the market positions and sales dynamics of major players in the electric vehicle sector, it is appropriate to examine a comparative overview of the leading companies in the global EV market (Table 1).

Table 1

Comparative Characteristics of Leading Companies in the Global Electric Vehicle Market, 2023

Company Name	Year Founded	Headquarters Country	Top Markets by Sales	Revenue (Billion USD)	EV Units Sold
BYD	1995	China	China, Thailand, Australia	~84,0	~3000000
Tesla	2003	USA	USA, China, Germany	~81,5	~1800000
Volkswagen	1937	Germany	China, Germany, USA	~295,9	~572100
BMW	1916	Germany	China, Germany, USA	~142,6	~433000
Mercedes- Benz	1926	Germany	China, Germany, USA	~155,5	~337000

Source: compiled by the authors based on materials from [17, 18, 19]

Passenger car registrations in the EU in 2024 totaled approximately 10.6 million units, marking a marginal increase of 0.8% compared to the previous year. Battery electric vehicles (BEVs) accounted for 13.6% of all new registrations, down from 14.6% in 2023. Plug-in hybrid electric vehicles (PHEVs) held a market share of 8.3%, slightly lower than in prior years. Together, BEVs and PHEVs constituted 21.9% of the total new car market. The reduction in BEV market share – though modest – signals a deceleration in adoption rates, suggesting that the EU EV market may be entering a phase of consolidation and structural realignment [18].

This decline follows three years of robust growth during which government stimulus packages, particularly post-COVID-19 green recovery funds, significantly boosted EV sales. The 2024 performance reflects both the withdrawal of fiscal incentives in key markets and an increasingly price-sensitive consumer base affected by economic uncertainty and inflationary pressures.

Despite EU-wide legislative coordination, the EV market remains deeply fragmented across Member States. Northern and Western European countries – such as Sweden, the Netherlands, Belgium, and France – continued to perform strongly in 2024. For instance, Belgium recorded a 35% year-on-year increase in BEV registrations, largely due to favorable tax regimes and corporate fleet electrification. France maintained steady growth, supported by national leasing programs and a domestically integrated automotive supply chain.

Conversely, Germany, the EU's largest car market, experienced a 27.4% decline in BEV registrations in 2024 after the government abruptly terminated purchase subsidies for private buyers in December 2023. BEVs accounted for only 13.5% of Germany's new car registrations in 2024, down from 18.4% in 2023, reflecting the policy's destabilizing impact on consumer demand [19].

Meanwhile, Southern and Eastern European countries continued to lag behind. In Italy and Spain, BEV market shares remained under 6%, and in several Central and Eastern European countries such as Bulgaria and Romania, EV adoption is still at the early stages. These disparities are explained by differences in GDP per capita, infrastructure investment, and national policy ambition.

From an industrial perspective, the European EV market is undergoing a significant transformation. While traditional automakers such as Volkswagen, Stellantis, and Renault continue to dominate the market in terms of scale, new entrants, particularly Chinese manufacturers, have gained traction. Brands such as BYD and MG (owned by SAIC) have capitalized on cost advantages and are expanding rapidly in Western Europe [20].

The increasing price competitiveness of Chinese EVs poses strategic challenges to European manufacturers, which are constrained by higher labor and production costs. In response, several EU-based automakers are accelerating plans to introduce lower-cost EV models and streamline supply chains. However, delays in model rollouts and hesitancy to commit to full electrification amidst fluctuating demand have generated uncertainty.

Policy remains the primary driver of EV development in Europe. The EU's commitment to banning the sale of new internal combustion engine (ICE) vehicles by 2035, as outlined in the Fit for 55 package, continues to set long-term expectations. However, short-term national policies have become more volatile [21].

Several countries reduced fiscal incentives in 2024, including Germany, which ended private BEV purchase grants, and Austria, which restructured its bonus-malus system. In contrast, France introduced a green leasing scheme, offering low-income households EV leases at €100/month – a model that has gained traction and may be emulated by other Member States [22].

While these policy experiments reflect a shift toward targeted, means-tested incentives, they also introduce complexity and risk undermining consumer confidence in long-term affordability. The EU's role in harmonizing support measures remains critical.

The transition to renewable energy sources is crucial for the decarbonization of the transport sector. The EU is investing in large-scale renewable energy projects, such as wind and solar power plants, to supply energy for transport networks and municipal operations. Energy storage systems are also being integrated into urban infrastructure to balance the grid and provide backup power during periods of high demand or intermittent renewable energy generation.

The development of electric vehicle technologies and charging infrastructure plays a central role in the EU's green transport strategy. Smart charging systems, which optimize the timing and intensity of electric vehicle charging, can facilitate the integration of renewable energy sources into the power grid and reduce overall energy system costs.

Bidirectional charging, or Vehicle-to-Grid (V2G) technology, enables electric vehicles to feed electricity back into the grid, offering a solution for energy storage and enhancing grid stability. Pilot projects in cities like Dresden demonstrate the potential of V2G systems in urban environments.

Despite significant technological advancements, battery systems still face a number of critical limitations, including limited lifespan, insufficient energy density, and environmental challenges associated with the extraction of raw materials used in their production. One of the key issues remains charging speed, which directly contributes to the phenomenon of "range anxiety" among users. To address these challenges, research into alternative energy sources has intensified, particularly focusing on fuel cells (FCs) and supercapacitors (SCs).

At the same time, governments around the world are investing heavily in the development of electric vehicle-friendly infrastructure, particularly in establishing charging station networks, with the goal of accelerating the transition to carbon neutrality by 2050 [1, 2]. However, debates continue regarding the long-term economic and environmental viability of electrofuels (e-fuels), especially when comparing their cost to full transport electrification. It is anticipated that investments in CO_2 reduction through the use of e-fuels will be more expensive than electric vehicle development, and their adoption may be limited among low-income households.

The evolution of electrified transport is progressing steadily, encompassing both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), which combine the advantages of both propulsion types. Current global strategies for decarbonizing the transport sector are increasingly focused not only on electrification but also on the integration of smart digital solutions. These technologies enable the adaptation of energy consumption, optimization of routes, and improved load management on power grids.

In this context, the concept of "green smart transport" is emerging – an integrated approach that merges environmental (green) and digital (smart) technologies into a unified transport ecosystem. This concept encompasses a broad range of innovations, from the use of clean energy sources (solar, wind, hydrogen) to digital transport management platforms, including the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), cybersecurity, and interoperable charging infrastructure [23, 24].

A key element of green mobility is the transition to renewable energy sources powering transport infrastructure. For instance, solar panels at charging stations or hydrogen fuel cells in heavy-duty vehicles help minimize dependence on fossil fuels [25].

Simultaneously, smart technologies – primarily IoT and AI – enable real-time monitoring of transport systems, traffic management, predictive maintenance, and dynamic interaction with the power grid. These features help increase energy efficiency, reduce downtime, extend battery lifespan, and lower the strain on infrastructure [26].

A critical component of the concept is also a high level of cybersecurity, as the digitalization of transport systems introduces new risks – from data interception to remote interference with vehicle control. To mitigate these threats, international standardization bodies have developed protocols such as ISO/SAE 21434, which sets cybersecurity requirements for all stages of the vehicle lifecycle (ISO, 2021).

Equally important is interoperability of charging infrastructure, which is supported by open protocols such as OCPP, ISO 15118, and Plug & Charge. These allow users to charge their vehicles across different countries using a single account and intuitive digital platforms [27]. This removes technical and administrative barriers to charging access, which is critical for promoting the widespread adoption of EVs.

Thus, the green smart transport concept is not merely an environmentally driven initiative – it is a comprehensive strategy for the digital transformation of mobility. It lays the foundation for the development of smart cities, where transport operates as a service (Mobility-as-a-Service, MaaS), synchronized with environmental, energy, and information infrastructures.

Successful implementation of the green smart transport concept is impossible without the active involvement of government bodies, industry, research institutions, and civil society. Government policy must play a key role in creating a regulatory environment that stimulates innovation, supports the transition to renewable energy sources, and ensures the seamless integration of digital technologies into transport infrastructure [19]. This includes tax incentives, subsidies for electric vehicle purchases, investments in charging station construction, and support for scientific research in AI, V2X communications, and energy efficiency.

Special attention must be given to institutional coordination between the energy and transport sectors. The creation of integrated data-sharing platforms between energy companies, municipalities, and EV users is a prerequisite for developing concepts such as Vehicle-to-Grid (V2G), which allow EVs not only to consume but also to feed electricity back into the grid [28]. This helps balance loads, reduce peak consumption, and ensure the resilience of energy systems to demand fluctuations.

In the context of urban transformations, green smart transport supports the development of sustainable mobility-focused cities (Transit-Oriented Development, TOD). This entails reducing dependence on private cars by promoting public electric transport, car-sharing, micromobility options (electric scooters, e-bikes), and building infrastructure for last-mile connectivity.

Moreover, integrating user data, traffic flows, and weather conditions into unified digital management systems (using AI/ML) enables real-time traffic modeling, logistics optimization, and congestion reduction, thereby lowering emissions and improving urban air quality [29].

However, social considerations must also be addressed. Ensuring equitable access to electromobility is a crucial factor. Consequently, it is important to implement government programs that provide financial assistance to socially vulnerable groups for the purchase of electric vehicles, as well as to expand charging infrastructure in rural and less densely populated areas.

In this study, we have developed scientific and practical recommendations to accelerate the adoption of digital technologies within the framework of the green smart transport concept. Specifically, we recommend:

1. Development of standards and protocols for IoT integration in vehicles.

To enable the effective operation of Internet of Things (IoT) systems in electric vehicles, it is essential to establish and implement unified international standards for integrating sensors and monitoring systems within the electric vehicle ecosystem. This includes standardizing communication protocols for charging stations, vehicles, and Smart Grid infrastructure. We particularly emphasize strengthening standards such as the Open Charge Point Protocol (OCPP), which facilitates interoperability across diverse charging networks and vehicles, thereby providing a seamless user experience. Simultaneously, measures should be taken to standardize the integration of data into cloud platforms that collect and process telemetry data in real time.

2. Investment in artificial intelligence and machine learning for optimizing energy consumption and safety.

Artificial intelligence (AI) and machine learning (ML) hold significant potential to enhance the efficiency of electric vehicle operation. Therefore, investment in the development of AI and ML algorithms is recommended, enabling adaptive energy management systems that respond to driving behavior, road conditions, and other variables, thereby minimizing energy consumption and extending battery lifespan. To support effective deployment, collaborative partnerships between research institutions and electric vehicle manufacturers should be fostered, alongside promoting the development of AI-driven autonomous systems to improve safety and reduce accident rates.

3. Development of robust cybersecurity systems to safeguard data and infrastructure.

Given the increasing cybersecurity risks associated with EV connectivity to external networks (IoT, Over-the-Air updates, Vehicle-to-Everything communications), implementing multi-layered security frameworks is imperative to protect data confidentiality and integrity. This includes adopting advanced data encryption, device authentication, and anomaly detection techniques to prevent unauthorized access to critical vehicle control systems. We strongly advocate for the adoption and enforcement of international cybersecurity standards such as ISO/SAE 21434 to defend automotive systems against cyber threats. Furthermore, establishing national and international platforms for information sharing and best practices in EV cybersecurity is recommended.

4. Enhancement of interoperability measures for charging infrastructure.

To ensure convenience in using electric vehicles and reduce consumer barriers, it is crucial to strengthen interoperability measures for charging stations. This includes implementing unified payment systems that provide unrestricted access to charging stations via mobile applications or a single user account. One key recommendation is the development of eRoaming initiatives, which enable users to charge their vehicles at different charging stations across various countries using a single account. Supporting initiatives that create common platforms for charging and payment operations across regional and national boundaries is essential to this goal.

5. Development of mobile applications to enhance user convenience.

Mobile applications can significantly simplify the user experience for electric vehicle owners. It is recommended to develop integrated mobile apps that combine multiple functionalities, including locating charging stations, route planning based on available charging points, managing energy costs, and predicting charging times depending on battery levels. Such integration will improve the convenience and efficiency of electric vehicle usage for end-users and encourage increased adoption of EVs in the future.

6. Integration of EVs with smart energy grids (Smart Grid).

Integrating electric vehicles with smart energy grids enables dynamic energy consumption management by balancing loads among charging stations, buildings, and the energy grid. Research and implementation of technologies such as Vehicle-to-Grid (V2G) are critical, allowing vehicles not only to charge but also to feed electricity back into the grid. This helps balance energy supply and demand, reducing stress on energy infrastructure during peak loads and promoting more sustainable and economical use of electric vehicles.

Thus, intensifying the adoption of digital technologies in the electric vehicle sector is a vital step towards realizing the concept of "Green Smart Transport." Efforts should focus on developing standards and protocols for IoT system integration, supporting AI and ML to optimize energy consumption, establishing effective cybersecurity systems, ensuring interoperability of charging infrastructure, and advancing mobile applications for users. Only through a comprehensive approach to implementing these recommendations can sustainable development of electric transport be achieved, improving its efficiency and convenience for end consumers.

Conclusions. The future of electric vehicles is closely linked to a significant acceleration of technological progress and favorable market conditions. Substantial advancements in battery technologies, particularly improvements in energy density and fast-charging capabilities, will enhance the performance of electric vehicles and make them more attractive to consumers. At the same time, improvements in charging infrastructure and its integration with renewable energy sources will reduce technical and organizational barriers to the widespread adoption of electric transport.

Active government policies promoting sustainable development will be a key factor in ensuring substantial investments in the automotive sector during the transition to electrification. The convergence of technical, economic, and political factors will create conditions for positioning electric vehicles as a tool for sustainable green transport with the potential to significantly reduce greenhouse gas emissions and transform the automotive market.

Despite notable progress, the broad adoption of green technologies in the European Union's electric transport sector faces challenges such as high energy costs and regulatory barriers. The EU's ability to balance internal support policies with global competitive pressures remains critical.

Significant competition for European manufacturers comes from the dominance of Chinese companies, which benefit from substantial government subsidies. The introduction of tariffs on electric vehicles from China is an important step in protecting the domestic market, but it also highlights the geopolitical complexities of the green transition.

Forecasts by the European Commission indicate that under current policy initiatives, the share of light electric vehicles in total sales could reach 40% by 2030 and nearly 55% by 2035. If announced commitments are realized, sales could rise to 47 million units in 2030 and 75 million in 2035, representing about two-thirds of total light vehicle sales.

To further accelerate the adoption of electric transport, governments should focus on raising consumer awareness, expanding charging station networks, providing incentives for the extraction and use of materials (notably lithium), lowering charging tariffs, and funding research and innovation in this area.

The European electric vehicle market holds significant potential for further growth due to technological innovations, political support, and increasing consumer demand. Although challenges remain, the trajectory indicates a gradual but steady transition to electrification in the automotive industry.

References:

1. Directorate-General for Climate Action. (2024). European Commission. Retrieved from: https://commission.europa.eu/about/departments-and-executive-agencies/climate-action_en. [in English].

2. Fit for 55 Package – Climate Target Plan 2030. (2023). European Commission. Retrieved from: https://ec.europa.eu/clima. [in English].

3. Building a European battery industry. (2024). European Battery Alliance. (EBA). Retrieved from: https://www.eba250.com/. [in English].

4. Woerter, M., Stucki, T., Arvanitis, S., Rammer, C., & Peneder, M. (2017). The adoption of green energy technologies: The role of policies in Austria, Germany, and Switzerland. International Journal of Green Energy, No. 14(14). Pp. 1192–1208. DOI: https://doi.org/10.1080/15435075.2017.1381612. [in English].

5. Martins, H., Henriques, C.O., Figueira, J.R., Silva, C.S., & Costa, A.S. (2023). Assessing policy interventions to stimulate the transition of electric vehicle technology in the European Union. Socio-Economic Planning Sciences, Vol. 87(PB). DOI: https://doi.org/10.1016/j.seps.2022.101505. [in English].

6. Kostenko, G. (2022). Overview of European trends in electric vehicle implementation and the influence on the power system. System Research in Energy, No. 1(70) Pp. 62–71. DOI: https://doi.org/10.15407/srenergy2022.01.062. [in English].

7. Gunkel, P.A., Bergaentzlé, C., Jensen, I.G., & Scheller, F. (2020). From passive to active: Flexibility from electric vehicles in the context of transmission system development. DOI: https://doi.org/10.1016/j.apenergy.2020.115526. [in English].

8. Preuß, S., Kunze, R., Zwirnmann, J., Meier, J., Plötz, P., & Wietschel, M. (2021). The share of renewable electricity in electric vehicle charging in Europe is higher than grid mix, Working Papers «Sustainability and Innovation. S11/2021, Fraunhofer Institute for Systems and Innovation Research (ISI). Retrieved from: https://publica-rest.fraunhofer.de/server/api/core/bitstreams/d3dad178-1535-4517-a0c6-9aa3d414b38b/content. [in English].

9. Goncharenko, N., & Shapoval, V. (2021). Eco-innovation financing as an element of a «green» economy formation in the globalization conditions of sustainable development. Green, Blue and Digital Economy Journal, Vol. 2, No. 2. Pp. 15-23. DOI: https://doi.org/10.30525/2661-5169/2021-2-3. [in English].

10. Kostenko, G. (2025). Cluster based deployment of second life ev batteries for reliable and sustainable backup power solution in power systems. System Research in Energy, No. 1(81). Pp. 40-60. DOI: https://doi.org/10.15407/srenergy2025.01.040. [in English].

11. Dovgal, O., Goncharenko, N., Honcharenko, V., Shuba, T., & Babenko, V. (2019). Leadership of China In the Innovative Development of the BRICS Countries. Journal of Advanced Research in Law and Economics, Vol. X. No. 8(46). Pp. 2305-2316. DOI: https://doi.org/10.14505/jarle.v10.8(46).09. [in English].

12. Dovgal, O., Goncharenko, N., Reshetnyak, O., Dovgal, G., Danko, N., & Shuba, T. (2020). Sustainable Ecological Development of the Global Economic System: the Institutional Aspect. Journal of Environmental Management and Tourism, Vol. XI. Iss. 3(43). Pp. 725-740. DOI: https://doi.org/10.14505//jemt.v11.3(43).27. [in English].

13. Dovgal, O., Goncharenko, N., Karp, V., & Revyakin, G. (2022). Integrated Evaluation of Innovative Development of the New EU Member States and Other EU Countries. Comparative Economic Research. Central and Eastern Europe, Vol. 25, No. 2. Pp. 117-136. DOI: https://doi.org/10.18778/1508-2008.25.16. [in English].

14. Dovgal, O., Goncharenko, N., Reshetnyak, O., Dovgal, G., & Danko, N. (2021). Priorities for Greening and Sustainable Development of OECD Member Countries and Ukraine: a Comparative Analysis. Comparative Economic Research. Central and Eastern Europe, Vol. 24. No. 1. Pp. 45-63. DOI: https://doi.org/10.18778/1508-2008.24.03. [in English].

15. Global EV Sales for 2023. (2024). EV Volumes. Retrieved from: https://ev-volumes.com/news/ev/global-ev-sales-for-2023/. [in English].

16. The most popular EVs across the world in the first half of 2024. (2024). Autovista24. Retrieved from: https://autovista24.autovistagroup.com/news/the-most-popular-evs-across-the-world-in-the-first-half-of-2024/. [in English].

17. Global EV Outlook 2024 – Trends in electric cars. (2024). IEA. Retrieved from: https://iea.blob.core.windows.net/assets/dacf14d2-eabc-498a-8263-9f97fd5dc327/GEVO2023.pdf. [in English].

18. New car registrations: +0.8% in 2024; battery-electric 13.6% market share. (2025). European Automobile Manufacturers Association (ACEA). Retrieved from: https://www.acea.auto. [in English].

19. EV Registration Highlights: 25% of New Cars Had a Plug. (2025). European Alternative Fuels Observatory. Retrieved from: https://alternative-fuels-observatory.ec.europa.eu. [in English].

20. Europe: Electric Car Sales per EU, UK, and EFTA Country. (2025). Best Selling Cars. Retrieved from: https://www.best-selling-cars.com. [in English].

21. Mobility & Transport achievements 2019-2024. (2024). European Commission. Retrieved from: https://transport.ec.europa.eu/transport-themes/eu-mobility-transport-achievements-2019-2024_en. [in English].

22. Khalid, M. (2024). Smart grids and renewable energy systems: Perspectives and grid integrationchallenges. Energy Strategy Reviews, No. 51. DOI: https://doi.org/10.1016/j.esr.2024.101299. [in English].

23. Reka, S.S., Venugopal, P., Ravi, V., & Dragicevic, T. (2023). Privacy-based demand response modeling for residential consumers using machine learning with a cloud–fog-based smart grid environment. Energies, No. 16(4). DOI: https://doi.org/10.3390/en16041655. [in English].

24. Gielen, D. et al. (2019). The role of renewable energy in the global energy transformation. Energy Strategy Reviews, Vol. 24. Pp. 38-50. DOI: https://doi.org/10.1016/j.esr.2019.01.006. [in English].

25. Abduljabbar, R. et al. (2019). Applications of Artificial Intelligence in Transport: An Overview. Sustainability, No. 11(1). DOI: https://doi.org/10.3390/su11010189. [in English].

26. Interoperable EV charging via eRoaming. (2023). Hubject. Retrieved from: https://www.hubject.com/company/newsroom?cba55d35_page=24&ee601273_page=2. [in English].

27. Lunz, B., Yan, Z., Gerschler, J.B., & Sauer, D.U. (2012). Influence of plug-in hybrid electric vehicle charging strategies on charging and battery degradation costs. Energy Policy, N0. 46. Pp. 511–519. Retrieved from: https://ideas.repec.org/a/eee/enepol/v46y2012icp511-519.html. [in English].

28. Lee, D., Camacho, D., & Jung, J.J. (2023). Smart Mobility with Big Data: Approaches, Applications, and Challenges. Applied Sciences, No. 13(12). DOI: https://doi.org/10.3390/app13127244. [in English].

Список використаних джерел:

1. Directorate-General for Climate Action. (2024). European Commission. URL: https://commission.europa.eu/about/departments-and-executive-agencies/climate-action_en.

2. Fit for 55 Package – Climate Target Plan 2030. (2023). European Commission. URL: https://ec.europa.eu/clima.

3. Building a European battery industry. (2024). European Battery Alliance. (EBA). URL: https://www.eba250.com/.

4. Woerter, M., Stucki, T., Arvanitis, S., Rammer, C., & Peneder, M. (2017). The adoption of green energy technologies: The role of policies in Austria, Germany, and Switzerland. International Journal of Green Energy, No. 14(14). Pp. 1192–1208. DOI: https://doi.org/10.1080/15435075.2017.1381612.

5. Martins, H., Henriques, C.O., Figueira, J.R., Silva, C.S., & Costa, A.S. (2023). Assessing policy interventions to stimulate the transition of electric vehicle technology in the European Union. Socio-Economic Planning Sciences, Vol. 87(PB). DOI: https://doi.org/10.1016/j.seps.2022.101505.

6. Kostenko, G. (2022). Overview of European trends in electric vehicle implementation and the influence on the power system. System Research in Energy, No. 1(70) Pp. 62–71. DOI: https://doi.org/10.15407/srenergy2022.01.062.

7. Gunkel, P.A., Bergaentzlé, C., Jensen, I.G., & Scheller, F. (2020). From passive to active: Flexibility from electric vehicles in the context of transmission system development. DOI: https://doi.org/10.1016/j.apenergy.2020.115526.

8. Preuß, S., Kunze, R., Zwirnmann, J., Meier, J., Plötz, P., & Wietschel, M. (2021). The share of renewable electricity in electric vehicle charging in Europe is higher than grid mix, Working Papers «Sustainability and Innovation. S11/2021, Fraunhofer Institute for Systems and Innovation Research (ISI). URL: https://publica-rest.fraunhofer.de/server/api/core/bitstreams/d3dad178-1535-4517-a0c6-9aa3d414b38b/content.

9. Goncharenko, N., & Shapoval, V. (2021). Eco-innovation financing as an element of a «green» economy formation in the globalization conditions of sustainable development. Green, Blue and Digital Economy Journal, Vol. 2, No. 2. Pp. 15-23. DOI: https://doi.org/10.30525/2661-5169/2021-2-3.

10. Kostenko, G. (2025). Cluster based deployment of second life ev batteries for reliable and sustainable backup power solution in power systems. System Research in Energy, No. 1(81). Pp. 40-60. DOI: https://doi.org/10.15407/srenergy2025.01.040.

11. Dovgal, O., Goncharenko, N., Honcharenko, V., Shuba, T., & Babenko, V. (2019). Leadership of China In the Innovative Development of the BRICS Countries. Journal of Advanced Research in Law and Economics, Vol. X. No. 8(46). Pp. 2305-2316. DOI: https://doi.org/10.14505/jarle.v10.8(46).09.

12. Dovgal, O., Goncharenko, N., Reshetnyak, O., Dovgal, G., Danko, N., & Shuba, T. (2020). Sustainable Ecological Development of the Global Economic System: the Institutional Aspect. Journal of Environmental Management and Tourism, Vol. XI. Iss. 3(43). Pp. 725-740. DOI: https://doi.org/10.14505//jemt.v11.3(43).27.

13. Dovgal, O., Goncharenko, N., Karp, V., & Revyakin, G. (2022). Integrated Evaluation of Innovative Development of the New EU Member States and Other EU Countries. Comparative Economic Research. Central and Eastern Europe, Vol. 25, No. 2. Pp. 117-136. DOI: https://doi.org/10.18778/1508-2008.25.16.

14. Dovgal, O., Goncharenko, N., Reshetnyak, O., Dovgal, G., & Danko, N. (2021). Priorities for Greening and Sustainable Development of OECD Member Countries and Ukraine: a Comparative Analysis. Comparative Economic Research. Central and Eastern Europe, Vol. 24. No. 1. Pp. 45-63. DOI: https://doi.org/10.18778/1508-2008.24.03.

15. Global EV Sales for 2023. (2024). EV Volumes. URL: https://ev-volumes.com/news/ev/global-ev-sales-for-2023/.

16. The most popular EVs across the world in the first half of 2024. (2024). Autovista24. URL: https://autovista24.autovistagroup.com/news/the-most-popular-evs-across-the-world-in-the-first-half-of-2024/.

17. Global EV Outlook 2024 – Trends in electric cars. (2024). IEA. URL: https://iea.blob.core.windows.net/assets/dacf14d2-eabc-498a-8263-9f97fd5dc327/GEVO2023.pdf.

18. New car registrations: +0.8% in 2024; battery-electric 13.6% market share. (2025). European Automobile Manufacturers Association (ACEA). URL: https://www.acea.auto.

19. EV Registration Highlights: 25% of New Cars Had a Plug. (2025). European Alternative Fuels Observatory. URL: https://alternative-fuels-observatory.ec.europa.eu.

20. Europe: Electric Car Sales per EU, UK, and EFTA Country. (2025). Best Selling Cars. URL: https://www.best-selling-cars.com.

21. Mobility & Transport achievements 2019-2024. (2024). European Commission. URL: https://transport.ec.europa.eu/transport-themes/eu-mobility-transport-achievements-2019-2024_en.

22. Khalid, M. (2024). Smart grids and renewable energy systems: Perspectives and grid integrationchallenges. Energy Strategy Reviews, No. 51. DOI: https://doi.org/10.1016/j.esr.2024.101299.

23. Reka, S.S., Venugopal, P., Ravi, V., & Dragicevic, T. (2023). Privacy-based demand response modeling for residential consumers using machine learning with a cloud–fog-based smart grid environment. Energies, No. 16(4). DOI: https://doi.org/10.3390/en16041655.

24. Gielen, D. et al. (2019). The role of renewable energy in the global energy transformation. Energy Strategy Reviews, Vol. 24. Pp. 38-50. DOI: https://doi.org/10.1016/j.esr.2019.01.006.

25. Abduljabbar, R. et al. (2019). Applications of Artificial Intelligence in Transport: An Overview. Sustainability, No. 11(1). DOI: https://doi.org/10.3390/su11010189.

26. Interoperable EV charging via eRoaming. (2023). Hubject. URL: https://www.hubject.com/company/newsroom?cba55d35_page=24&ee601273_page=2.

27. Lunz, B., Yan, Z., Gerschler, J.B., & Sauer, D.U. (2012). Influence of plug-in hybrid electric vehicle charging strategies on charging and battery degradation costs. Energy Policy, N0. 46. Pp. 511–519. URL: https://ideas.repec.org/a/eee/enepol/v46y2012icp511-519.html.

28. Lee, D., Camacho, D., & Jung, J.J. (2023). Smart Mobility with Big Data: Approaches, Applications, and Challenges. Applied Sciences, No. 13(12). DOI: https://doi.org/10.3390/app13127244.