UDC 620.9-047.44(477.87):352

ANALYSIS OF THE DEVELOPMENT OF RENEWABLE ENERGY RESOURCES IN THE TRANSCARPATHIAN REGION IN THE CONTEXT OF BALANCED DEVELOPMENT OF TERRITORIAL COMMUNITIES

S. Pop, *professor of the Department of Physical Geography,*
E-mail popstepan7@gmail.com;
https://orcid.org/0000-0003-4390-6366
V. Peresoliak*, associate Professor of the Department of geodesy,*
E-mail v.peresolyak@gmail.com;
https://orcid.org/0000-0002-6255-1559
I. Sharodi, *associate Professor of the Department of Optics,*
E-mail iryna.sharodi@uzhnu.edu.ua
https://orcid.org/0000-0001-8770-9917
Uzhhorod National University

This article analyzes the current state of the potential of renewable energy resources in the Transcarpathian region. The main problems of the use of renewable energy resources by territorial communities of the region are identified and the main problems that hinder the construction of new renewable energy (RE) facilities are clarified. In order to determine the strategic directions of development of balanced environmental management of territorial communities and the prospects for the development of renewable energy resources of Transcarpathian region, up-to-date information on the development of the unique potential of renewable energy resources (RER) is updated as of mid-2024. Taking into account the inexpediency of resuming the operation of the Burshtynska TPP, which provided the energy needs of Transcarpathia, the prospects and importance of accelerating the achievement of the goals of self-energy supply of Transcarpathia and sustainable development in the long term by activating the development of the existing unique RE potential are

considered. Given the significant destruction of the Unified Energy System (UES) facilities by the Russian occupiers, on 13 of August 2024, the government approved the National Action Plan for Renewable Energy until 2030, which provides for accelerating the diversification, decarbonization, decentralization and security of the Unified Energy System, commissioning 24 GW of green energy generating capacities, and achieving a 27% share of its share in total electricity consumption. This requires the construction of 6,1 GW of wind power, 12,2 GW of solar power, 4,7 GW of hydropower, 876 MW of bioenergy, and 40 MW of geothermal energy. In the current realities of martial law, this must be done quickly, reliably, and rationally in terms of financial costs and environmental protection. Therefore, to achieve the above indicators, it is important to develop available renewable energy resources (RER) in all regions of Ukraine, which, due to their spatial distribution and proximity to consumers, will strengthen the stability of the unified energy system (UES).

Keywords: *green energy, geothermal energy, solar energy, small hydropower, wind energy, ecology, sustainable development of territories, decarbonization, energy self-sufficiency.*

Introduction. The Low-Carbon Development Strategy of Ukraine until 2050 declares: "Ukraine needs high GDP growth rates to overcome poverty and impoverishment of the population, but at the same time a new development model must be formed – "green" revival, "green" growth, "green" development, based on the influx of investments in renewable energy sources, environmentally friendly production, "green" technologies" [1, p. 11]. The strategy envisages the transition of the economy to a low-carbon growth trajectory (in accordance with the Association Agreement with the EU and the Paris Agreement on Climate Change signed by Ukraine) to implement the state policy of ensuring the global sustainable development goals (SDGs) in the near and long term [2]. One of the main directions for achieving these ambitious goals is the formation of a favorable investment climate, stimulating innovative activity. In particular, in the field of decarbonization of the energy sector of Ukraine by increasing the share of renewable energy facilities

(RE), and in the economy by reducing the energy intensity of production and increasing energy efficiency. It should be noted that the Energy Strategy of Ukraine for the period until 2035 envisages the sustainable expanded use of all types of renewable energy resources, an increase in the share of renewable energy to the level of not less than 25% of the total primary energy supply [3]. Legislative acts have been adopted that promote investments in their development [4-7]. At the same time, the share of solar and wind energy should increase significantly and amount to 2.4% by 2025 and 10.4% by 2035, provided that the share of nuclear energy is maintained at the level of 25-32%.

Analysis of their latest research and publications. The study of the potential and development of renewable energy in the territory of the Western region was carried out at different times by O. Kudrya, O. Shcherbyna, S. Denisyuk, P. Vasko, O. Kyrylenko, A. Korolchuk, Yu. Bashynska, Ya. Ivakh and others. [10-14]. Directly on the territory of the Transcarpathian region, such studies were systematically conducted by the authors and partially analyzed by Yu. Bashynska, Z. Hamkalo, B. Koperlyos [13, 15-21]. The most thorough description of the state of development of renewable energy in Transcarpathia in recent years is highlighted in the works of the authors [16-21]. However, given the large-scale targeted destruction by the Russian occupiers of the main generating capacities of the country's Unified Power System, urgent measures are being taken at the state and regional levels to partially restore them, build new ones with better protection, including from military threats. Effective measures are being taken to further increase the capacity of all types of renewable energy, taking into account their potential, economic and environmental characteristics in the regions. The Transcarpathian region has perhaps the best potential of all types of renewable energy and could, in the short term, by developing only about 20% of the most economically and environmentally sound renewable energy potential, achieve green energy production exceeding the needs of its own energy supply.

Research objective is to substantiate the basic foundations and opportunities for the development and development of renewable energy resources by territorial

communities of the Transcarpathian region in the context of sustainable nature management.

Materials and research methods. When conducting a study of this topic, general scientific and specific research methods were used. Namely: to systematize the theoretical justification for the development of renewable energy resources, the method of scientific abstraction was used; to determine the features of the impact of green energy on the development of territorial communities in terms of energy self-sufficiency in the Transcarpathian region - the method of system-structural analysis; to study the economic and environmental features of the development of renewable energy in the region - the method of logical generalization; to develop organizational measures for the development of renewable energy in the region - the method of analysis and synthesis.

Results and discussion. The Transcarpathian region region has a unique renewable energy potential among the regions of Ukraine. According to the calculations of the State Design Institute "Lviv Prombudproekt", the total potential of renewable resources in Transcarpathian region is over 45 billion kWh per year, of which 30 billion kWh are estimated as real for development [8]. Under strict compliance with environmental requirements, the total potential of technically available renewable energy is estimated at 3.27 million tons of equivalent fuel (25 billion kWh), which is more than 10 times higher than the region's needs for heat and electricity. Thus, Transcarpathian region has a quarter of the all-Ukrainian technically achievable potential of energy resources of mountain rivers (which is 34% of the total renewable energy potential of the region), more than half of the country's geothermal energy resources (26%), biomass of both forest and agricultural origin (22%), environmental energy (9%), solar energy (4%) [4]. These are data from the Institute of Renewable Energy of the National Academy of Sciences of Ukraine, which do not mention wind energy resources, the potential of which is considerable in the mountainous areas of Transcarpathia, especially on unforested mountain ranges. There are stable wind fields here, of sufficient strength to build powerful wind

turbines. They can be partially used as maneuvering capacity, given the constant wind force throughout the year.

In the economic development of the Transcarpathian region, one of the main tasks is the implementation of energy efficiency: self-energy supply and energy saving based on the rational use of its own renewable energy resources. For the further development of Transcarpathia, there is no alternative to the development of renewable energy resources (RE), the potential of which is more than sufficient to fully meet the region's needs for heat and electricity. Therefore, it is urgent to conduct a permanent analysis of the state of development of renewable energy in Transcarpathia, to clarify the problems of effective use of the unique potential of RE and the prospects for their rational development in the context of balanced economic, social and environmental development, which is declared in the Regional Development Strategy of Transcarpathia for the period 2021-2027 [8,9].

To implement the Energy Strategy of Ukraine, the Transcarpathian region should be among the leaders, since having the best potential for the development of green energy, it is obliged to make a greater contribution than regions that are poorer in such resources. However, here the construction of renewable energy generating capacities is often accompanied by social tension. Mainly due to the lack of a clear strategy for the development of the region in this area, insufficient coordination of actions of government structures, industry institutions, investors, scientists. and public organizations. The latter often misinform local communities and the general public about the impact of planned green energy facilities on the environment and about the socio-economic benefits of their construction. Let's consider what has been done as of mid-2024 and what hinders the proper development of the significant renewable energy potential of Transcarpathia. Indeed, in the last decade, investors have shown increased interest in their development, which was largely facilitated by the high “green” tariff in previous years, which guarantees payment for the produced “green” energy until 2030 [7]. Currently, the critical state of the Unified State Electric Power System, caused by military operations, obliges everyone to create energy facilities more responsibly and as soon as possible. After all, without them it

is impossible to ensure the vital activity of the population and the economy of the country, which is also in a state of protracted war.

Solar energy, the resource potential for which in the region, which has a small area, is relatively small, is developing rapidly. As of 2024, industrial solar power plants with a total installed capacity of 240 MW have already been put into operation in the region, most of which were built before the large-scale war. Recently, the construction of industrial solar power plants has slowed down, but a significant number of land plots suitable for their construction have been allocated to interested developers. At the same time, there is a great demand for the installation of non-industrial solar power plants. Solar power plants are being built at a rapid pace in homestead territories and on the roofs of buildings of individuals and legal entities. Their number has doubled every year in recent years and by mid-2024 will reach about 5,000 solar power plants with a total installed capacity of over 140 MW. Surplus electricity generated by non-industrial power plants is partially sold at a "green" tariff or accumulated for own consumption at night and during temporary power outages.

Small hydropower. The first small diversion hydroelectric power plants in Onokivska and Uzhgorod with installed capacities of 2.65 and 1.92 MW, respectively, were built in 1937-1943 on the canal that diverts water from the river Uzh to meet the needs of the city of Uzhgorod. They are still successfully operating on old equipment, the replacement of which could increase their profitability. During the Soviet era, dozens of small hydroelectric power plants were built on the rivers of Transcarpathia, which were dismantled during the large-scale construction of hydroelectric power plants on the river Dnipro and powerful thermal and nuclear power plants. Currently, their restoration is considered inexpedient. In 1956, the unique Tereble-Ritskaya hydroelectric power plant was built on two rivers (27 MW), which continues to operate, although not at full capacity. The hydropower potential of Transcarpathia was planned to be developed back in the Soviet era, in particular, the construction of a cascade of 5 dam hydroelectric power plants on the river Tysa (on the section from the city of Tyachiv to the village of Vylok) with a total capacity

of 200 MW was planned. This project was not implemented, both due to its significant impact on the environment and lack of funding.

Small hydropower in Transcarpathia began to develop actively after the introduction of the "green" tariff incentive. As of 2019, 13 small and mini-hydroelectric power plants with an installed capacity of hydroturbines from 0.63 to 2.2 MW were built at the expense of non-state funds, a list of which is given below. Their total capacity is about 15.6 MW, and together with the dammed Tereble-Ritskaya HPP, 42.6 MW. Given the potential of mountain rivers available in the region that can be developed, this is very small. Together, small hydropower plants produce an average of about 90 million kWh per year. The most promising rivers for the construction of new small hydropower plants are the Teresva, Rika, Shopurka, Serednya Shopurka, Turya, Brusturyanka, Latorytsa, etc. Of course, investors must clearly comply with the requirements for environmental protection and mutually beneficial cooperation with local communities, which are managers of local resources. Both parties are interested in choosing such sections on the rivers for the placement of MHPPs, where the impact on the environment would be minimized, and the energy of the water flow would be optimally used. If only 15-20% of the existing hydropower potential of Transcarpathia is used and MHPPs are placed in the least environmentally vulnerable places, this will be enough to provide all the needs of the region with electricity. It is important to increase the capacity of small hydropower and as an important tool for balancing capacities in the energy system. It is also positive that the developer partially solves the issues of bank fortification and flood protection, contributes to solving the issues of maintaining the cleanliness of the riverbed and banks, raising the environmental awareness of the population, creates new jobs, replenishes budgets of various levels, etc. It should be noted that MHPPs built in recent years, in particular on the rivers Turya, Brusturyanka, etc. are the best in Ukraine, meet European standards in terms of technical and technological, environmental and aesthetic level of implementation. Modern SHPPs of Transcarpathia are visited by both tourists and domestic and foreign specialists who

wish to familiarize themselves with the positive experience of constructing diversionary HPPs on small mountain rivers.

1.Operating derivation small, mini and micro hydroelectric power plants in Transcarpathia

№	Name of the hydroelectric power plant	Power MW	Year of construction	Власники
1.	Onokivska	2,65	1941	Akvaresursenergo LLC
2.	Uzhgorodska	1,92	1942	Akvaresursenergo LLC
3.	Bilynska on the Ilmin stream	0,63	2006	Energy of the Carpathians LLC
4.	Turya-Polyanska (Shypit-1)	1,036	2012	Green Energy Plus LLC
5.	Krasnyanska	1,16	2013	Ukrelektrobud LLC
6.	Turya-Polyanska (Shypit-2)	0,999	2014	Green Energy Plus LLC
7.	Nizhne-Bystryanska	2,2	2014	Akvanova Development" LCC
8.	Lopukhovska near the village of Brustury	1,0	2016	LLC "Altener"
9.	Ust-Chornyanska	0,999	2016	LLC "RENER"
10.	On the Mokryanka River	0,996	2017	LLC "Altener"
11.	Micro-HPP near the village of Ruska Mokra	0,1	2018	LLC "Hydro Plus"
12.	Kostylivska 1	0,996	2019	LLC "RENER"
13.	Kostylivka 2	0,996	2019	LLC "RENER"

Geothermal resources of Transcarpathia for the production of electricity are not yet used, although their potential, as can be seen from Table 1, is attractive due to the smallest depths of wells with high temperature. It should be noted that we have already explored promising deposits for use with known characteristics in terms of resource flow rate, temperature and other well indicators (in particular, Beregivske, Kosynske, Zaluzske, Tereblyanske, Velyatynske, Poladske, Veliko-Baktyanske, Uzhgorodske deposits). The Zaluzske deposit is the most promising for the

construction of geothermal power plants (GTPs), because here, on a significant area (about 400 sq. km.), the temperature of the subsoil reaches over 200 ºC at a depth half that of other territories of the country (see Table 1). It is important that this type of resource is not dependent on climatic conditions, which means it will ensure constant stable operation of the power plant. The world experience of using such resources and the practice of operating geothermal power plants are known. The risk of investing in the implementation of projects for the construction of a GTPP is associated with the choice of a well location, the depth of which should be as small as possible due to the cost of drilling. The high voltage of the thermal field of the Transcarpathian region is due to the peculiarities of the geological and tectonic structure of its territory. The geothermal surface of 50ºC is traced within the Transcarpathian Lowland at depths from 520 to 600 m, and the geothermal gradient here is twice as high as this indicator for other geological formations of the Carpathians and reaches 60ºC per hundred meters of depth. Heat flows within the plain are 67 - 92 mW/sq.m, which is almost twice as high as the average values of this indicator for other territories of Ukraine, which is decisive for the prospects for the construction of a GTPP precisely in the territory of Transcarpathia.

The use of thermal waters is also promising as a heat carrier for heating buildings and greenhouses, for medical purposes in balneology and recreation. In recent years, the direction of recreation has begun to develop with renewed vigor in the Beregov, Mukachevo, Khust and Uzhgorod districts. Synergistic systems using several types of energy carriers, for example, natural gas, thermal waters and solar radiation, are promising. This is for wells, at the outlet of which the water has an insufficiently high temperature. Currently, the use of only low-temperature (40-70°C) thermal waters for recreational purposes is actively developing in the Transcarpathian region. In the future, in order to decarbonize the economy, it is advisable to use the existing medium-temperature (70-100°C) and high-temperature (100-150°C) thermal waters. The renewable energy resource of geothermal waters may become the basis for the region's energy self-sufficiency in the future.

2. Forecasted geothermal energy resources in Ukraine for electric power generation [13]

Deposits of regions	Depth of drilling, km	Water temperature, °C	Field area, km^2	Efficiency, %	Geothermal power plant capacity, thousand MW
Transcarpathia	3-6	210–250	50-130	1,7	5,8
Pedascarpathia	4-7	200	600	1,3	4,6
Crimea	4-7	200-220	300-500	3,1	10,5
Eastern Ukrainian Region	5-7	185-217	660-2800	14,0	48,0
TOTAL					70

Bioenergy resources in the territory of Transcarpathia are a significant amount of biomass of both forest and agricultural origin. Their development has not yet found proper development, if we do not take into account vegetable fuel, as one of the oldest resources of the countrymen. The rational way to use biomass to produce biogas (a mixture of methane and carbon dioxide) is. The region has the prospect of developing biogas production technology, given that livestock and poultry farming are sufficiently developed, as well as a large amount of wood waste in the logging and wood processing industry and plant residues in the agro-industrial and household sectors. In the regional energy saving program, bioenergy is given the second most important place after solar energy. However, at present, only one enterprise, LLC "Ekokoshet" in the village of Chopivtsi, Mukachevo district, has built a bioenergy complex (BEC) for processing and utilization of manure effluents from the Chopiv pig complex using modern technologies since 2018. The bioenergy complex produces electricity and heat by burning biogas obtained from processed manure effluents with the addition of additional plant raw materials (corn silage and other crops or solid agricultural waste).

Wind energy in Transcarpathia has development prospects mainly in mountain ranges and valleys, that is, where there are necessary wind fields. In 2024, the first

wind turbine with a capacity of 5.3 MW was put into operation in the Nyzhno-Voritska community, where the construction of a wind farm with a total capacity of 80 MW is underway.

Back in 2017, an investor from Turkey proposed an attractive project to build a Volovetska wind farm with a total capacity of 120 MW outside the boundaries of individual settlements in the Volovetska and Svalyavsky districts (the taper of the Mukachevo district) on certain sections of the Polonyna Borzhava massif. This is a very good choice of location for the wind farm, where at one time a military air defense unit was located, which ceased its activities after the closure of the Pistryalivka radar station in 1990. A number of locations have been identified here that have stable and strong winds throughout the year. This location is also advantageous due to its small distance from the power grid, which will transport the generated electricity. A certain temporary and permissible negative impact on the environment by environmental standards is not an obstacle to a construction permit, as established by scientists from the National University of Life Resources and Sustainable Environmental Management and Uzhgorod National University, who thoroughly studied the possible environmental impact of the planned construction of the Volovets Wind Farm with a capacity of 120 MW, and the regional body of the Ministry of Environment provided a corresponding positive conclusion. However, the Turkish investor has difficulties with the allocation of certain land plots for the wind farm, and is concerned with the consideration of claims in courts by public organizations regarding the violation of the land allocation procedure. A significant part of the territory of the mountain ranges was privatized at one time, and many owners of such plots are not located in Ukraine at all. Other mountain ranges of Transcarpathia are also promising for the construction of wind farms, where there are good wind fields. In particular, the Runa mountain range, where there was also a military unit known as "Bars", which also operated in conjunction with the Pistryalivska radar station.

Conclusions and suggestions. The results of the study of this issue provide an opportunity to make strategic management decisions for state authorities and local

governments regarding the development of the regional economy based on renewable energy resources for the production of heat and electricity. In the strategic vision of the development of green energy, it becomes a powerful impetus for the development of sectoral industries of the regional economy, the rational use of labor and natural resources, the growth of environmental culture and solving the problem of removing and recycling household waste of territorial communities. In the direction of educational and educational work for the development of a strategy for the development of a territorial community and the development of comprehensive spatial plans. The experience of a biogas power plant in the village of Chopivtsi, Mukachevo district, is a vivid example of the possibility of using organic waste from livestock and crop production for the decarbonization of the regional economy sectors in the context of balanced development of the territory.

The genesis of renewable energy in the Transcarpathian region is strategic and has no alternative to decarbonizing the economy in the context of balanced development of the territory and corresponds to the strategy of sustainable development of Ukraine. In the future, for the needs of the regional economy in thermal and electrical energy, it is enough to develop 15-20% of the available potential of renewable energy resources. This can be achieved under the condition of strict adherence to environmental regulations and standards for ensuring balanced environmental management. At the same time, about 2 billion kWh of electricity from the Burshtyn TPP, which the station generated and transmitted to the region before the missile attack carried out by Russia in March 2024, will be replaced. Bringing generating capacities closer to consumers will reduce significant technological losses on long power transmission lines and increase the energy security of the region by building low-power stations on the territory using existing unique local renewable energy resources (solar radiation, wind energy, river energy, geothermal energy, biomass).

References

1. Rozporiadzhennia Kabinetu Ministriv Ukrainy «Pro skhvalennia Ochikuvanoho natsionalno vyznachenoho vnesku Ukrainy do proektu novoi

hlobalnoi klimatychnoi uhody» 16.09.2015 № 980. [Order of the Cabinet of Ministers of Ukraine “On approval of the Expected Nationally Determined Contribution of Ukraine to the draft of a new global climate agreement” from September 16th, 2015 №980]. Availabte at: http://zakon5.rada.gov.ua/laws/show/980-2015-%D1%80 [in Ukrainian].

2. Rozporiadzhennia Kabinetu Ministriv Ukrainy «Pro skhvalennia Kontseptsii realizatsii derzhavnoi polityky u sferi zminy klimatu na period do 2030 roku» vid 7.12.2016 № 932-r. [Resolution of the Cabinet of Ministers of Ukraine “On Approval of the Concept of Implementation of State Policy in the Field of Climate Change for the Period Until 2030” from December 7th, 2016 № 932-r.]. Availabte at: http://www.kmu.gov.ua/control/uk/cardnpd?docid=249573705 [in Ukrainian].

3. Rozporiadzhennia Kabinetu Ministriv Ukrainy «Pro skhvalennia Enerhetychnoi stratehii Ukrainy na period do 2035 roku “Bezpeka, enerhoefektyvnist, konkurentospromozhnist” vid 18.08.2017 № 605-r.[Resolution of the Cabinet of Ministers of Ukraine “On approval of the Energy Strategy of Ukraine for the period until 2035 “Security, Energy Efficiency, Competitiveness” from August 18th, 2017 № 605-r]. Availabte at: http://zakon2.rada.gov.ua/laws/show/605-2017-%D1%80 [in Ukrainian].

4. Instytut vidnovliuvanoi enerhetyky NAN Ukrainy [Institute of Renewable Energy of the NAS of Ukraine]. Availabte at: https://zakarpattya.net.ua/News/90392-Enerhetychnyi-potentsial-vid [in Ukrainian].

5. Atlas enerhetychnoho potentsialu vidnovliuvanykh ta netradytsiinykh dzherel enerhii Ukrainy / Za red. A.K. Shydlovskoho. — Kyiv, 2001.[Atlas of the energy potential of renewable and non-traditional energy sources of Ukraine / Edited by A.K. Shydlovsky. — Kyiv, 2001].

6. Pro alternatyvni dzherela enerhii Zakon Ukrainy. [On Alternative Energy Sources Law of Ukraine]. Availabte at: http://zakon2.rada.gov.ua [in Ukrainian].

7. Pro vnesennia zmin do deiakykh zakoniv Ukrainy shchodo vstanovlennia «zelenoho taryfu» Zakon Ukrainy vid 25.09.2008. № 601 [On Amendments to Certain Laws of Ukraine Regarding the Establishment of a "Green"

Tariff" Law of Ukraine of September 25th, 2008 № 601] Availabte at: http://zakon2.rada.gov.ua/laws/show/601-17 [in Ukrainian].

8. Enerhetychna prohrama Zakarpatskoi oblasti do 2015 roku.//Uzhhorod: 1997.-32 s. Natsionalnyi plan dii z vidnovliuvanoi enerhetyky na period do 2020 roku [Energy Program of the Transcarpathian region until 2015.//Uzhgorod: 1997.-32 p. National Action Plan for Renewable Energy for the Period Until 2020]. Availabte at: https://www.uzhnu.edu.ua/uk/infocentre/get/61984 [in Ukrainian].

9. Rehionalna stratehiia rozvytku Zakarpattia na period 2021-2027 rokiv. Rishennia sesii oblrady vid 20.12.2020. №1631. [Regional Development Strategy for Transcarpathia for the period 2021-2027. Decision of the Regional Council session from 12.20.2020 №1631.] [in Ukrainian].

10. Shcherbyna, O. (2003). Hidroenerhetyka Zakhidnoho rehionu [Hydropower of the Western Region] Green Energy. 2(10), 20–21[in Ukrainian].

11. Kudria, O. S. (2022). Perspektyvy rozvytku vidnovliuvanoi enerhetyky v Ukraini. Rozvytok vitroenerhetyky ta soniachnoi enerhetyky: prezentatsiia [Elektronnyi resurs] [Prospects for the development of renewable energy in Ukraine. Development of wind energy and solar energy: presentation. Availabte at: http:// uaenergy.org/upload/files/16_EIF_Kudria [in Ukrainian].

12. Vasko, P. F. (2010). Mala hidroenerhetyka: svitovi tendentsii rozvytku ta ukrainski perspektyvy [Small hydropower: global development trends and Ukrainian prospects// Elektropanorama, 3.] [in Ukrainian].

13. Bashynska, Yu. I. (2015). Perspektyvy rozvytku maloi vidnovliuvalnoi enerhetyky v Zakhidnomu rehioni Ukrainy. [Prospects for the development of small-scale renewable energy in the Western region of Ukraine] Investytsiino-innovatsiini zasady rozvytku natsionalnoi ekonomiky v rynkovykh umovakh [Investment and innovation principles for the development of the national economy in market conditions]. 23-24.02.2015 Uzhhorod, Ukraina. [in Ukrainian].

14. Ivakh, Ya. Ie. (2017). Suspilno-heohrafichni aspekty rozvytku alternatyvnoi enerhetyky u zakhidnomu rehioni Ukrainy [Socio-geographical aspects of the development of alternative energy in the western region of Ukraine] Zbirnyk

naukovykh prats IX mizhnarod. nauk.-prakt. konf."Netradytsiini i ponovliuvani dzherela enerhii yak alternatyvni pervynnym dzherelam enerhii v rehioni"[Collection of scientific papers of the IXth International Scientific-Practical Conference "Unconventional and renewable energy sources as alternative to primary energy sources in the region"] 6-7, 34-38. [in Ukrainian].

15. Pop, S. S., Sharodi I. S., Sharodi Yu. V., Hanzel A. V. (2015). Hidroenerhetyka Zakarpattia: stan ta perspektyvy rozvytku [Hydropower of Transcarpathia: state and development prospects] UHZh, № 2, P.65-71. DOI: https://doi.org/10.15407/ugz2015.02.065 Ukr. geogr. z. 2, 65-71 [in Ukrainian].

16. Pop, S. S., Sharodi I. S., Shardi V. V. (2017). Vidnovliuvani enerhetychni resursy Zakarpattia. [Renewable energy resources of Transcarpathia] Mat. 4-oi mizhn. nauk. prakt. konf. «Nadrokorystuvannia v Ukraini. Perspektyvy investuvannia». [4th int. scient. practical. conf. "Subsoil use in Ukraine. Investment prospects"] [in Ukrainian].

17. Sharodi, Yu. V., Sharodi I. S. (2018). Perspektyvy rozvytku heotermalnoi enerhetyky v Zakarpatskii oblasti. [Prospects for the development of geothermal energy in the Transcarpathian region] IX Mizhn. nauk. prakt. konf. «Novi tekhnolohii v heodezii, zemlevporiadkuvanni, lisovporiadkuvanni ta pryrodokorystuvanni»[IX International Scientific Practical Conference "New Technologies in Geodesy, Land Management, Forest Management and Environmental Management"] Uzhhorod. 356-360 [in Ukrainian].

18. Pop, S. S., Sharodi, I. S. (2022). Osvoiennia vidnovliuvanykh enerhetychnykh resursiv Zakarpatskoi oblasti v konteksti zbalansovanoho rozvytku [Development of Renewable Energy Resources in the Transcarpathian Region in the Context of Balanced Social Development.] Ukr. Geogr. zh., 2, 36–44. DOI: https://doi.org/10.15407/ugz 2022.03.036 [In Ukrainian].

19. Pop, S. S. (2019). Perspektyvy rozvytku vitrovoi enerhetyky na terytorii Zakarpatskoi oblasti.[Prospects for the development of wind energy in the territory of the Transcarpathian region.] NPK «Nadrokorystuvannia . v Ukraini. Investytsiinyi

analiz. Truskavets [Scientific. practical. conf. "Subsoil use. in Ukraine. Investment analysis. Truskavets] [in Ukrainian].

20. Pop, S. S, Peresolyak, V. Yu., Potish, L.A., Prykhodko, V. P. Environmental Impact Assessment Report “Limited Liability Company” “Atlas Volovets Energy”, registration file number in the Unified Register of Environmental Protection 2018821379. Availabte at: https://ecozakarpat.gov.ua/?page_id=4743

21. Koperlos, B.M. (2020). Vidnovliuvana enerhetyka v umovakh Zakarpattia [Renewable energy in the conditions of Transcarpathia] Zbirnyk naukovykh prats ΛΌΗΟΣ. [Collection of scientific papers ΛΌΓΟΣ] 49-51. DOI: https://doi.org/10.36074/26.06.2020.v1.19 [in Ukrainian].

22. Enerhozberezhennia ta enerhoefektyvnist [Elektronnyi resurs] [Energy saving and energy efficiency. Availabte at: http://energovpu7.ucoz.ua/load/tema_1/vidnovljuvalni_dzherela_energiji_geotermalna_energija/11-1-0-30 [in Ukrainian].

23. Enerhetyka: istoriia, suchasnist i maibutnie. Elektroenerhetyka ta okhorona navkolyshnoho seredovyshcha. Funktsionuvannia enerhetyky v suchasnomu sviti . [Energy: history, present and future. Electric power and environmental protection. Functioning of energy in the modern world. Availabte at: http://energetika.in.ua/ua/books/book-5 [in Ukrainian].

24. Vyrobnytstvo elektrychnoi i teplovoi enerhii z VDE. [Production of electricity and heat from renewable energy sources. Availabte at: https://ua.energy/wp-content/uploads/2018/11/Zvit-z-otsinky [in Ukrainian].

25. Ishchvan, Hadnad (2023). Enerhetychna kharakterystyka prypoverkhnevoho vitrovoho polia na Zakarpatti [Energy characteristics of a near-surface wind field in Transcarpathia]. Berehovo-Uzhhorod: TOV «RIK-U», 224 [in Hungarian]

26. Rozporiadzhennia KMU Pro skhvalennia Enerhetychnoi stratehii Ukrainy na period do 2035 roku «Bezpeka, enerhoefektyvnist, konkurentospromozhnist» [Resolution of the Cabinet of Ministers of Ukraine On approval of the Energy Strategy of Ukraine for the period until 2035 “Security,

Energy Efficiency, Competitiveness”]. Availabte at: https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80#Text [in Ukrainian].

27. Ziabina, Ye. A., Pimonenko, T. V. (2020). Enerhetychna polityka Ukrainy: efektyvnist ta napriamy yii pidvyshchennia [Energy policy of Ukraine: effectiveness and directions of its improvement] Ekonomichnyi prostir, 160, 55-59. DOI: https://doi.org/10.32782/2224-6282/160-10. [in Ukrainian].

С. С. Поп*, *В. Ю.Пересоляк*, *І. С. Шароді

АНАЛІЗ ОСВОЄННЯ ВІДНОВЛЮВАНИХ ЕНЕРГЕТИЧНИХ РЕСУРСІВ ЗАКАРПАТСЬКОЇ ОБЛАСТІ В КОНТЕКСТІ ЗБАЛАНСОВАНОГО РОЗВИТКУ ТЕРИТОРІАЛЬНИХ ГРОМАД

Анотація. *В даній статті сучасний стан потенціалу відновлюваних енергетичних ресурсів в Закарпатській області. Визначено основні проблеми використання відновлювальних енергетичих ресурсів територіальними громадами регіону* та *з’ясовано основні проблеми, що гальмують спорудження нових об’єктів відновлюваної енергетики (ВЕ). З метою визначення стратегічних напрямів розвитку збалансованого природокористування територіальних громад та перспективи освоєння відновлюваних енергетичних ресурсів Закарпаття, на середину 2024 року осучаснено актуальну інформацію щодо освоєння унікального потенціалу відновлюваних енергетичних ресурсів (ВЕР). Враховуючи недоцільність відновлення роботи Бурштинської ТЕС, яка забезпечувала енергопотреби Закарпаття, розглянуто перспективи і важливість прискорення досягнення цілей самоенергозабезпечення Закарпаття та сталого розвитку на довготривалу перспективу шляхом активізації освоєння наявного унікального потенціалу ВЕР. Зважаючи на значну руйнацію російськими окупантами об’єктів об’єднаної енергетичної системи (ОЕС) 13 серпня 2024 року уряд, затвердив Національний план дій з відновлюваної енергетики до 2030-го, яким передбачено пришвидшення диверсифікації, декарбонізації, децентралізації та безпеки ОЕС, введення в дію 24 ГВт генеруючих потужностей зеленої*

енергетики, досягнення 27 % її частки у загальному споживанні електроенергії. Це потребує побудувати 6,1 ГВт вітрової енергетики, 12,2 ГВт сонячної енергетики, 4,7 ГВт гідроенергетики, 876 МВт біоенергетики, 40 МВт геотермальної енергетики. В сучасних реаліях воєнного стану це потрібно робити швидко, надійно, раціонально щодо фінансових витрат та збереження довкілля. Тому для досягнення зазначених вище показників важливо у всіх регіонах України освоювати наявні відновлювані енергетичні ресурси (ВЕР), що через їх просторову розподіленість і наближеність до споживачів посилить стійкість об'єднаної енергетичної системи(ОЕС).

Ключові слова: *зелена енергетика, геотермальна енергетика, сонячна енергетика, мала гідроенергетика, вітрова енергетика, екологія, сталий розвиток територій, декарбонізація, самоенергозабезпечення.*