https://doi.org/10.33271/nvngu/2023-4/089

A. Polyanska[*1],
orcid.org/0000-0001-5169-1866,
Yu. Pazynich[2],
orcid.org/0000-0003-2516-8638,
Kh. Mykhailyshyn[1],
orcid.org/0000-0003-2845-1965,
V. Buketov[3],
orcid.org/0000-0003-3243-3970

1 – Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine
2 – AGH University of Krakow, Krakow, the Republic of Poland
3 – Universidad Nacional de San Agustin de Arequipa, San Agustin de Arequipa, the Republic of Peru
* Corresponding author e-mail: parvs@ukr.net

ENERGY TRANSITION: THE FUTURE OF ENERGY ON THE BASE OF SMART SPECIALIZATION

Purpose. To justify the prerequisites of the energy transition as a necessary condition for the implementation of changes in the energy sector and the importance of the concept of smart specialization as a potential for generating investments for the implementation of measures within the framework of the energy transition.

Methodology. The method for calculating the average annual rate of growth of renewable energy capacities was used. To substantiate the growth potential of investments in the energy transition in regions, the compound interest method was used, and an investment forecast was made based on the growth rates of foreign investments in Ukraine and the growth rate of global investments in low-carbon energy.

Findings. The necessity of energy transition for Ukrainian energy industry is substantiated, and it is proposed to implement the policy of smart specialization for the implementation of energy changes. An example of coal-mining regions was considered, and attention was drawn to the importance of the development of the coal industry to ensure energy security, while the priority of the development of renewable energy sources was emphasized.

Originality. The relationship between the implementation of the energy transition policy and the regional policy of smart specialization is substantiated, taking into account the provisions and content of modern regulatory acts on regional development and energy transition, as well as familiarizing with the experience of foreign countries.

Practical value. The expediency of considering the issue of energy transition together with the implementation of the concept of smart specializations at the regional level is substantiated. This will make it possible to focus on energy sector to explore the prerequisites for the implementation of energy changes and to attract additional investments, taking into account the world experience of investing in low-carbon energy.

Keywords: *energy transition, smart specialization, coal, renewable energy sources, investment*

Introduction. In the context of the global needs for energy resources and consumption problem, there is growing interest in the energy transition [1], which involves countries into sustainable economies through the development of renewable energy, energy efficiency as well as protection and reduction of negative impact of people's activities on the environment. For Ukraine, the issue of energy transition is urgent and ambiguous, and requires the investigation of changes not only on the plane of renewable resources development, but also on sustainable usage of traditional energy resources, namely for energy security issue. This is important, because the energy transition involves the complete abandonment of such an energy resource as coal in the future, but this stage of the energy situation in Ukraine requires the production and consumption of coal as an energy resource in the conditions of an energy crisis and the lack of a sufficient number of alternative sources of energy resources. A complete abandonment of coal will not contribute to the balancing of energy needs and the possibilities of their satisfaction. Ukraine is among the countries in terms of natural coal reserves. According to the Statistical Review of World Energy 2020, explored coal reserves in Ukraine make up 3.21 % of the world's in comparison with Germany (3.36 %), Poland (2.52 %), Kazakhstan (2.39 %). An overview of analytical sources on production and consumption of energy resources shows the accelerated use of coal as a relatively cheap and affordable energy resource, which is also considered as a reserve of energy security for countries that have deposits of this resource. In 2021, 29.39 million tons of coal was produced in Ukraine, which is 1.98 % more than in 2020. However, the development of coal-fired power generation is accompanied by problems of environmental pollution with waste and CO_2 emission. Coal accounted for over 40 % of the overall growth in global CO_2 emissions in 2021. Coal emissions now stand at an all-time high of 15.3 Gt, surpassing their previous peak in 2014 by almost 200 Mt [2]. This is a critical limitation of the energy transition, so the issue of finding ways and methods to reduce the energy threat to the development of the coal industry, in particular due to modern concepts of development, requires attention. Considering the development trends of the coal industry on the example of individual countries, we would like to highlight the prerequisites for energy transformation. The course chosen by Ukraine according to the Energy Strategy, to increase the production of alternative energy sources currently does not meet the existing need for energy

resources and accounted for up to 9 % of the country's energy balance in 2021.

In 2022, global investments in energy transition technologies, namely renewable energy, energy efficiency, etc reached 1.3 trillion USD despite the prevailing macroeconomic, geopolitical and supply chain challenges. Global investments were up 19 % from 2021 levels, and 50 % from 2019, before the COVID-19 pandemic [3]. This trend demonstrates a growing recognition of the climate crisis and energy security risks associated with over-reliance on fossil fuels.

Thus, along with the development of low-carbon energy sources, in the presence of natural coal deposits, an important issue is the energy transformation that forms the potential background to the reforming of coal industry, ensuring the profitable operation of mines and eliminating man-made and environmentally dangerous impacts, and making the path to the energy transition less threatening for society and economy. Thus, the energy transition requires a "complex" approach that must be considered and implemented.

Literature review. In Ukraine the study on smart specialization as an effective tool for the development of regions with a priority of innovation has been carried out by scientists, including V. Brych, P. Pucenteilo, Y. Kostetskyi and S. Hunko [4], Patytska H. [5] According to the authors mentioned above, smart specialization is aimed at transformational changes in the strategic management of regional development. The energy transition within the implementation of smart specialization is a serious challenge, which was studied by Steen M., Faller F., Ullern E., according to whom, the setting of smart specialization priorities related to energy differs significantly within RIS3, and that the priorities of the regional innovation policy may hinder the implementation of initiatives in the energy sector [6]. Instead, according to Nauwelaers K., Seigneur I., Gomez Prieto J., it is smart specialization that can give priority to regional innovative opportunities and potential associated with actions specifically in the direction of the energy transition [7]. However, the issue of energy transition on the basis of smart specialization requires further research and study in the Ukrainian conditions.

Unsolved aspects of the problem. Today, the problems of changes in the energy sector remain a priority on the agenda in the conditions of post-war recovery. However, these changes require new approaches and sources of their implementation. In particular, the concept of energy transition affects not only the issue of low-carbon energy production, but also the creation of conditions for safe and clean energy supply. Currently, the achieved results of the development of alternative energy sources do not allow us to fully solve the problem of meeting the energy needs of the country. At the same time, solving the issue of reducing dependence on imports of energy resources requires the development of appropriate measures on the basis of existing energy industries, in particular coal. However, the implementation of traditional approaches to support the development of the coal industry does not meet modern requirements and opportunities. There is a need to find new approaches, in particular from the standpoint of regional development, rather than from the point of financing the individual enterprises or their associations, as well as taking into account global trends in financing activities within the framework of the energy transition.

Purpose. Taking into consideration mentioned above, the purpose of article is to justify the prerequisites of the energy transition as a necessary condition for the implementation of changes in the energy sector and the importance of the concept of smart specialization as a potential for generating investments for the implementation of measures within the framework of the energy transition.

Methods. The article examines the importance of smart specialization conception implementation in Ukraine, in particular, to create prerequisites for the implementation of the energy transition policy, which is aimed at expanding the potential of using alternative energy sources and reducing CO_2 emissions from the use of traditional energy sources, in particular coal. The trend of renewable energy capacities development in Ukraine compared to other European countries is analysed. For this, the method for determining the average annual growth rate CAGR (Compound annual growth rate) was used, which describes the growth rate of capacities, if they grew at the same rate, and makes it easier to understand the change and track the effectiveness of this indicator. The CAGR is calculated using the formula

$$CAGR = \left(\frac{E_w}{S_w} \right)^{1/n} - 1, \quad (1)$$

where E_w is the final value of the parameter; S_w – the initial value of the parameter; n – the number of years.

To determine the prospects of the energy transition, in particular by creating favourable conditions due to investments in low-carbon production, a study on the potential of investments in the energy sector was conducted based on the pace of investments in low-carbon energy in the world. To carry out the relevant calculations, the dynamics of capital investments in the regions where coal basins are found and the coal mining infrastructure is in place were analysed, and investment activity was forecast based on the growth rates of investments in low-carbon energy. The formula was used to forecast investments based on dynamics

$$I_{fi} = I \cdot CAGR_i, \quad (2)$$

where I_{fi} is the potential average annual foreign investment volume in Ukraine in the energy sector; I – actual foreign investment in the development of the region; $CAGR_i$ – average annual growth of foreign investments.

Taking into account the time factor based on the method for calculating compound interest as well as combination of average annual growth rates in low-carbon energy with average annual growth rates of foreign investments, will allow forecasting the additional volume of investments for comprehensive energy transition, namely

$$I_{ET/SS} = I_{fi} \cdot (1 + CAGR_{i.c.e.})^n,$$

where $I_{ET/SS}$ is potential investment into energy transition on the base of Smart specialisation; I_{fi} – the average annual foreign investment volume in Ukraine at energy sector; $CAGR_{i.c.e}$ – average annual growth rates in low-carbon energy; n – investigation period.

To describe the object under study, the method of comparative analysis was used to characterize the policy of smart specialization in the regions of Ukraine before the war [8]. Programs' measures in the context of the regional development policy implementation are also considered for guide lining the energy changes, namely The New energy strategy of Ukraine until 2035: "Safety, energy efficiency, competitiveness", The State regional development strategy for 2021–2027, The national program for the transformation of coal regions of Ukraine until 2027 [9].

Ukraine's experience in reforming the coal industry. The development of the coal industry in Ukraine is taking place against the background of russia's military aggression. The seizure of Eastern Ukraine in 2014, where a large part of coal mines is located, did not contribute to the development of the coal industry. The issue of reforming the coal industry is urgent for Ukraine. In the approved Concept of reform and development of the coal industry for the period until 2020, it is determined that the coal industry, which is one of the basic branches of the national economy, has been in a state of crisis for a long time.

In the energy balance of Ukraine, in the structure of primary energy consumption, until 2035, coal consumption will be almost halved, remaining at 12.5 %, based on the fact that Ukraine possesses natural minerals, which in the medium

term are considered as a source of the country's energy dependence. Despite the fact that Ukraine has significant natural reserves of coal, there is an energy crisis in the country, overcoming which was considered at the expense of imports, which in 2022 it amounted to 420.5 million dollars (40.92 %) of imports from russia, from the USA – by 277.9 million dollars (27.05 %), from Australia – by 100.2 million dollars (9.76 %), and 228.67 million dollars (22.26 %) from other countries. For countries that have coal deposits, the problem of energy supply is partially solved by the development of the coal industry. Global coal consumption rebounded in 2021, after a sharp decline in 2020 due to the COVID-19 pandemic. An economic recovery, especially in countries that rely on coal consumption, prompted a fuel switching to coal, namely to power generation up 8 % as well as for industrial activity that boosted coal use for non-power applications by 2.2 % [10].

Design capacity of coal mining by state mines is 32.6 million tons per year, and the actual coal production in 2021 was 24.923 million tons, which is 1.98 % more than last year. The cost price of commercial coal products at state mines was on average over 4,000 UAN per ton at the market price of 1,350 UAN per ton. State coal mining enterprises are unprofitable and require constant financial support from the state budget [11]. Almost two-thirds of the units of the main stationary equipment of state-owned mines have completed the standard period of operation.

Lack of investment resources caused the increasing subsidies at fossil-fuel production. There were substituted in analysis that subsidies are economically inefficient, environmentally harmful, fiscally costly and not particularly equitable. Due to their social impact, reforming such subsidies also meets with a lot of resistance. Despite this, the increase was driven by spending in Ukraine about USD 2.8 billion in 2020 or 89 % of total regional support [12].

Existing subsidies do not cover losses from coal production of state mines, which leads to the accumulation of accounts payable. In connection with the unsatisfactory financial condition of the state mines, there are constant delays in the payment of wages; arrears from the payment of a single contribution to the mandatory state social insurance are accumulating. This leads to an exacerbation of socio-economic tension in the mining regions and an increase in the burden on local budgets and underfunding of most of the planned activities. As of the beginning of 2020, there were 148 mines in Ukraine, of which 102 are owned by the state. Most of the mines are located in the territory not under the control of Ukraine (67), another 2 mines are not active, 33 are working (but only 4 are considered profitable) [11]. Despite the fact that the main goal of the activity of all coal mining enterprises is to make a profit, during 2018–2020, only PJSC Shakta "Nadia" located in Lviv Region, was profitable.

In order to comprehensively solve the problematic issues of the functioning of the coal industry, implement systematic measures to use its potential to increase the volume of coal production, increase efficiency and transfer the coal industry to a non-subsidy and self-supporting mode of activity while simultaneously solving environmental and social problems of mining regions and creating favourable investment conditions for the privatization of mines, the Concept of the reform and development of the coal industry for the period until 2027 was approved.

The presentation in October 2020 of the draft Concept of Coal Industry Reform, designed for 2020–2024, was already the fourth conceptual document in the last 15 years, according to which the restructuring of coal enterprises should be carried out. Particular attention of the proposed Concept was paid to the provisions which align it with the climate obligations of Ukraine in accordance with the Paris Agreement and other documents, namely the Concept of the "green" energy transition of Ukraine by 2050, National program of transformation of coal regions of Ukraine until 2027. It is also advisable to take into account the results of the long-term modelling of the energy industry development, which is carried out as part of the preparation of the second NPP and the Integrated Plan for the fight against climate change and the development of the energy industry until 2030, in particular, to adjust actions in view of realistic scenarios of the development of demand for coal products.

Thus, in Ukraine the situation in the coal industry is characterized by crisis phenomena and is accompanied by an effort to improve it due, first of all, to the formation of a clear vision of the trajectory of future development and focusing on those areas of activity that will allow creating conditions for changing the current state and achieving development indicators, which are declared in program documents for the development of not only the coal industry, but also the Ukrainian energy industry in general.

Advantages of smart specialization for the energy transition. Content and significance of the regional policy of smart specialization. In the conditions of aggravation of environmental problems, success is achieved by those regions that have innovative industries, are creative and strive for constant development. Achieving this goal is facilitated by the concept of "smart specialization" (S3 – Smart Specialization Strategy) – a modern policy of innovative regional development, initiated by the European Union with the aim of promoting economic growth in regions through better disclosure of their potential. In Ukraine, the practice of implementing this concept to stimulate the development of regions is at the stage of formation, which significantly slows down their competitive development, restrains the process of effective use of resources on the basis of sustainable development, and does not allow one to fully realize the potential of the innovative industries development. The solution of this task is facilitated by the concept of Smart specialization, the implementation of which was started in three pilot regions of Ukraine: Kharkiv, Zaporizhzhia, and Odesa regions in 2017.

Smart specialization consists in identifying the unique characteristics and assets of the region and is aimed at implementing new management methods through cooperation between regional and national authorities responsible for making decisions on the development and execution of innovation policies with the relevant stakeholders involved in such a process (entrepreneurs, universities, research institutions, society, etc.).

Further development of the idea of smart specialization is declared in the State Strategy of regional development for 2021–2027 as a territorially oriented development policy based on stimulating the use of territories' own potential, providing support to individual territories characterized by special problems of socio-economic development, high historical and cultural potential, ecological conditions and environmental protection needs. In the task under the direction of "Restoration and development of territories, restructuring of the economies of regions affected by the armed aggression of russia against Ukraine" the following priorities are defined: assistance in the formation of infrastructure facilities for the development of entrepreneurship, such as business centres, business incubators, innovative and consulting centres, venture funds; promoting the implementation of innovative solutions in the field of coal mining, the use of related resources (in particular, mine gas methane, underground gasification technology of coal, mine waters, etc.), creating proper conditions for the functioning of domestic traditional energy, stimulating the development of alternative energy.

Certain steps have been taken towards the implementation of this task. Ukraine already has experience in strategic planning of the development of regions taking into account the concept of smart specialization. The content analysis of regional development strategies approved by regional councils showed that most of them were developed in accordance with current regulations, methodological instructions of the Ministry of Regions and JRC (The Joint Research Centre) recom-

mendations when determining smart specialization of regional development. However, in content it is difficult to determine whether the strategy of individual regions takes into account the criteria of smart specialization. It is also important that when determining the specialization of the region, most regions of Ukraine focused on "traditional specialization", which in principle is not surprising, since the EU countries planned their first innovative strategies similarly [13]. So, during the analysis of the situation in Ukraine, it was determined that the smart strategy was available in 19 regions of Ukraine (76 %), which is a promising indicator on the way to the implementation of the concept of smart specialization. Researchers studying this issue conclude that the smart strategy of 14 regions (56 %) is more in line with the principles of the traditional strategy of the regions than the broad smart approach.

The experience of foreign countries demonstrates how smart specialisation facilitates regional development. Network of Regional Specialized Observatories on Entrepreneurship is an EU-funded initiative in which leading academic and research institutions and technology parks in Silesia (Poland) work together to analyse the region's economic sectors and identify "smart specializations" that have the potential to stimulate development and therefore should have priority access to EU funds. The study by Polish scientists on the effectiveness of the restructuring process results in the coal industry and its achievement of sufficient efficiency to sustainably compete on the open market covered all coal mining enterprises included in official statistics during the long-term perspective (1990–2020), starting from the beginning of the systemic transformation in Poland. The general conclusion of the study was that there is a lack of coherence (follow-up) between the forms and consequences of coal mining companies restructuring in Poland, on the one hand, and changes in the composition of the country's energy balance as a result of energy transfer, on the other hand. In particular, this means that such restructuring, being ineffective, could not accelerate changes in the energy balance [14]. Smart specialization was defined as "a local approach developed within the framework of EU cohesion policy, which aims to identify strategic areas for intervention based on both an analysis of the strengths and potential of the economy, and a process of entrepreneurial discovery involving a wide range of stakeholders. It is outward-looking and takes a broad view of innovation, including but not limited to technological approaches, supported by effective monitoring mechanisms" (European Commission 2022a). It as a way to maximize the benefits of innovation and development of EU funds by identifying and exploiting the strengths of individual regions [15]. In addition to $600 million in regular funds for regional development, Silesia has benefited from $540 million under the Just Transition Fund from EU.

Ukraine is also discussing the fair transformation of the coal regions with the European Union, the World Bank and other partners following the example of the European Just Transition Program. A comprehensive policy of fair transformation of coal regions is being developed at the state level. The priority tasks are the introduction of the necessary incentives to make such regions an attractive place for investment, as well as the development of a detailed plan for the creation of new jobs and the creation of new opportunities for the development of small and medium-sized businesses.

Implementation of the concept of smart specialization for energy recovery. The first few years of the 2020s saw a series of major shocks that affected the economy and energy markets, from a drop in energy demand at the start of the COVID-19 pandemic to renewed energy supply uncertainty resulting from the international response to the russian invasion of Ukraine. In this context, a policy framework supporting the long-term transition to a low-carbon economy is important to guide the decision-making process. For example, the recovery plans developed by EU member states in response to the COVID-19 crisis clearly recognize the importance of investing in a green economy (European Commission 2020). In addition, the EU has confirmed its commitment to an accelerated energy transition through the REPower EU plan (European Commission 2022b). In both cases, these initiatives build on and connect to the existing long-term policy architecture, facilitating the mobilization and allocation of additional resources in line with strategic priorities at European, national and regional levels [16]. However, in the process of developing the strategy of smart specialization, an important component of it, namely the synergy of chain "business-science-government", was not observed, since the Strategy was developed with minimal participation of representatives of science and business. Ideas and directions for strategy development do not have support from the business side, because the issue has not gained enough publicity, and a significant part of the business does not understand the goals and potential benefits of this concept, as well as the benefits for their own business. This situation requires attention from the authorities, because by changing the level of awareness and motivation of business, the authorities can receive support for the development of smart specialization industries and achieve the goals of strategic development. The role of science, in particular regarding the implementation of energy transition measures on the basis of domestic universities, also has a significant impact on the creation of prerequisites for the energy transition. We would like to note the experience developed by Ukrainian higher education institutions. Thus, Dnipro University of Technology, which is a leader in the training of specialists in the field of "Mining", participates in and has successfully completed several international projects within the framework of the European Union program "Horizon 2020". Among them projects within the implementation of the program: "Science in universities" of the Ministry of Education and Science, Youth and Sports of Ukraine, namely:

1. OB-48: "Highly efficient use of the energy potential of geotechnical systems of Ukraine: resources, energy-saving technologies, eco-safety" (state registration number: 0109U005905), approved.

2. OB-54: "Complex generation and utilization of energy in the conditions of urbanized and industrial territories of Ukraine" (state registration number: 0111U009111), approved [17].

Therefore, higher education institutions have the potential to provide the connection between the science and global challenges on the issue of energy transition. Their further development is possible through the use of such organizational forms as public-private partnership ensuring the search for optimal mechanisms of interaction between the state, educational institutions and the private sector as well as usage of modern technologies, which would meet modern conditions.

The issue of a mine-based energy resource complex formation is also considered by scientists [18], which could be relevant to the creation of preconditions for strengthening the potential for energy transition. Moreover, the experience of countries, which have reached the progress, namely the Baltic countries on working out Smart Specialization strategies is very important, particularly by disseminating the knowledge transfer between matured innovators and young innovators [19].

Scientific and practical results in the implementation of smart specialization in coal mining regions for energy transition. The scientific problem of the energy transition has been raised as the request on the need to take into account the dynamic conditions of climate change, environmental protection, the necessary technical and digital changes capable of supporting the energy transition. As it was mentioned before, changes in the parameters of the equipment and technology functioning at enterprises of the energy industry under the influence of technological progress and digitalization require financing. For example, China is increasing investments in the coal industry, justifying such a decision with the desire to ensure energy security and meet the needs of energy resources at the

expense of the existing potential of coal reserves. We associate the solution of the specified scientific problem of the energy transition with the application of the concept of smart specialization. This will allow focusing attention on priority industries for Ukraine, and in the conditions of the energy crisis, regions with coal deposits, potentially could receive investment support for reconstruction of the energy system of Ukraine basing on the latest technologies of the industry, focusing on the energy efficiency, reduction of carbon dioxide emissions, reliability and sustainability, etc.

According to the article purpose we analysed investments in coal-mining regions of Ukraine on the base of official statistic information (Table 1) in order to relate regional investment tendencies with the requisitions of energy transition progress.

A large amount of capital investments was directed in Dnipropetrovsk region, and the highest rate was in Donetsk region. But these are investments into the region development and the investment into the energy transition deserves the additional attention. The information on RES capacities published on the official website of the European-Ukrainian Energy Agency indicates that Lviv region has such capacities, which amount to 338.3 MW of solar energy, 33.9 MW of wind energy and 2.4 MW of biogas and biomass; Dnipropetrovsk region has capacities, which amount to 1134.1 MW of solar energy and 29.7 MW of biogas and biomass.

So, there is some progress in the energy transition. The analysis has shown that the alternative energy capacities growth dynamics in Ukraine in comparison with the growth rates in the world and Europe is higher and is 1.78 compared to 1.10 and 0.69, respectively [3]. And the result of such a trend is higher of annual growth rate of renewable energy capacity in Ukraine in comparison with the world and Europe (Fig. 1).

But energy changes are to be comprehensive and linked to objects related to the energy transition, including infrastructure and consumption areas. As can be seen from Table 2, the average annual growth rates of investments in RES in Ukraine over the pre-war period are low. At the same time, considering energy transition changes, it is important to address the energy challenges accounting the best practices of the world, focusing on the most successful. The post-war recovery is predicted to change this situation. In this case, attention should be paid to the fact that post-war recovery involves attracting foreign investments. First of all, sectors that create high added value and whose products can be competitive on world markets are of interest to the investor. In Ukraine, 10 industries with significant investment potential have been identified, including energy, which has an investment potential of 177 billion dollars.

We can predict the size of foreign investments based on the average annual growth rate Investments in RES in Ukraine (Table 2).

We calculate the average annual growth rate of foreign investments in Ukraine ($CAGR_{fi}$) according to the formula (1)

$$CAGR_{fi} = \left(\frac{1.4}{0.8}\right)^{1/11} - 1 = 0.05.$$

The potential average annual foreign investment volume in Ukraine at energy sector will be calculated on the base of formula (2), billion dollars and the results will demonstrate the potential annual growth and 0.0893 billion dollars within 3 years

$$I_{fi(2023)} = 0.83 \cdot (1 + 0.05)^1 = 0.8715;$$

$$I_{fi(2024)} = 0.83 \cdot (1 + 0.05)^2 = 0.9151;$$

$$I_{fi(2025)} = 0.83 \cdot (1 + 0.05)^3 = 0.9608.$$

We propose to complement the trend of foreign investments in Ukraine with the trend of global investments in low-carbon energy (Table 3).

Taking into account the above, namely the combination of investment flow trends, in particular by requests for energy transition, the formula can be used to determine the potential growth of the average volume of external investments, in particular, in energy transition. Thus, the implementation of the concept of smart specialization will stimulate investors to attract their funds to specific industries, in this case, to energy to identify investment objects.

We calculate the average global annual growth rates in low-carbon energy ($CAGR_{l.c.e}$)

$$CAGR_{l.c.e} = \left(\frac{370}{210}\right)^{1/12} - 1 = 0.05. \quad (3)$$

Table 1

Capital investments in coal-mining regions of Ukraine, million UAN

Year	Lviv region	Dnipropetrovsk region	Donetsk region
2017	24,105.9	42,908.5	17,268.9
2018	28,995.5	60,288.6	26,979.4
2019	32,649.9	66,951.11	31,473.96
2020	16,220.7	52,355.69	25,103.89
2021	24,041.9	65,469.77	30,072.85
Total	126,013,9	287,973,7	130,899
CAGR, %	0.999	1.089	1.12

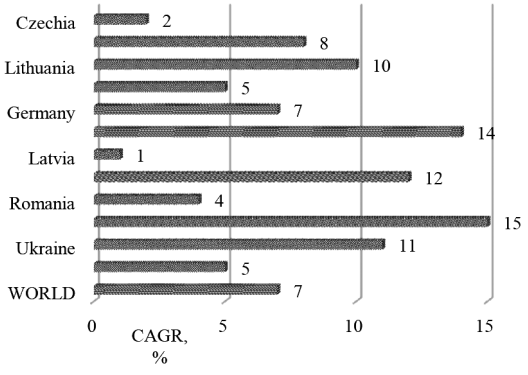

Fig. 1. Compound annual growth rate of renewable energy capacity for Ukraine in comparison with other countries

Table 2

Investments in RES in Ukraine [3]

Year	Value, billion dollars
2010	0.8
2011	0.9
2012	1.2
2013	0.6
2014	0.2
2015	0.1
2016	0.2
2017	0.3
2018	2.4
2019	4.1
2020	1.4
2021	–
Average annual investment volume	0.83

Table 3

Global investments in low-carbon energy [20]

Year	Value, billion dollars
2010	210
2011	260
2012	240
2013	210
2014	260
2015	300
2016	250
2017	215
2018	290
2019	315
2020	340
2021	370

Based on formula (3), it is possible to determine the potential growth of external investments average amount in energy transition, billion dollars

$$I_{ET/SS(2023)} = 0.8715 \cdot (1 + 0.05)^1 = 0.9151;$$

$$I_{I_{ET/SS}(2024)} = 1.9151 \cdot (1 + 0.05)^2 = 1.0089;$$

$$I_{I_{ET/SS}(2025)} = 1.9608 \cdot (1 + 0.05)^3 = 1.1123.$$

The visual comparison of the potential foreign investment growth in energy transition with the potential foreign investments growth in energy transition on the base of smart specialisation is presented below.

Thus, the implementation of the concept of smart specialization will stimulate investors to attract their funds to specific industries, in this case to energy, to identify investment objects. Namely, in the conditions of the war in Ukraine, the issue of energy security is of priority importance; the energy infrastructure needs significant reconstruction. At the same time, changes must be implemented taking into account the challenges of the energy transition. It should be noted that realizing the investment potential in Ukraine, in turn, requires strengthening legislation in the areas of carbon-neutral and self-sufficient energy system development; renewable energy sources; construction of microgrids and implementation of smart energy systems for the purpose of decentralization and ensuring stability; long-term energy storage systems, etc.

It should be noted that the implementation of the smart specialization conception requires compliance with practical examples from different regions and countries across Europe and the use of already developed principles. Experts in the field of smart specialization note that each governance setting is unique and "...there is no such thing as a 'governance template' that can be universally applied to every regional context, regardless of the circumstances of time and place". Putting the concept of smart specialization into practice relies on a well thought out approach to governance. Many of the points are made, such as the need for participation of the entrepreneurial community, a transparent approach to priority setting and an effective monitoring mechanism, continue to apply in the implementation phase. Some issues become even more relevant, such as integrated policy delivery and the design of funding calls.

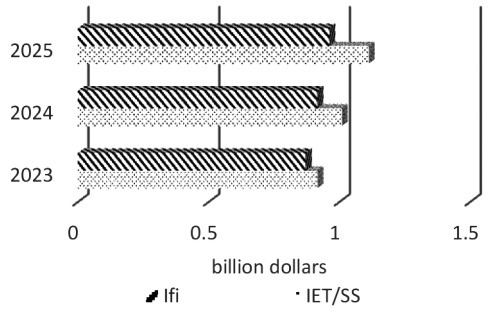

Fig. 2. The potential growth of the average amount of external investments in energy transition based on smart specialisation

Conclusions. Thus, the energy transition as a modern trend of developed economies creates prospects for progress for developing countries, ensuring their advanced development in energy field. When implementing the energy transition policy in Ukraine, the issues of post-war recovery and energy security should be taken into account. That is, support for the growth of the share of renewable energy in Ukraine should also be accompanied by the support for the reform of traditional energy sectors to meet energy needs during the energy transition period. However, the activities in this direction must meet modern trends and requirements. The coal industry remains one of the sources of national energy security, but as the experience of certain countries shows, a complete rejection of them does not correspond to the policy of energy security. Therefore, in such conditions, it is necessary to look for ways to reduce the negative impact on the environment of the coal industry, in particular CO_2 emissions. In such conditions, smart specialization is a modern direction for the development of regions in Ukraine. It allows focusing on those competitive advantages that are characteristic for each region, are in priority, have innovative areas that can ensure dynamic development and create attractiveness for potential investors in implementing the necessary changes. Therefore, the development of smart specialization in coal-mining regions will allow focusing attention on problematic issues and attract potential investors to the implementation of energy transition measures. In response to challenges in coal production the development policy must be directed to the restructure and increase the competitiveness of the industry, reduce the negative impact on environment, address the social and economic consequences of mine closures and associated job losses, and stimulate economic development outside the coal industry. We refer to experience of smart specialisation in European counties but count on the peculiarities of Ukrainian conditions. It is unreasonable to reduce the production and consumption of coal as an energy resource in the conditions of the energy crisis and the lack of a sufficient volume of alternative sources of energy resources.

The main idea of the paper consists of the proposed concept of using smart specialisation in the energy transition. The main scientific prerequisite for this work is to justify the opportunities for investing in the industry that correspond to the generation of energy resources in accordance with the accepted world concepts of energy transition as well as smart specialization. As a result, the authors received the following important scientific results of the studies:

- to ensure the energy transition, it is important to develop low-carbon energy, in which the largest share is RES, but the development of traditional energy sources, in particular coal, is also important, especially to ensure energy security and independence. It is important in the conditions of the energy transition to create such conditions to reduce the harmful impact of coal energy on the environment, and such changes require investments;

- the expediency of using smart specialisation conception in the regions, namely of coal production is substantiated;

- the possibility of increasing the amount of investments using supposed conclusion that potentially investments could be applied with the accounting of the world tendency of increasing investment into the low carbon energy was confirmed with calculation;

- the need to increase the level of appropriate regional policy and government on smart specialisation was argued;

- attention is drawn to the expediency of combining the efforts of the state, science, business to develop and support the idea of smart specialisation in real rector of economy.

References.

1. Diachuk, O., Chepeliev, M., Podolets, R., Trypolska, G., Venger, V., Saprykina, T., & Yukhymets, R. (2017). *Transition of Ukraine to the Renewable Energy by 2050.* (Y. Oharenko, & O. Aliieva, Eds.). Kyiv: Publishing house "Art Book" Ltd. Retrieved from https://ua.boell.org/sites/default/files/transition_of_ukraine_to_the_renewable_energy_by_2050_1.pdf.

2. *Global Energy Review: CO_2 Emissions in 2021* (2021). Retrieved from https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2.

3. IRENA and CPI (2023). *Global landscape of renewable energy finance, 2023, International Renewable Energy Agency, Abu Dhabi. Global landscape of renewable energy finance 2023.*

4. Brych, V., Putsenteilo, P., Kostetskyi, Ya., & Hunko, S. (2022). Smart specialization as a driver of the innovative regional development system. *Innovative Economy*, *1*, 141-151. https://doi.org/10.37332/2309-1533.2022.1.19.

5. Patytska, Kh. (2019). Smart specialization strategy in the context of regional competitiveness: theoretical aspect. *Efektyvna ekonomika*, *11*. https://doi.org/10.32702/2307-2105-2019.11.53.

6. Steen, M., Faller, F., & Ullern, E.F. (2019). *Fostering Renewable Energy with Smart Specialisation? Insights into European Innovation Policy*. https://doi.org/10.1080/00291951.2018.1554696.

7. Nauwelaers, C., Seigneur, I., & Gomez Prieto, J. (2018). *Good practices for smart specialisation in energy: S3 Working paper Series No. 16/2018, EUR 29313 EN, Publications Office of the European Union, Luxembourg, 2018.* https://doi.org/10.2760/344826.

8. Polyanska, A., & Shyroka, Kh. (2021). Management of Region Competitiveness on the Base of Smart Specialization. *State and regions: Economics and entrepreneurship*, *6*(123), 97-104. https://doi.org/10.32840/1814-1161/2021-6-17.

9. Verkhovna Rada of Ukraine (n.d.). *Resolution "On Approval of the Concept of the State Targeted Program for the Fair Transformation of the Coal Regions of Ukraine for the Period Until 2030". Cabinet of Ministers of Ukraine*. Retrieved from https://zakon.rada.gov.ua/laws/show/1024-2021-%D0%BF#n11.

10. Coal 2022. Analysis and forecast to 2025 (2022). *Analysis and forecast to 2025.* Retrieved from https://iea.blob.core.windows.net/assets/91982b4e-26dc-41d5-88b1-4c47ea436882/Coal2022.pdf.

11. *The coal industry in Ukraine: the number of mines and production level* (2020). Retrieved from https://www.slovoidilo.ua/2020/04/30/infografika/ekonomika/vuhilna-haluz-ukrayini-kilkist-shaxt-riven-vydobutku.

12. *Fossil-fuel subsidies in the EU's Eastern Partner countries. How governments supported fossil fuels in 2020* (n.d.). Retrieved from https://www.oecd.org/countries/ukraine/Fossil-Fuel-Subsidies-in-the-EU's-Eastern-Partner-countries.pdf.

13. Storonyanska, Z. (2020). Territorial development and regional policy. Strategizing regional development on the basis of smart specialization: scientific report. *Lviv, National Academy of Sciences of the National Academy of Sciences*. Retrieved from http://surl.li/axryg.

14. Kaczmarek, J., Kolegowicz, K., & Szymla, W. (2022). Restructuring of the Coal Mining Industry and the Challenges of Energy Transition in Poland (1990–2020). *Energies, 15*, 3518. https://doi.org/10.3390/en15103518.

15. Śniegocki, A., Wasilewski, M., Zygmunt, I., & Look, W. (2022). *Just Transition in Poland: A Review of Public Policies to Assist Polish Coal Communities in Transition*. Retrieved from https://media.rff.org/documents/Report_22-06_June_1_2022.pdf.

16. Gianelle, C., Kyriakou, D., Cohen, & Przeor, M. (2016). *Implementing Smart Specialisation: A Handbook, Brussels: European Commission, EUR 28053 EN*. https://doi.org/10.2791/61039.

17. Vladyko, O., Maltsev, D., Sala, D., Cichoń, D., & Buketov, V. (2022). Simulation of Leaching processes of polymetallic ores using the similarity theorem. *Rudarsko-Geološko-Naftni Zbornik*, *37*(5), 169-180. https://doi.org/10.17794/rgn.2022.5.14.

18. Falshtynskyi, V., Dychkovskyi, R., Khomenko, O., & Kononenko, M. (2020). On the formation of a mine-based energy resource complex. *E3S Web of Conferences, 201*, 01020. https://doi.org/10.1051/e3sconf/202020101020.

19. Lankauskiene, R., Simonaityte, V., Gedminait e-Raudone, Ž., & Johnson, J. (2022). Addressing the European Green Deal with Smart Specialization Strategies in the Baltic Sea Region. *Sustainability*, *14*, 11912. https://doi.org/10.3390/su141911912.

20. Henze, V. (2022). *Global Investment in Low-Carbon Energy Transition Hit $755 Billion in 2021. Global Investment in Low-Carbon Energy Transition Hit $755 Billion in 2021.* Retrieved from https:// about.bnef.com/?url=https%3A%2F%2Fabout.bnef.com%2Fblog%2Fglobal-investment-in-low-carbon-energy-transition-hit-755-billion-in-2021%2.

Енергетичний перехід: майбутнє енергетики на основі смарт спеціалізації

А. С. Полянська[*1], *Ю. М. Пазиніч*[2], *Х. В. Михайлишин*[1], *В. Букетов*[3]

1 – Івано-Франківський національний технічний університет нафти і газу, м. Івано-Франківськ, Україна

2 – AGH Університет у Кракові, м. Краків, Республіка Польща

3 – Національний університет Сан-Агустіна Арекіпа, м. Сан-Агустіна Арекіпа, Республіка Перу

[*] Автор-кореспондент e-mail: parvs@ukr.net

Мета. Обґрунтувати передумови енергетичного переходу як необхідної умови для здійснення змін в енергетичному секторі й важливість концепції розумної спеціалізації як потенціалу для генерування інвестицій для впровадження заходів у рамках енергетичного переходу.

Методика. Використана методика розрахунку середньорічного темпу зростання потужностей відновлюваної енергетики. Для обґрунтування потенціалу зростання інвестицій в енергетичний перехід у регіонах використано метод складних відсотків і зроблено інвестиційний прогноз на основі темпів зростання іноземних інвестицій в Україну та темпів зростання світових інвестицій у низьковуглецеву енергетику.

Результати. Обґрунтована необхідність енергетичного переходу для української енергетики й запропонована реалізація політики розумної спеціалізації для здійснення енергетичних змін. Розглянуто приклад вугледобувних регіонів і звернена увага на важливість розвитку вугільної галузі для забезпечення енергетичної безпеки, а також наголошено на пріоритеті розвитку відновлюваних джерел енергії.

Наукова новизна. Розглянуто взаємозв'язок реалізації політики енергетичного переходу й регіональної політики смарт спеціалізації з урахуванням положень і змісту сучасних нормативно-правових актів з питань регіонального розвитку та енергетичного переходу, а також ознайомлення з досвідом зарубіжних країн.

Практична значимість. Запропоновано розглядати питання енергетичного переходу разом із реалізацією концепції смарт-спеціалізацій на регіональному рівні. Це дасть змогу зосередитись на енергетичному секторі з урахуванням особливостей і переваг регіону, дослідити передумови впровадження енергетичних змін і залучити додаткові інвестиції з урахуванням світового досвіду інвестування в низьковуглецеву енергетику.

Ключові слова: *енергетичний перехід, смарт спеціалізація, вугілля, відновлювальні джерела енергії, інвестиції*

The manuscript was submitted 09.02.23.