

УДК 338.24

JEL classification: Q48, O38, O33

DOI: 10.20535/2307-5651.20.2021.252851

Smoliar LubovPh.D. in Economics, Professor
ORCID ID: 0000-0002-5626-4043**Trofymenko Olena**Doctor of Economics, Associate Professor
ORCID ID: 0000-0002-2339-0377**Pavlenko Tetiana**ORCID ID: 0000-0002-7888-7348
Ph.D. in Economics, Associate Professor
National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"**Смоляр Л. Г., Трофименко О. О., Павленко Т. В.**Національний технічний університет України
«Київський політехнічний інститут імені Ігоря Сікорського»

LEADING PRACTICES OF ENERGY INNOVATION DEVELOPMENT IN THE CONTEXT OF DIGITALIZATION OF PRODUCTION ON THE BASIS OF INDUSTRY 4.0

ПРОВІДНІ ПРАКТИКИ РОЗВИТКУ ЕНЕРГЕТИЧНИХ ІННОВАЦІЙ В УМОВАХ ЦИФРОВІЗАЦІЇ ВИРОБНИЦТВА НА ЗАСАДАХ ІНДУСТРІЇ 4.0

The article examines global initiatives to ensure the energy transition towards sustainable development, which involves innovative energy development to achieve climate neutrality. The main programs and activities to ensure the functioning of mechanisms for the development of energy innovations, which will strengthen the industrial and technological development of the state were analysed. Global initiatives have been structured separately to ensure the development of Industry 4.0 and the innovative development of energy. The main features, directions and activities of providing energetics innovative development based on the principle of complexity are defined. Stages of realization of state regulation for effective maintenance of development of energy innovations are established. The main problems of Ukraine on the way to innovative development of the energy sector are identified and the main recommendations for their solution are given.

Keywords: energy innovation, energy transition, sustainable development, Industry 4.0, digitalization of production, innovative economic development.

В межах оновлення державних концепцій для досягнення Глобальних цілей сталого розвитку та формування засад для розповсюдження проривних технологій в умовах становлення Четвертої промислової революції, в різних країнах впроваджуються оновлені стратегії та програми для досягнення цих завдань як комплексно, так і окремо. У статті досліджено низку глобальних ініціатив для забезпечення енергетичного переходу в напрямі сталого розвитку, що передбачає інноваційний розвиток енергетики для досягнення кліматичної нейтральності. Визначені основні програми та заходи для забезпечення функціонування механізмів розвитку енергетичних інновацій, що дозволить зміцнити промислово-технологічний розвиток держави. Структуровано світові ініціативи для забезпечення інноваційного розвитку економіки та енергетики. Досліджено програми та заходи як для забезпечення розвитку Індустрії 4.0, так і для інноваційного розвитку енергетики. Визначені основні підходи для забезпечення інноваційного розвитку енергетики на засадах принципу комплексності. Запропоновано реалізувати такі ключові етапи в межах державного регулювання для ефективного забезпечення розвитку енергетичних інновацій як 1) моніторинг сучасних програм та ініціатив країн з різною структурою промислового розвитку 2) визначення спільних ознак та ідентифікація унікальних характеристик та заходів; 3) співставлення світових програм з українськими та визначення можливості їх реалізації; 4) узагальнення кращих світових практик та особливостей їх впровадження; 5) імплементація світових практик в Україні з врахуванням існуючого потенціалу та поставлених цілей сталого розвитку. Ідентифіковано основні проблеми України на шляху до інноваційного розвитку енергетичного сектору та надано основні рекомендації щодо їх вирішення.

Ключові слова: енергетичні інновації, енергетичний перехід, сталий розвиток, Індустрія 4.0, цифровізація виробництва, інноваційний розвиток економіки.

Problem statement. Today, the energy sector is undergoing a global transformation. This is due to the new challenges and opportunities of Industry 4.0, as well as the need for sustainable development. As part of the renewal of national development visions for achieving

the Global Sustainable Development Goals and laying the groundwork for the diffusion of breakthrough technologies in the context of the Fourth Industrial Revolution, various countries are implementing renewed strategies and programs to achieve these goals, both comprehensively

and individually. To ensure high-tech development and sustainable energy development, developed countries are implementing strategies to support Industry 4.0, which already include initiatives to support energy innovation, as well as some strategies for innovative energy development.

That is why it is important to study the best practices of innovative energy development to identify areas and mechanisms for their possible implementation in Ukraine.

Analysis of recent research and publications.

Ukrainian and foreign scientists, in particular, P. Borowski, F. Libertson, D. Kurbatov, R. Madlener, W. Ostley, O. Prokopenko, N. Ryazanova, L. Friedstrom, F. Hackstein in their theoretical and empirical studies have repeatedly considered the key aspects of the national economy in the context of innovative improvements in the energy sector. However, given the rapidly changing economic environment and the development of breakthrough technologies in the context of the fourth industrial revolution, more research is needed on topical issues of energy development, taking into account the latest global best practices.

The purpose of this article is to identify mechanisms for the development of energy innovation in the context of digitalization of production based on Industry 4.0, taking into account the world's leading practices.

Results of the research. In order to identify leading practices in the development of energy innovation in the context of digitalization of production based on Industry 4.0, the regulatory framework for energy innovation in state and global regulation was structured. The main programs defining the global mechanisms of innovative development of energy, energy saving, and ecological transition include such programs as: The European Green Deal, a series of policy initiatives of the European Commission to ensure climate neutrality on the European continent by 2050; UN General Assembly official document Transforming our world: the 2030 Agenda for Sustainable Development, dated September 25, 2015, with a new action plan to put the world on a sustainable and stable development path; Energy Union Strategy (COM / 2015/080), published February 25, 2015, as a key priority of the Juncker Commission (2014–2019); The Renewable Energy Directive – a legal basis for the development of renewable energy in all sectors of the EU economy; the EU Hydrogen Strategy 2020–2050; the European Energy Security Strategy, etc.

A series of global European energy transition initiatives for sustainable development, providing innovative energy development to achieve climate neutrality in Europe by 2050, formed as part of the European Green Deal. The plan is expected to electrify the economy and increase the use of renewable energy, leading to job growth in these sectors, as well as improving the energy efficiency of buildings and creating construction jobs. In addition, the New Industrial Strategy of the European Union (EU) [1] includes three key priorities, which also correspond to the European Green Deal: 1) supporting the global competitiveness of European industry, defining and maintaining a level playing field at national and global level; 2) achieving climate neutrality in Europe by 2050; 3) ensuring a digital future for Europe.

An important element of the global mechanism for accelerating the energy transition is the world's first classification of environmentally sustainable activities – the so-called "green" taxonomy of the EU, whose adoption was approved by the European Commission on June 18, 2020.

This taxonomy is based on the scientific criteria of the system, which determines for investors those activities that will allow the decarbonization of the economy [2]. This is an important legal mechanism to ensure the implementation of innovative projects in the energy sector.

The association agreement between Ukraine and the EU also defines innovative solutions, particularly in the energy sector.

One of the main tasks today on the way to Industry 4.0 is comprehensiveness in the development of the industrial and technological component of the economy, creating the prerequisites for the introduction of energy innovation. That's why the work considers the existing initiatives at the state level regarding the implementation of Industry 4.0 (Fig. 1), as well as specifically in the energy sector (Fig. 2) to find common features, directions, activities to combine these solutions in Ukraine based on the principle of comprehensiveness.

Global initiatives to ensure the development of Industry 4.0 at the state level are presented on Fig. 1 [3–9], including Global initiatives for the development of Industry 4.0 at the state level; EU Industrial Strategy 2020–2024; European ICT Innovation Initiatives for EU SMEs (I4MS), since 2013; Green Paper on Industrial Policy; Development of ICT programs Estonia, since 2017; New Industrial France Program, France since 2013; Produktion 2030, Sweden, since 2020; MADE Denmark, since 2014; Industria Conectada 4.0 Spain, since 2015; National Technology Cluster Fabbrica Intelligente Italy, since 2012; Marshall Plan 4.0 "Priority measures for the economic redeployment of Wallonia" Belgium, since 2015.

Thus, the EU Industrial Strategy (2020–2024) defines the main objectives of the strategic document in the framework of the Green Deal Europe, namely: ensuring the digital transformation of industry; "Climate Neutrality" of the European industrial sector; ensuring the competitiveness of European industry in world markets, etc. Key to achieving these plans are initiatives and financial instruments related to the strengthening of the Common Market, the creation of the European Innovation Fund, etc.

The European ICT Innovation Initiatives for SMEs (I4MS) was launched in 2013. It is an initiative to connect SMEs, start-ups and manufacturing companies with European Digital Innovation Centers to help companies test and implement the latest digital technologies.

Marshall Plan 4.0 "Priority measures for the economic redeployment of Wallonia" was approved by the Belgian government in 2015. It is a government plan with priority measures for economic redistribution to structure a real industrial policy based on innovation with the integration of good governance. Organization of the program "Generation of Entrepreneurs 2015–2020" and the creation of business parks 4.0. provides support for energy efficiency, energy transition and circular economy; development of digital innovation; mechanisms for financing energy efficiency projects.

The New Industrial France program was launched in France and adopted in 2013. The program foresees the modernization of its industrial potential with the transformation of its economic model through digital technologies. The Industry of the Future Alliance is an organization supporting a new sector of the future solutions industry.

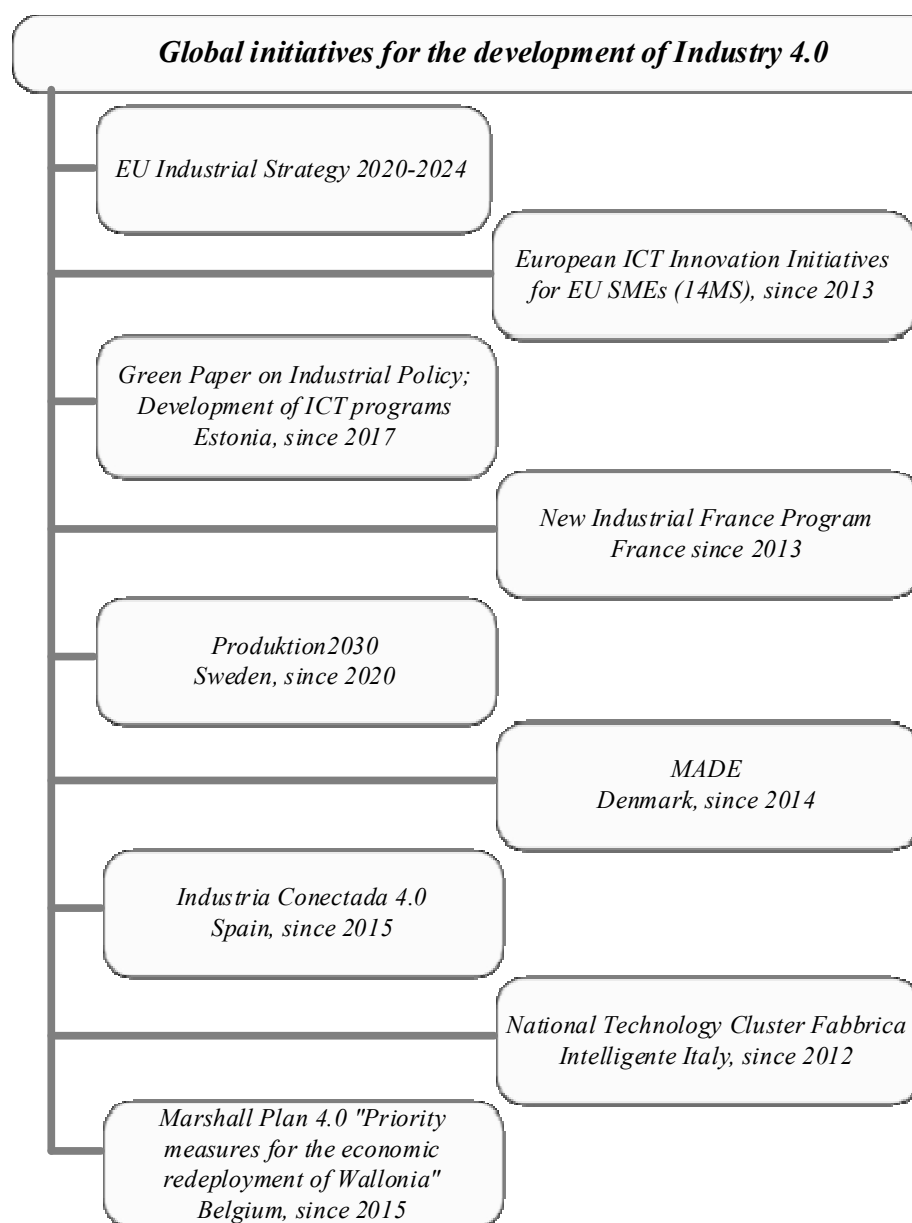


Figure 1 – Global initiatives to promote Industry 4.0 and energy innovation at the state level

Compiled by the authors

In Sweden, the Produktion2030 innovation program is a strategic innovation program supported by the Swedish Innovation Systems Agency (Vinnova), the Swedish Energy Agency and the Swedish Research Council for Sustainable Development (Formas). Strengthening networks and cooperation both in Sweden and internationally; and bringing together ideas, players and funding opportunities to create valuable solutions for the manufacturing industry of the future. There are four tools: projects, SMEs, education, analysis and internationalization.

One of the most interesting global initiatives is the national platform in Denmark, MADE – launched in 2014 and designed for research and innovation in Danish manufacturing – bringing together companies, universities, associations, public and private foundations. MADE's work is based on applied research into the current needs and challenges of Danish industry. Assistance in testing new methods and technologies in manufacturing companies.

Industria Conectada 4.0 is a strategy developed by the General Secretariat of Industry, Small and Medium Enterprises of Spain in 2015. It promotes the digital transformation of Spanish industry through joint and coordinated action between public and private companies. The main objectives of the strategy are: increasing industrial value added and skilled employment in the industrial sector; promoting the future industrial model of Spanish industry to strengthen future industrial sectors of the economy; developing local supply of digital solutions; developing competitiveness and increasing exports of industrial products.

To ensure the synergy of cooperation, in particular to achieve the digitalization of production in Industry 4.0 in Italy, the National Technological Cluster "Intelligent Factory" (Fabbrica Intelligente), an association in Italy operating since 2012, created to implement a strategy based on research and innovation on the competitiveness

of Italian production. It includes large and medium-sized enterprises, universities and research centers, business associations, and other advanced manufacturing stakeholders.

Estonia is one of the leading countries in the development of digitalization of industry. The Green Paper on Industrial Policy and Development of ICT Programs in Estonia dates back to 2017. The Estonian government published the Green Paper on Industrial Policy, the first comprehensive attempt to analyze the challenges faced by industry and propose relevant solutions. Measures to specifically support the digitalization of industry in the ICT development program. The updated version of the Digital Agenda 2020 for Estonia promotes the use of ICT and the development of smart solutions in Estonia. 5.6 million euros were allocated from the state budget for the development of ICT programs.

The above-mentioned world leading practices refer to the development of Industry 4.0. As for the development of energy innovations, the main programs for their development are systematized in Fig. 2.

Such global initiatives include Global initiatives to ensure the development of energy innovation; EU Energy Union Strategy, since 2015; New EU Renewable Energy Directive (REDII), 2018–2030; EU Hydrogen Strategy 2020–2050; Plan within the energy transition "Energiewende" 2010–2050; BEIS Energy Innovation Programme, 2015–2021; Long-term energy plan France 2018–2030; Canada's Energy Future 2020: Energy Supply and Demand Projections to 2050 (EF 2020); National Energy Efficiency Action Plans (NEEAPs) Turkey 2017–2023; Strategic Energy Plan Japan, since 2014.

First of all, it is worth mentioning the Energy Union Strategy, agreed in 2015, which aims to create an energy union that will provide EU consumers (households and businesses) with secure, sustainable, competitive and affordable energy. The strategy defines five dimensions of an energy union: security, solidarity and trust; a fully integrated domestic energy market; energy efficiency; climate protection actions, decarbonization of the economy; research, innovation and competitiveness.

According to the EU's New Renewable Energy Directive (REDII) (2018–2030), the EU's main target for the share of renewable energy is 32% of final energy consumption by 2030. This target has not been distributed among the member states, but the share of renewable energy in the member states must be at least the same as in 2020.

A global trend in the newest areas of renewable energy is the introduction of hydrogen technology into industry. The EU hydrogen strategy for 2020–2050 is designed with a step-by-step approach, and its goal is to increase the share of hydrogen from less than 2% today to 13–14% by 2050.

The German Energy Transition Plan 2010–2050 Energiewende is ambitious. Germany's energy concept, which includes measures for Germany's transition to a low-carbon, environmentally friendly, reliable and affordable energy supply.

The BEIS Energy Innovation Programme for the period 2015–2021 in the United Kingdom is coming to an end. The goal of the program is to accelerate the commercialization of innovative clean energy technologies and processes by 2020. The £505 million program for 2015–2021 consists of 6 themes for investment: about

£70 million in smart systems; about £90 million in energy efficiency and heating; nearly £100 million in industrial decarbonization and sequestration, carbon use and storage (Carbon Capture, Utilization, and Storage (CCUS)); about £180 million in nuclear innovation; around £15 million in renewable energy; approximately £50 million to support energy entrepreneurs and green finance.

The Multiannual Energy Programme 2018–2030 in France aims to complete the energy transition to ensure sustainable energy, reduce energy consumption, especially energy from fossil fuels, and ensure a harmonious balance between different energy sources. This will help achieve the goals of minimizing greenhouse gas emissions, meeting obligations to the EU and the Paris Climate Agreement to protect human health and the environment, and ensuring access to energy at reasonable prices while stimulating economic activity and employment in France.

Canada is one of the world leaders in the development of renewable energy. More than 60% of its own electricity is generated from renewable energy sources. It is worth noting the thorough national study, Canada's Energy Future 2020: Energy Supply and Demand Forecasts to 2050 (EF2020), which identifies how new technologies and climate policies will affect trends in Canadian energy consumption and production. Depending on the rate of change in technology and government policy, two scenarios are considered: the new energy system scenario and the reference energy system scenario.

Renewable energy sources are developing quite rapidly in Turkey. For example, Turkey's National Energy Efficiency Action Plans (NEEAPs) for 2017–2023 identify measures to reduce primary energy consumption by 14% compared to normal levels in sectors including buildings and services, electricity and heat, transportation, industry and technology, agriculture, etc.

Japan's Strategic Energy Plan was adopted in 2014. It provides for the introduction of a hydrogen economy that will ensure a stable energy supply, increase economic efficiency, improve the environment, and enhance energy security.

There will be extensive systematic cooperation between government, industry and the research sector to develop technology and promote the hydrogen economy. A technology map of Japan (promotion of the hydrogen economy) has been developed. By the 2030s, Japan will have introduced an innovative CO₂-free hydrogen economy that will enable Japanese society to achieve sustainable economic growth by actively exporting and transferring hydrogen energy technologies.

Given these programs, it should be noted that the main directions of development of national economies, in general, have a similar vector to the Energy Union Strategy (COM /2015/080), published on February 25, 2015, which provides five dimensions, closely related and complementary to each other:

1) Security, solidarity and trust – the diversification of European energy sources and energy security through solidarity and cooperation among EU countries.

2) Fully integrated internal energy market – ensuring the free flow of energy through the EU through adequate infrastructure and without technical or regulatory barriers.

3) Energy Efficiency – improved energy efficiency will reduce dependence on energy imports, reduce emissions, and stimulate jobs and growth.

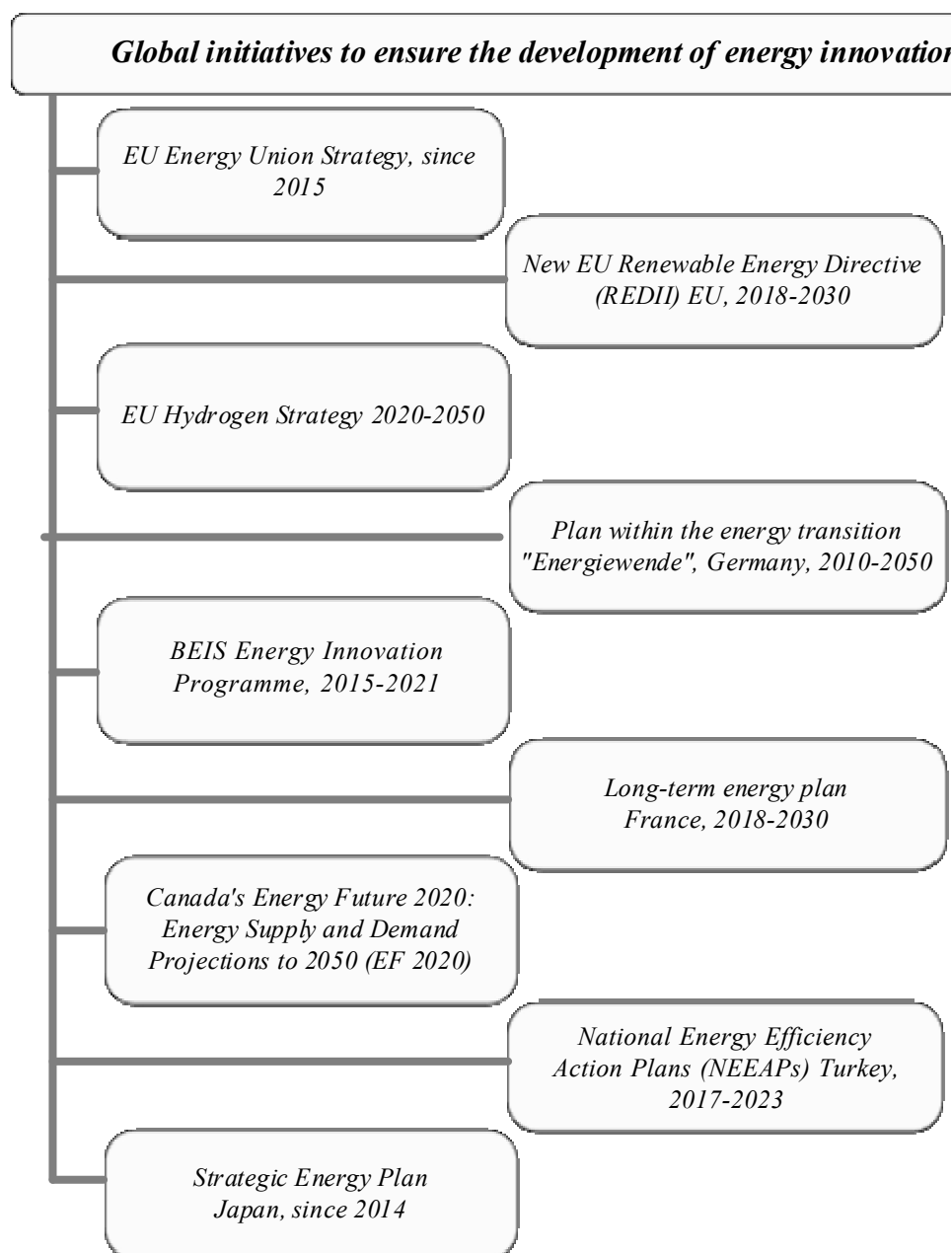


Figure 2. Global initiatives to ensure the development of energy innovation at the state level
Compiled by the authors

4) Climate action, decarbonization of the economy – the EU seeks to quickly ratify the Paris Agreement and maintain leadership in renewable energy.

Research, innovation and competitiveness - supporting breakthroughs in low-carbon and clean energy technologies by prioritizing research and innovation to drive the energy transition and improve competitiveness.

Conclusions. Thus, ensuring the innovative development of the energy sector is the basis for industrial development and modernization of the industrial complex of the world economy, ensuring the global digitalization of production. The formation of effective mechanisms for the development of energy innovation with a combination of technologies of Industry 4.0, which involves bringing the industrial complex to world standards, for Ukraine as a new European country is a priority for the progress of

the national economy in the Fourth Industrial Revolution. Energy transition, innovation, decarbonization, circular economy, and digitalization of production are key elements of most energy and Industry 4.0 planning documents. For effective state support of the development of energy innovation, in particular, it is important to ensure the implementation of such stages at the state level [10–13]: 1) monitoring current programs and initiatives of countries with different structures of industrial development; 2) identifying commonalities and determining unique characteristics and activities; 3) comparison of world programs with Ukrainian and determine the possibility of implementation; 4) generalization of the best world practices and their implementation; 5) adaptation of global practices in Ukraine, taking into account the existing potential and the projected results of achieving the goals.

It should be noted that the main document defining the tasks of achieving energy goals in Ukraine today is the Energy Strategy of Ukraine until 2035 "Security, Energy Efficiency, Competitiveness" [14], which defines the mechanisms of improving the energy sector and bringing it to European standards. The main mechanisms of energy development in the strategy are only named, but not detailed, which creates a need for their detailing and structuring. There is also no comprehensive approach to the implementation and functioning of these mechanisms.

In addition, this strategy was approved in 2017, so it may be necessary to update it with the above-mentioned global mechanisms. In particular, give priority to the development of hydrogen technologies.

Since the Strategy for the development of the industrial complex up to 2025 in Ukraine has not yet been adopted and the process of finalizing it is still underway. Based on the already established European practice of innovative energy development for industrial growth, it is advisable to adapt these mechanisms in Ukraine.

References:

1. A new Industrial Strategy for a green and digital Europe. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_416.
2. Sustainable Finance: Commission welcomes the adoption. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1112.
3. Plan Marshal 4.0. Available at: https://joinup.ec.europa.eu/sites/default/files/document/2015-06/synthese_plan_marshall_4.0.pdf.
4. CFI. Available at: <https://clustercollaboration.eu/cluster-organisations/cluster-fabbrica-intelligente>.
5. Financing renewable energy Options for Developing Financing Instruments Using Public Funds. Available at: <https://documents1.worldbank.org/curated/en/196071468331818432/pdf/765560WP0Finan00Box374373B00PUBLIC0.pdf>.
6. Integrated national energy and climate plan for France. Available at: https://ec.europa.eu/energy/sites/default/files/documents/fr_final_necp_main_en.pdf.
7. Produktion2030. Available at: <https://produktion2030.se>.
8. The energy Union Strategy (COM/2015/080). Available at: https://ec.europa.eu/energy/topics/energy-strategy/energy-union_en.
9. Accelerating clean energy through Industry 4.0. Available at: https://www.unido.org/sites/default/files/2017-08/REPORT_Accelerating_clean_energy_through_Industry_4.0.Final_0.pdf
10. Smoliar, L.H., Ilyash, O.I., Trofymenko, O.O., & Dzhadan, I.M. (2021). Ekolohichnyy skladnyk zabezpechennya innovatsiynoho rozvytku natsional'noyi ekonomiky v umovakh Industriyi 4.0 [An environmental component of securing the national economy's innovative development in the Industry 4.0]. *Rehional'na ekonomika* [Regional Economy], 99(1), 61–71. DOI: <https://doi.org/10.36818/1562-0905-2021-1-7>. [in Ukrainian].
11. Trofymenko, O. (2021). Theoretical principles of functioning of the mechanism of innovative development of the national economy in the energy sphere in the condition of Industry 4.0. *Economy and Society*, 27. DOI: <https://doi.org/10.32782/2524-0072/2021-27-52>.
12. Trofymenko, O. (2021). Development of a mechanism for implementation of a national innovative policy in the energy sector based on Industry 4.0. *Technology audit and production reserves*, 4/4(60), 34–40.
13. Smoliar, L., Ilyash, O., Kolishenko, R., & Lytvak, T. (2020). Benchmarks of ensuring an «economic breakthrough» of Ukraine in technological and innovative areas. *Innovative economy*, 5–6, 19–29. DOI: <https://doi.org/10.37332/2309-1533.2020.5-6.3>.
14. Enerhetychna stratehiia Ukrainy na period do 2035 roku «Bezpeka, enerhoefektyvnist, konkurentospromozhnist» [Energy Strategy of Ukraine for the period up to 2035 "Security, energy efficiency, competitiveness"]; Rozporiadzhennia Kabinetu Ministriv Ukrainy vid 18 serpnia 2017 № 605-r. Available at: <https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80#Text>.