

The Development Of Renewable Energy In The Context Of Formation Of Innovative Economy And Energy Independence As The Geopolitical Priorities Of The State

O. Liutak¹, O. Baula¹, A. Poruchnyk², Stoliarchuk Ya.², P. Kravchuk¹,
Iu. Kostynets³

¹Lutsk National Technical University, Lvivska 75, Lutsk, 43016, Ukraine

² Kyiv National Economic University named after Vadym Hetman, Victory Avenue 54/1, Kyiv, 03113, Ukraine

³ Assoc. Professor of the Department of Economic Cybernetics and Marketing, Kyiv National University of Technology and Design, Kyiv, Ukraine

E-mail: olenalutak@gmail.com

Abstract. Due to the deepening imbalances in the development of world energy and the uneven distribution of traditional energy resources, countries are forced to apply innovative forms and methods of radical changes in the structure of energy consumption. The formation of energy independence is based on the use of the innovative potential of the economy and the introduction of renewable energy sources. The econometric analysis showed a high level of influence of energy consumption based on wind and solar energy, the share of energy supplies from renewable sources, imports of mineral fuel, oil and its distillation products, financing of innovative activities of industrial enterprises on the country's GDP in a multifactor model. The implementation of innovative restructuring of the energy sector will reduce the level of energy intensity of GDP, increase the share of energy derived from renewable energy sources and reduce the consumption of traditional energy resources, which will provide an appropriate level of energy independence. The assimilation of complex world-class innovations in the field of energy determine the criteria of energy efficiency, encourage the active implementation of such measures, through which it is possible to predict the results of further scientific and practical search.

1. Introduction

At the time of intensification of economic reforms, intensification of consumption, priority of sustainable development, imbalances in the development of world energy and uneven distribution of traditional energy resources are increasingly deepening, which requires countries to apply innovative forms and methods of radical changes in the structure of energy consumption. These measures should begin with the diversification of ways of supply of traditional energy resources, as well as the search for and use of renewable alternative energy sources.

The innovative potential of renewable energy sources should be considered as the main source of reducing the costs of irreplaceable energy reserves, ensuring sustainable economic development, ensuring the proper degree of innovation of the economic system, increasing the export potential and, as a consequence, improving the welfare of the population.



Alternative and renewable energy sources have considerable potential to reduce and counter the risks in the energy sector at the micro, macro and mega level that improves the competitiveness as economic entities, individual countries and the global economy as a whole.

2. Review of Literature

The works of such domestic scientists as: S. Denisiuk [1], D. Zerkalov [2], N.Kazakova, A. Azarenkov [3], B. Korobko [4], S. Kudria [5], Yu. Makohon [6], Ya. Malyk [7], L. Matviichuk [8], M. Melnyk [9], S. Naraievsky [10], P. Nemish [11], A. Pavlyk [12], T. Reichenbach [13], A. Rozhko [14], V. Syvolapov, N. Guz, A. Novytskyi, V. Marchenko [15], V. Stoika, P. Kurmaiev, S. Stoika [16], I. Taranenko [17], etc.

At the same time, the study of system and technical aspects of energy development characterize the scientific importance and significance for the study of renewable and alternative energy sources. Therefore, outstanding domestic and foreign scientists of this side of problems are V. Barannik, V. Verbynskyi, A. Wiese, H. Heletukha, A. Dolinskyi, B.Zanner, S. Yermilov, N. Kaltschmitt, A. Konechenkov, V. Kukushkin N. Mkhitarian, W. Nordhaus, Ye.V. Obukhov, M. Porovskyi, A. Prakhovnik, V. Rau, Ye.I. Sukhin, G. Sheier, A. Szydlovskyi, W. Streicher, A. Shchokin, R. Jungk and others.

Issues of energy efficiency and energy management are investigated by I. Stadler, M. Klobasa, B. Danylyshyn, A. Halchynskyi, A. Pabat, O. Sukhodolia, Yu. Tunytsia. M. Dolishnyi made his contribution to the study of regional aspects of energy development.

A number of scientists and researchers, among whom the most important figures are members of the Club of Rome, are engaged in the understanding of global trends in the development of the world energy sphere in the civilizational aspect (J. Forrester D. Meadows, I. Tinbergen, E. Pestel, M. Mesarovich, B. Gavrylyshyn, etc.). Social and ethical vision of the interaction of man and nature in the context of domination of environmental and energy issues are in the works of the philosophical direction of T. Andreieva, R. Atfild, N. Borlaug, V. Vernadskyi, D. Ehrenfeld, D. Ikeda, H. Jonas, W. Calcote, G. Toro, and others.

From the point of view of solving global problems of our time, O. Bilorus, D. Lukianenko, V. Saveliev, S. Sidenko, S. Fedchun, A. Filipenko, A. Flissak, S. Yurii made their contribution to the study of the world energy sphere. They conducted their scientific work, seeing the depth and relevance of the problem, their research is of great scientific and practical importance. However, among the scientific results presented in the professional literature there are a number of unresolved issues that would highlight the innovative potential of renewable and alternative energy sources through the prism of the geopolitical priorities of the country.

3. Purpose

The purpose of the work is study of the influence of factors related to the development of renewable energy, innovative saturation and alternative sources on the country's GDP in the context of the formation of energy independence and the implementation of geopolitical priorities of the state.

4. Methodology

To perform the investigation, we used analytical data from statistical forms of reporting of Ukrainian enterprises through their generalization in the statistical data of the State Statistics Service of Ukraine.

An integrated methodological approach based on the application of general, scientific and applied methods, primarily economic and mathematical modelling and extrapolation, as well as statistical and graphical methods for processing and generalization of statistical data and their display.

5. The Results

Ukraine is an energy-dependent country, but at the same time, it has significant energy potential (significant deposits of coal and uranium ore, oil, gas, as well as untapped opportunities of non-traditional and renewable energy sources). This problem is especially acute on the background of the peculiarities of the sectoral structure of the economy, a significant level of energy intensity of products, insufficient level of innovativeness regarding the use of the capacities of renewable and alternative energy sources. As well as the annexation of Crimea and the hybrid war with Russia in

which the gas is used in the form of "energy weapon" to exert political pressure on the country's leadership.

The European vector of development of the domestic economy requires the liberalization of the energy market to attract investment in this area, reduce the energy intensity of products and energy dependence of Ukraine. One of the priority directions of ensuring energy security of Ukraine is the use of renewable energy potential. It is possible to confirm the relevance, expediency and necessity of these actions in Ukraine by the following facts:

- there is an urgent need to reduce the harmful burden on the environment and to modernize the domestic energy sector in accordance with the requirements of the XXI century;
- the ability of renewable energy sources in the shortest possible time and with minimal costs to solve the problems of lack of traditional energy capacity confirmed by world practice;
- the growing global demand for fuel and energy with resource and environmental constraints of traditional energy necessitates the timely preparation of new energy technologies that can take a significant part of the increase in energy needs and stabilize the consumption of fossil fuels.

The above-mentioned statements can be confirmed by existing studies of the renewable energy potential.

Thus, Professor and Vice-President of the Academy of economic Sciences of Ukraine Belopolskyi M. H. believes that to ensure energy independence of Ukraine it is advisable to increase the share of the use of the main Ukrainian energy raw materials – coal. "Having large enough natural reserves of high-quality coal Ukraine irrationally uses this raw material. It is advisable to review the methods of extraction and use of coal Ukraine has significant reserves of coal for the construction of underground gasification enterprises, which are effective in environmental and economic terms compared to conventional mines" [18, p. 17-18].

I. Borokhov concluded that "in a market economy it is necessary to consider various options for energy supply: the construction of air and cable power lines, the use of primary energy carriers or the use of alternative sources. The radiation energy of the Sun has a pronounced seasonal and diurnal character...The energy of wind and sea waves is random... Solutions to the problem of ensuring the energy security of the country is much easier if alternative sources are used in combination" [19, p. 128-129].

V. Burda justifies the choice of appropriate for the production of modern non-traditional energy sources to ensure energy conservation of the country. He notes, "the potential for biogas in our country is extremely high. Processing of organic waste in biogas reactors would solve the energy problem largely, which would have a positive impact on the development of the economy of Ukraine. It is proved that the most acceptable form of energy saving for the domestic economy is the processing of solid waste, which is due to the availability of resources for this, and does not require significant financial investments" [20].

O. Vozniak and M. Yaniv consider the problem of energy potential of solar energy. They point to the advantages of using solar installations and the feasibility of using solar energy potential in Ukraine [21].

H. Geletukha, T. Zhelezna, A. Bashtovyi in their study, having analysed the existing energy strategies and forecasts of energy development until 2050, prove the need to reduce the total consumption of primary energy through the widespread introduction of energy-efficient technologies and energy-saving measures [22, p. 63-66].

Having analysed the domestic and world experience in the use of alternative energy sources and the prospects of cooperation between Ukraine and foreign countries in the implementation of Energy strategy, proves that in Ukraine the problem of provision of the main consumers of energy resources is particularly relevant, because, having refused to import energy from the Russian Federation, the country is forced to reduce energy consumption and look for new ways of production of energy resources. "Reforms in the energy sector of Ukraine will improve the energy efficiency of the country, will ensure the development of alternative energy and will contribute to the growth of energy independence from external energy suppliers" [23, p. 43-48].

As we can see from the examples of scientific research on the potential of renewable and alternative energy sources, scientists are almost unanimous in their opinion about the need and feasibility of using these types of resources to ensure the energy security of the country. In addition, it is worth noting the high level of innovation in this segment of the economy, which requires both significant financial investments and further scientific developments to improve the efficiency of biofuel use, cheaper installation of solar panels and an increase in the amount of energy storage, further modernization of energy-efficient facilities and products.

Global scientific progress in this area is marked by the speed of transformation and the interest of both the public and private sectors in financing innovation. This is due to the high level of payback of such projects and the ability to ensure the energy independence of the state in the context of globalization threats, which is typical for Ukraine as well.

Analysing the volume of production and consumption of alternative energy in Ukraine it is advisable to give the following data (Fig. 1).

As can be seen from the figure, the largest weight in renewable sources in Ukraine is biofuel energy and waste, the increase of which during the study period amounted to 2.3 times, from 1508 to 3495 thousand tons of oil equivalent. As for wind and solar energy, the increase is much more – 36 times (from 4 to 144 thousand tons), due to the interest in the use of "green tariff", reducing the cost of solar panels and the ease of installation and use. The volume of increase in the commissioning of the corresponding capacities is growing rapidly. In particular, Ukraine in April-June 2019 introduced 656 megawatts of renewable energy capacity, which is six times more than in the same period last year. Thus, as of the end of the first half of the year, the installed capacity of renewable energy facilities reached 3634.4 MW, including SES – 2640.4 MW, WPP – 776.6 MW, biomass plants – 51.3 MW, biogas – 66.4 MW [25].

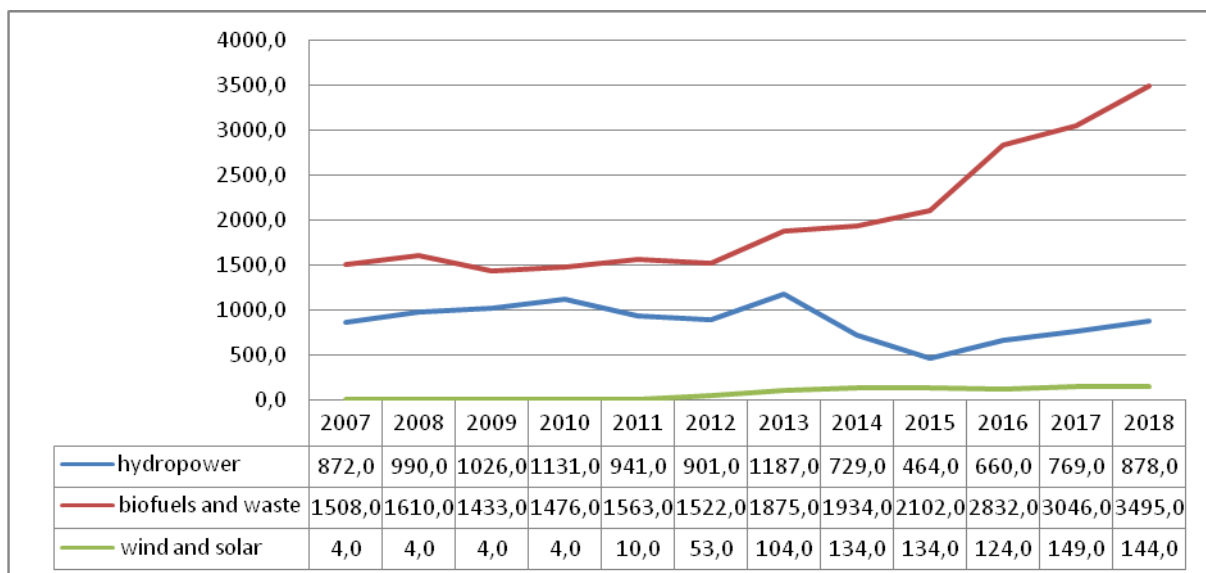


Fig. 1. Energy consumption from renewable sources in 2007-2018, thousand tons (compiled on the basis of [24])

That is why taking into account the impact of energy consumption based on wind and solar energy on the country's GDP can serve as a significant factor in the construction of the strategy of Ukraine's energy independence as a geopolitical priority of our state.

The involvement of private households before the installation and use of energy capacity based on alternative energy sources provides a reduction in the use of exhaustible energy sources, reducing the negative impact on the environment by reducing emissions and waste in the case of bio-installations, which as a result significantly reduces the volume of gas consumption and the growth of energy security of our state.

In continuation of the research, the authors propose the development of a regression model using economic and mathematical tools to determine the impact of the use of alternative energy sources and investments in these segments of the economy, financing of innovative development on the country's GDP. The analytical database for this model is shown in table 1.

Commenting on a number of selected indicators, we can say that the country's energy independence is formed based on the ability to meet their needs at a certain time at an affordable price. The volume of such resources that Ukraine is forced to buy abroad is reflected in the commodity structure of export-import operations under the code and the name of goods according to Ukrainian classification

of goods of foreign economic activity 27 "Energy materials; oil and products of its distillation" or "Mineral fuels; oil and products of its distillation".

Table 1. Initial indicators for the construction of economic and mathematical model

Year	GDP, million UAH.	Total primary energy supply, thousand tons of oil equivalent.	Total final energy consumption, thousand tons of oil equivalent	Energy consumption based on wind and solar energy, thousand tons of oil equivalent	Share of energy supply from renewable sources, %	Import of mineral fuel, oil and products of its distillation, million dollars. USA	The volume of completed scientific and scientific-technical works, million UAH	Financing of innovative activity of industrial enterprises, million UAH.
	Y	X1	X2	X3	X4	X5	X6	X7
2007	751100,0	139330,0	85955,0	4,0	1,7	15984,2	6700,7	10821,0
2008	990800,0	134562,0	83283,0	4,0	1,9	22832,0	8538,9	11994,0
2009	947000,0	114420,0	67555,0	4,0	2,2	14638,7	8653,7	7649,9
2010	1120600,0	132308,0	74004,0	4,0	2,0	19602,7	9867,1	8045,5
2011	1349200,0	126438,0	75852,0	10,0	2,0	28605,3	10349,9	14333,9
2012	1459100,0	122488,0	73107,0	53,0	2,0	26192,8	11252,7	11480,6
2013	1522700,0	115940,0	69557,0	104,0	2,7	21226,7	11781,1	9562,6
2014	1586900,0	105683,0	61460,0	134,0	2,6	15143,8	10950,7	7695,9
2015	1988500,0	90090,0	50831,0	134,0	3,0	10882,4	12611,0	13813,7
2016	2383200,0	94383,0	51649,0	124,0	3,8	7851,5	12610,8	23229,5
2017	2983882,0	89625,0	50086,0	149,0	4,4	11699,6	13025,8	9117,5
2018	3558706,0	90901,0	50110,3	144,0	5,1	13398,6	13440,7	11569,8

It is important to note that the share of energy supplies from renewable sources during the study period is growing. Despite the fact that 5% is a small figure compared to the average European 18%, Ukraine is moving in the right direction and in the future, we can significantly reduce the consumption of imported energy resources.

The volume of scientific and technical works has a tendency to increase and is determined by the positive trend of growth of state financing for the development of innovative economy on the basis of fundamental and applied research, at the same time, financing of innovative activity of industrial enterprises is characterized by sharp fluctuations and the inability to predict and form a stable trend.

The use of the software product "Data analysis" allowed determining the key factors in the multifactorial equation of the impact of the selected indicators on the country's GDP. As a result, we have such a ratio:

$$Y=18,7935*X_1-41,6172**X_2+2728,226*X_3+746101,566*X_4+43,5775*X_5-79,3287*X_6+13,2780*X_7+20158,5522$$

It should be noted that the main coefficients of checking the equation – the coefficient of determination is 0.9855, and the Fisher Criterion 39.078 with a table value of 4.16, give grounds to assert the adequacy of the model.

Thus, the most significant indicators affecting GDP are energy consumption based on wind and solar energy (2728,226) and the share of energy supply from renewable sources (746101,566). The total supply of primary energy and the volume of scientific and technical work performed is characterized by a negative impact on the resulting indicator.

Deepening the analysis of the impact of each factor on GDP, we have carried out the construction of pair regressions of the selected factors and the corresponding types of equations that describe the interdependence.

Table 2. Initial indicators for the construction of economic and mathematical model

	The type of equation describing the relationship, and R ²				
	Linear	Logarithmic	Polynomial	Degree	Exponential
Total supply of primary energy, thousand tons of oil equivalent.	y = - 39,67239x + 6203676,394 07 R ² = 0,72579	y = - 4457012,0502 6ln(x) + 53522431,585 67	y = 0,00077x ² - 212,00738x + 15657401,1652 9 R ² = 0,77045	y = 93839697003282 80000,00000x^{2,53240} R² = 0,79811	y = 20202347,7374 4e ^{-0,00002x} R ² = 0,79109
Total final energy consumption, thousand tons of oil equivalent.	y = 20202347,73 744e ^{-0,00002x} R ² = 0,79109	y = - 3713894,5290 2ln(x) + 42872685,660 11 R ² = 0,76240	y = 0,00154x ² - 259,52942x + 11917524,5502 7 R ² = 0,79004	y = 21331411670290 100,00000x^{-2,10696} R² = 0,81466	y = 13185548,6686 7e ^{-0,00003x} R ² = 0,80350
Energy consumption based on wind and solar energy, thousand tons of oil equivalent.	y = 11121,56339 x + 915680,9148 6 R ² = 0,68393	y = 397419,092161 n(x) + 360564,45075 R ² = 0,59538	y = 128,52708x ² - 7277,84369x + 1089677,65851 R ² = 0,74423	y = 675274,92891x ^{0,24} 246 R ² = 0,73573	y = 967204,65819e^{0,00650x} R² = 0,77564
Share of energy supply from renewable sources, %	y = 765117,1940 4x - 411560,8489 5 R ² = 0,95845	y = 2320305,2920 4ln(x) - 511242,28455 R ² = 0,93351	y = 22187,34261x² + 617387,46442x - 196958,08571 R² = 0,95910	y = 464175,16082x ^{1,25} 232 R ² = 0,90281	y = 505569,57574e ^{0,40160x} R ² = 0,87667
Import of mineral fuel, oil and products of its distillation, million USA dollars.	y = - 69,80781x + 2930481,598 35 R ² = 0,26732	y = - 1234584,0262 9ln(x) + 13690116,483 46 R ² = 0,30207	y = 0,00656x ² - 311,30454x + 4901072,64901 R ² = 0,35009	y = 834657719,38306 x ^{-0,64877} R ² = 0,27694	y = 2845467,72405 e ^{-0,00004x} R ² = 0,22462
The volume of scientific and technical works, million UAH.	y = 360,26673x - 2176238,586 88 R ² = 0,75007	y = 3400877,9778 4ln(x) - 29805695,425 53 R ² = 0,67720	y = 0,08294x² - 1344,24930x + 6230140,48063 R² = 0,90812	y = 0,00594x ^{2,09043} R ² = 0,84945	y = 148460,74984e ^{0,00022x} R ² = 0,90142
Financing of innovative activity of industrial enterprises, million UAH.	y = 52,94251x + 1105504,980 64 R ² = 0,06928	y = 723525,124551 n(x) - 5015291,9001 9 R ² = 0,07071	y = -0,00033x ² + 63,04397x + 1038977,86072 R ² = 0,06936	y = 21830,81622x ^{0,457} 75 R ² = 0,09397	y = 1037714,71813 e ^{0,00003x} R ² = 0,09733

As can be seen from the table 2, polynomial and degree equations often describe the relationship between GDP and the variable factor on the basis of the highest correlation coefficient.

Comparing the results of multi-factor and two-factor models, we can say that such indicators as the import of mineral fuel, oil and its distillation products and the financing of innovative activities of industrial enterprises do not directly affect the GDP of our country. As previously noted, the information in the table.1 certify the absence of a constant upward or other trend that would affect GDP and, accordingly, the formation of an innovative economy and energy independence as geopolitical priorities of our state. An important element of policy implementation in the field of

energy saving and use of alternative sources is the introduction of financial, organizational and economic activities that give the opportunity to implement the principles of sustainable development in public administration, and decentralization and local governments [26].

Financial instruments and programs are key to achieving energy security at independence, the main of which are shown in the table 3.

Table 3. Programs and projects in the field of alternative energy operating in Ukraine

Name of the program	Amount of financing	Credit period	Grace periods / conditions	Notes
The program of crediting of the Ukrainian-German Fund via banking institutions	Loans up to 300 thousand euros	Loan term up to 5 years	Interest rate from 15% in UAH and 7% in Euro	Terms and conditions of partner banks may vary
Ukrhazbank	Preferential loans (including in Euro)	Financing projects with a payback period of up to 10 years	Financing up to 80% of the project cost	The development strategy of "Eco lending" and offers preferential interest rates on loans and higher interest rates under deposits
"Development of municipal infrastructure»	Loans to municipalities and private enterprises from 10 million euros	Loan period up to 22 years (including a grace period of 5 years)	Interest rate 2.4 - 4% per annum	One-time fee of 50 thousand euros
Danish Investment Fund	up to 200 thousand euros		Financing up to 50% of the project cost and up to 25% of the investment involved	Participation of Danish enterprises, the use of Danish technology and equipment, the participation of Denmark in the management of the company and the like.
"The program of financing of alternative energy in Ukraine," EBRD (USELF)	Loans to private enterprises from 1.5 million Euro			Scope - Renewable Energy at production of electricity
Loans from EBRD	Loans from 5 to 250 million euros	Loan period up to 15 years	Interest rate – LIBOR + spread (~7-10%)	Must provide guarantees to the lender in the form of pledges of assets, shares of the company and other (by agreement). Usually, the average size of EBRD loans is about 25 million euros, but recently projects of 5-10 million euros have been actively considered.
«Clean production»	Loan from 50 to 500 thousand euros	Up to 5 years	6% per annum	Equity participation
NEFCO funds up to 90% of the project cost	Loan up to 5 million euros	Up to 8 years	6% per annum	Equity participation up to 35%

The use of international grants and programs makes it possible to implement mechanisms for the formation of energy security for certain priorities, in particular the Agency's Energy programs contribute to improving the energy efficiency of Ukraine's economy and reducing its dependence on energy imports, which is now at a critical level. In cooperation with the leaders of Ukraine, USAID is working to reform the municipal sector, which is now very energy-intensive; the tool is to strengthen the legislative, regulatory and institutional framework to improve heat supply systems [27].

Tetra Tech, ES Inc.' key ongoing energy security programs and projects." (implementation period July 1, 2018 – June 30, 2023), "Transparency of the energy sector" (Executive – DiXi Group, implementation period February 1, 2019 – December 31, 2023), the Program "Regulatory support of the energy sector of Ukraine" (implementation period: June 2016 – December 2019).

Anticipating the development of renewable energy in 2020, leading agencies have stated [28] that the share of energy supply from renewable sources in Ukraine will increase to 8%. Taking into account the equation of interdependence of this indicator and GDP ($y = 22187,34261 * x^2 + 617387,46442 * x - 196958,08571$), we can predict that the estimated value of GDP in 2020 will be 6162131,56 million UAH.

Further scientific research may be aimed at developing a model of an efficient energy market in Ukraine, taking into account the economic security of the country and optimizing the green tariff, which will reduce the cost of the total 1 kW of energy in the energy balance.

6. Conclusion

Consequently, the development of renewable energy in the context of the formation of innovative economy and energy independence is a key factor in the implementation of geopolitical priorities of Ukraine and the growth of its economy. The econometric analysis showed a high level of influence of energy consumption based on wind and solar energy, the share of energy supplies from renewable sources, imports of mineral fuel, oil and its distillation products, financing of innovative activities of industrial enterprises on the country's GDP in a multifactor model.

In addition, two-factor regression analysis also determined the impact of total final energy consumption on the growth of economic development of Ukraine. As a consequence, energy independence, which can be seen in the reduction in the volume of imported energy resources and the growth of the establishment and consumption of alternative energy sources can serve as the basis for energy security in the context of a certain European integration course and the rejection of the political influence of the "gas needle" of the Russian Federation. The European community helps us to implement a certain strategy through a significant number of programs and projects that Finance the introduction of alternative sources in Ukraine.

Thus, innovative solutions to spread the practice of using alternative energy sources in Ukraine can not only significantly preserve the environment, but also contribute to the sustainable development of the domestic economy.

Taking into account the current state of Ukrainian energy and the latest global trends in the development of energy markets, the main directions of ensuring the energy independence of our state:

- introduction of innovations aimed at saving and optimizing the consumption of traditional energy sources in production, as well as the gradual reorientation to renewable energy sources;
- introduction of innovations in the system of transmission of generated energy from renewable sources;
- use of innovations in the development and use of energy-saving and energy-efficient equipment.

The implementation of innovative restructuring of the energy sector will reduce the level of energy intensity of GDP, increase the share of energy derived from renewable energy sources and reduce the consumption of traditional energy resources.

World experience proves that the energy sector of the state is quite sensitive to changes in technological and political nature. In our country, the problem of deep assimilation of complex world-class innovations in the field of energy, which determine the criteria of energy efficiency, encourage the active implementation of such measures, through which it is possible to predict the results of further scientific and practical search, is acute.

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МУКАЧІВСЬКИЙ ДЕРЖАВНИЙ УНІВЕРСИТЕТ

89600, м. Мукачево, вул. Ужгородська, 26

тел./факс +380-3131-21109

Веб-сайт університету: www.msu.edu.ua

E-mail: info@msu.edu.ua, pr@mail.msu.edu.ua

Веб-сайт Інституційного репозитарію Наукової бібліотеки МДУ: <http://dspace.msu.edu.ua:8080>

Веб-сайт Наукової бібліотеки МДУ: <http://msu.edu.ua/library/>