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ASSESSMENT OF NATURAL RESOURCE POTENTIAL OF TERRITORIES DISTURBED BY MINING WORKS IN THE CONTEXT OF EFFECTIVE USE OF POST-TECHNOGENIC LANDSCAPE

Kopach P.I., Yakubenko L.V., Mormul T.M., Danko T.T., Gorobets N.V., Halchenko Z.S.
Institute of Geotechnical Mechanics named by N. Poljakov of The National Academy of Sciences of Ukraine

Abstract. In the article, the concepts of natural resource potential, post-technogenic landscape, and anthropogenic transformation are defined. The difference between quantitative and qualitative changes in the natural ecological system is considered. The types of resource waste and natural resources promising for use are analyzed. An assessment of the natural resource potential of the territories affected by mining operations is presented. The assessment is carried out on the example of the Kryvyi Rih iron ore complex. The use of renewable energy sources is considered as the most important prospects for the development of post-technogenic landscapes in mining regions, the main advantages of using renewable energy sources are determined. In the context of the effective use of post-technogenic landscapes, the potential of solar energy and wind power plants (wind turbines) was investigated. Calculations of the efficiency of the use of renewable energy sources in the territories disturbed by mining operations are given. A comparison of the efficiency of wind turbines (electricity production) in the conditions of Kryvbas dump sites with vertical and horizontal wind power plants is made taking into account the height of the location. Evidence is presented regarding the feasibility of using windmills with a vertical axis of turbine rotation. It is established that vertical wind power plants can produce electricity 7 times more than traditional (horizontal) ones. The main factors that determine the need for the development of non-traditional sources of energy in Ukraine are determined. The possibility of using post-technogenic landscapes for nature conservation, recreational and tourist purposes is considered. Examples of the use of the natural resource potential of territories disturbed by mining operations during open-pit mining operations are given, and the use of disturbed lands in the coal industry is discussed. Possibilities of involving post-technogenic landscapes in the economic activity of mining regions are considered. In the article, the authors prove that the degree of transformation of the natural resource potential of territories disturbed by mining operations determines the possibility of reclamation or use of these territories for the needs of society.

Keywords: natural resource potential, territories affected by mining operations, landscape transformation, renewable energy sources, solar energy, wind power plants, vertical windmills, horizontal windmills, reclamation of territories, use of post-technogenic landscapes, man-made landscape.

1. Introduction

In Ukraine, there is an existing technical, scientific, land, and natural resource potential for involving post-technogenic landscapes to the economic fund of the country. There is a possibility of their, if not complete restoration, but effective use for the needs of society.

The ability of the natural complex or its individual components to satisfy society's needs for energy, raw materials, and the implementation of various types of economic activity constitute its natural resource potential.

The degree of transformation of the natural resource potential of territories disturbed by mining operations determines the possibility of reclamation or use of these territories for the needs of society.

The most interesting thing today is the use of land unsuitable for agricultural needs for renewable energy sources - solar panels, wind turbines, or the creation of forest park recreation areas.

2. Methods

A post-technogenic landscape is a technogenic (changed by man) landscape that is formed under the influence of the activities of a certain industrial enterprise. The depth of landscape change by man depends mainly on the form of production activity.

The post-technogenic landscape should be considered as a space-time system of components, which is characterized by a high level of organization, which develops as a whole and is subject to general geographical regularities. Post-technogenic landscapes are complexes purposefully formed by human activity to perform certain socio-economic functions. The post-technogenic landscapes inherits from the natural landscape only the geological basis, the main features of the relief and the zonal features of the climate. The meso-relief is transformed (valleys are filled in, terrain irregularities are cut, etc.), its own microclimate is created.

A common feature of all types of post-technogenic landscapes is a certain degree of their change, transformation as a result of economic activity. This makes it possible to talk about the concept of anthropogenic transformation of the landscape.

Anthropogenic transformation is a change in natural systems under the influence of human economic activity. Anthropogenic transformation characterizes the combined impact of various types of burden on the landscape system, which takes into account not only changes in the structure of the geosystem as a whole, but also physical and chemical pollution of the components of the landscape system, changes in the species composition, etc.

The degree of landscape transformation depends on the size, type, intensity of influence, directionality; the nature of the impact of economic activity on the components of the environment.

The production activity of man makes certain changes in the processes taking place in the natural ecological system, and thereby causes a disturbance of the balance between its individual elements.

As a result, new less productive ecological systems appear in place of natural ones. At the same time, both quantitative and qualitative changes in ecological systems may appear.

Quantitative changes can occur if external changes do not contradict natural biochemical processes and do not exceed the natural level of viability (sustainability) of living organisms in terms of intensity (that is, quantitatively). In this case, in response, the reaction of the ecological system will be to increase the activity (increase the productivity) of certain groups of populations of living organisms; as a result, the sustainable balance of the ecological system is restored or ensured at another, higher level, without any qualitative changes.

Qualitative changes in the natural ecological system occur when they contradict natural biochemical processes or exceed the limits of viability (sustainability) of individual elements (populations) of the natural ecological system. Qualitative changes in the ecological system (replacing one biocenosis with another) will occur until a qualitatively new sustainable ecological system appears. For example, a change in the hydrogeological regime of waters in the zone of influence of mining operations can qualitatively change the flora and fauna of the surrounding area: marshes or shrub communities may appear in the place of forests.

The new ecological system that has arisen in the zone of an industrial enterprise may differ sharply by its parameters from the natural one and be unsuitable for the normal life of people.

Even small local changes in this system can lead to significant qualitative changes over large areas.

When solving production tasks, positive results can be achieved when changes in the environment are of a purely quantitative nature. At the same time, the new ecological system, in which the enterprise is an active element, does not differ qualitatively from the original natural one. In the presence of quality changes in the natural environment, it is not always possible to develop and implement measures that ensure its initial or set parameters (quality).

At the present stage, the most important tasks of rational nature management of mining regions are: comprehensive use of mineral resources extracted from the subsoil, protection of the natural environment, economic efficiency of landscape existence.

Solving these tasks is related to the definition of the concept of the natural resource potential of the landscape and, as a result, the development of fundamentally new and improvement of existing technologies for the extraction of useful components from the subsoil, complex processing of mined mineral raw materials using closed and low-waste schemes, the use of post-technogenic landscapes as areas for the placement of alternative energy facilities.

The identification of a set of natural factors that are of the most importance for human life support existing in a particular landscape constitutes the natural resource potential of the territory.

The mining landscape is formed as a result of mineral extraction and soil movement during construction, as well as mining waste storage activities. It is very diverse and is determined by the nature of the mined mineral raw materials and the properties of the mining rocks containing them, general natural conditions (climate, groundwater level, etc.), mining methods and technical means used in mining.

In the process of conducting mining operations, the landscape is radically changed, the damage of which is due to the formation of man-made waste from overburden (external dumps), beneficiation waste (tailings), recesses in the earth's crust (the manufactured space of the quarry field). The underground method of deposits mining is characterized by a violation of the stability of the massif of mining rocks with significant losses (up to 20-40%) of contour reserves of useful minerals with outcrop of sinkholes to the earth's surface and even the occurrence of man-made earthquakes.

Mining processes have a negative impact on the air and water environment as well, the pollution of which leads to a decrease in their quality indicators.

At the same time, storage of primary mining waste on the earth's surface creates prerequisites for their further use.

In modern conditions, man-made mining landscapes are not only widespread, but also quite diverse.

In the developed countries of the world, the level of use of industrial waste is quite high (today it reaches 80%).

In Ukraine, the most promising resource waste should include:

1) tailings of ferrous and non-ferrous metal ore enrichment, the total reserves of which (Kremenchutsk-Kryvorizkyi Iron Ore Basin) have already reached 2.5 billion tons with a total iron content of 14-20%, and in the Nikopol-manganese ore district - 240 million tons, the content manganese in which is 10-15%. Utilization of sludge from the Mykolaiv alumina plant will allow obtaining gold-rutile-zirconium (gold – 36-42%, zircon – 40-60%, rutile – 14-20%) concentrates;

2) mineral raw materials left in previously mined-out deposits, the volume of which reaches 30-40% of outlined reserves, the content of total iron in which is 45-67%;

3) stocks of poor and oxidized ores, which are stored in dumps.

The use of these resources will allow obtaining additional volumes of iron ore concentrate and materials for the construction industry.

In addition, promising types of natural resources should include:

– the potential of post-technogenic landscapes, which is characterized by a large area of vacant plots of land and an anomalous increase in the height of new man-made formations, promising and the possibility of its use for the development of renewable energy, which will contribute to the revival of the secondary ecosystem in the territories disturbed by mining operations, will provide electricity for high-energy processes of demineralization of mine and quarry waters;

– recreational, natural and tourist potential of some post-technogenic landscape objects.

The high significance of the results of the development of this resource potential transformed by previous exploitation of deposits, its impact on the level of development of mining regions, as well as the insufficient study of the possibility of its development determine the urgency of solving this problem.

One of the most important prospects for the development of post-technogenic landscapes in mining regions is the use of renewable energy sources (RES).

Among the problems of renewable energy development in Ukraine, one of the main is a significant shortage of land plots for the location of alternative energy facilities. In the conditions of mining regions, there is no problem of shortage of land plots for the placement of RES.

Nowadays, the Kryvyi Rih Iron Ore Complex is represented by 5 mining and beneficiation enterprises with 9 quarries, 8 operating mines, as well as a number of auxiliary structures. The total area of alienated lands in Kryvorizhzhia is 69.9 thousand hectares. Of these, 15% are allocated to quarries, 25% to landfills, and 28% to tailings storage facilities. And only about 1% of the disturbed areas have been rehabilitated, and up to 8% of the areas are outside the scope of mining operations and are not used in agriculture. Thus, there are prospects for the use of alternative energy sources in the conditions of technogenically changed landscapes of the country's mining regions.

In the context of the effective use of post-technogenic landscapes, the potential of solar energy must first be considered. Solar radiation is not a constant value and depends on many factors - the season, time of day, weather conditions and geographical location. These factors should also be taken into account when calculating the amount of solar panel power required. If it is planned to use the system all year round, then the calculation should be carried out with taking into account the most unfavorable months from the point of view of solar radiation.

3. Results and discussion

When calculating for each specific region, it is necessary to analyze statistical data on solar activity for several years. Based on these data, the average effective power of the solar flux per square meter of the earth's surface should be determined. This data can be obtained from local or international weather services. Statistical data will make it possible to predict with minimal error the amount of solar energy for the system, which will be converted by solar panels into electricity [1].

The specific power of solar radiation for the city of Kryvyi Rih, Dnipropetrovsk region, in kW/m^2/day is given in Table 1.

Table 1 – Specific power of solar radiation for the city of Kryvyi Rih, kW/m^2/day by month

Month	January	February	March	April	May	June	July	August	September	October	November	December	Average for the year
Power of solar radiation, kW/m^2/day	1.21	2.00	2.91	4.20	5.62	5.72	5.88	5.18	3.87	2.44	1.25	0.95	3.44

As of 2020, the efficiency coefficient of the photovoltaic panel reaches 30%. We accept the average statistical value of the products presented on the market of photovoltaic panels efficiency EF = 16%.

The coefficient of losses per charge-discharge of batteries: K = 0.83.

Theoretical specific power of the photovoltaic panel:

$$E = 3.44 \times 0.83 \times 0.16 = 0.456 \text{ kW/m}^2.$$

Theoretically, 2.2 m^2 of panel area is needed to produce 1 kW.

In fact, the most common standard solar module has the following parameters:

Standard solar module size 1.966 × 0.992 = 1,95 m^2.

The power of the module is 250 W.

To produce 1 kW, it is necessary to use 6.5 m^2 of the area of the panels or 7.5 m^2 of the area of the territory.

The number of hours of sunshine per year is 2430 hours.

Annual capacity of the 1st module: 2430 × 0.25 = 730 kW/h.

Annual capacity from an area of one hectare:

$$10000 : 7.5 \text{ m}^2 \times 730 \text{ kW/h} = 973330 \text{ kW/h}.$$

Thus, totally: 10,000 m^2 : 7.5 m2/kW = 1334 panels can be placed on the area of 1 ha which can generate 973 thousand kW/h of electricity.

The averaged data on the average monthly energy of solar radiation (insolation) with taking into account climatic conditions (frequency and strength of cloudiness) for fixed panels oriented to the south at various angles of inclination and for systems that do not track the movement of the Sun is given above. Insolation was measured in an open space. Strong terrain, the proximity of high-rise buildings or big trees can reduce the power of solar radiation several times. On the contrary, the proximity of an open water surface or snow cover can slightly increase the perceived insolation due to reflected radiation (primarily this applies to panels installed at a significant angle to the horizon or vertically).

Areas disturbed by mining operations, which cannot be used in agriculture, are suitable for the placement of solar panels.

The second effective way of using the natural potential of man-made landscape objects is wind energy. Let's consider the wind energy potential of external dumps. In a wind flow, the wind speed increases with increasing height above the Earth's surface. Objects of man-made landscape of mining areas (dumps) are characterized by a significant height in relation to the day surface mark. This value reaches 100-120 m and may grow over time [2].

Therefore, wind power plants (WPP) can be located on dumps of different heights, thereby increasing the production of electricity. Research in the calculation of the vertical profile of the average annual wind speed values revealed the dependence of this indicator both on the season and on the value of the average wind speed (table 2).

Table 2 – Growth coefficient of average wind speed with height

Season	Height, m					
	10	20	40	60	80	100
Winter	1	1.12	1.26	1.35	1.43	1.50
Spring	1	1.17	1.36	1.50	1.59	1.66
Summer	1	1.18	1.40	1.55	1.67	1.76
Autumn	1	1.12	1.26	1.35	1.43	1.50
Year	1	1.15	1.32	1.44	1.53	1.60

Figure 1 shows the calculations of the vertical wind profile based on the average annual data in Table 2.

Figure 1 shows, for example, if the average speed at a height of 10 m is 6 m/sec, then at a height of 100 m it is already 9.6 m/s. Thus, the wind energy potential on high dumps will exceed the flat one by 60%.

For more efficient use of the wind flow, it is necessary to establish a vertical profile of wind speeds.

Nowadays, wind turbines with a horizontal axis of rotation of the turbine have become the most widespread. They were effectively used in areas with strong winds. Such installations begin to generate electric current at a wind speed of 8 m/s, and work normally at speeds greater than 12-14 m/sec. But for areas with moderate wind speed (from 3 m/sec to 13 m/sec), wind generators with a vertical axis of turbine rotation are more effective.

A comparison of the efficiency of wind turbines (electricity production) in the conditions of the Kryvbas dump by vertical and horizontal wind power plants with taking into account the height of the location, is shown in Table 3.

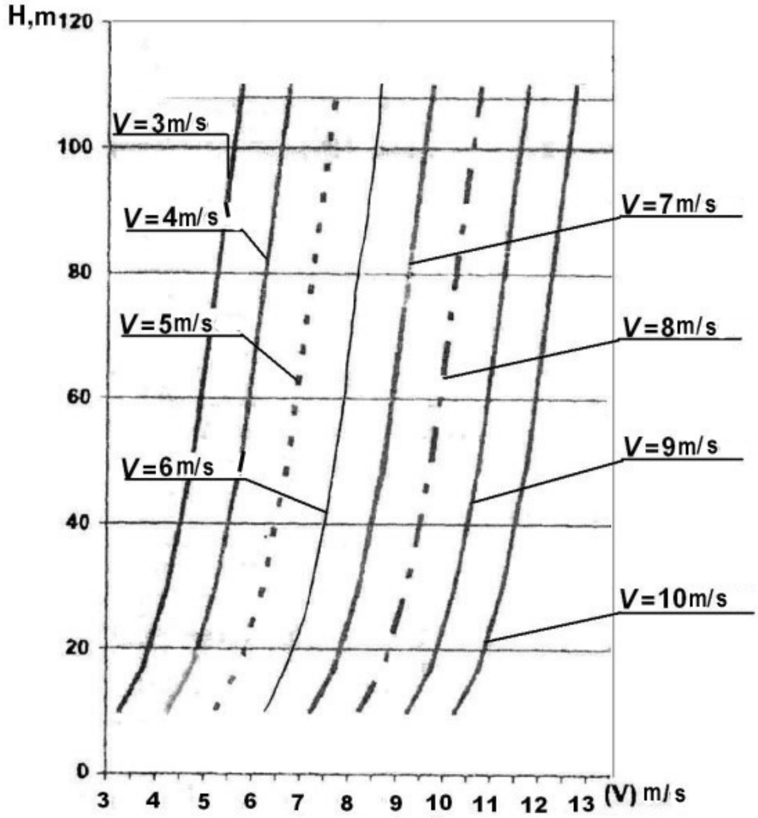

Figure 1 – Vertical profile of average annual wind speeds V in the surface layer up to 100 m high at a wind speed of 10 m from 3 to 10 m/sec

Based on the calculation results (table 3), when the wind turbines are located outside the landfill (relative height 0 m), in the conditions of Kryvyi Rih, vertical wind power plants can produce electricity more than 7 times more than traditional (horizontal) ones. The amount of produced electricity increases with the height of the wind turbine location.

The location of horizontal wind power plants on the surface of a high dump with a height of 100 m increases the amount of generated electricity from 1228 kW/days to 3607 kW/days, that is by 2.9 times.

A vertical wind energy installation under similar location conditions increases the amount of energy produced from 8.849 to 16.544 kW/days, that is by 1.8 times.

Comparing the indicators of vertical and horizontal installations when they are located on landfills (16544:1228 kW/days), we can conclude that the efficiency of vertical wind turbines increases by 13.4 times.

The main factors determining the need for the development of non-traditional sources of energy in Ukraine:

– lack of sufficient volumes of own organic fuel, dependence on its import, growing scarcity of traditional energy resources, their high cost on the world market and problems with external supply;

– negative state and trends in the fuel and energy complex, in particular insufficient efficiency of traditional fuel and energy resources and wear and tear of fixed assets;

– environmental problems, in particular the need to fulfill international obligations to limit the volume of harmful emissions;

– the presence of territories disturbed by mining operations, which cannot be used in agriculture, residential construction, etc.

Table 3 – Production of electricity in the conditions of Kryvbas dump sites by vertical and horizontal wind power plants with a capacity of 100 kW for various variants for their placement

Wind speed, m/s (at the bottom of the dump)	Wind speed, m/s (on a dump with a height of 100 m)	Number of days with wind, per year (city Kryvyi Rih)	Vertical windmill				Horizontal windmill			
			Power, kW		Produced electricity, kW/days		Power, kW		Produced electricity, kW/days	
			placement at the bottom of the dump	placement on a dump with a height of 100 m	placement at the bottom of the dump	placement on a dump with a height of 100 m	placement at the bottom of the dump	placement on a dump with a height of 100 m	placement at the bottom of the dump	placement on a dump with a height of 100 m
1.8	3.0	-	-	3	-	-	-	-	-	-
2	4.4	9	1	6	9	54	-	-	-	-
2.5	5.0	12	2	13	24	288	-	-	-	-
3	5.6	67	6	22	402	1474	-	-	-	-
4	6.7	76	13	34	988	2584	-	-	-	-
5	7.6	79	22	46	1738	3634	1	6	79	474
6	8.5	54	34	57	1836	3078	3	15	162	810
7	9.6	36	46	70	1656	2520	7	24	252	864
8	10.8	18	57	84	1026	1512	12	32	216	576
9	11.8	6	70	100	420	600	22	46	132	276
10	13.0	4	84	100	336	400	38	68	152	272
11	13.0	2	100	100	200	200	48	73	96	146
12	13.0	1	108	10	108	100	59	89	59	89
13	13.0	1	108	100	108	100	80	100	80	100
Total		365	-		8849	16544	-		1228	3607

Also, specialists of the Institute of Nature Management and Ecology of the National Academy of Sciences of Ukraine (IPPE of the National Academy of Sciences of Ukraine) conducted complex studies on the restoration of secondary ecosystems in territories disturbed by mining operations, and the effectiveness of using post-technogenic landscapes for nature conservation, recreational and tourist purposes was proven. Thus, at present, 3 landscape reserves "Vizirka", "Vershina" and "Bohdanivskyi" with a total area of 1556 ha have already been created on the lands of Inguletskyi, Prosyanskyi and Pokrovskyi GZK [3].

The priority areas of use of disturbed lands in the coal industry are:

– agricultural – agricultural lands on areas that are suitable by relief, quality of soils that make up the upper horizons, with taking into account the application of a reclamation layer;

– forestry – forestation on lands where forest restoration with valuable species can be ensured;

– sanitary and hygienic – planting herbs, bushes and trees.

Therefore, there is an available technical, scientific, land, natural resource potential for involving post-technogenic landscapes to the country's economic base in Ukraine. There is a possibility of their, if not complete restoration, but effective use for the needs of society.

4. Conclusions

Hence, it can be concluded that open-pit and underground mining works have a special influence on the occurrence of disturbed lands. The negative impact of the territories disturbed by mining operations on the environment in most cases only increases over time, therefore their further use is very important.

The following main advantages of the use of RES are determined:

– energy obtained from renewable energy sources is free;

– renewable energy sources, unlike traditional ones, are evenly distributed over the territory;

– RES are ecological sources, since their use practically does not pollute the environment and does not have a significant impact on climate change;

– thanks to RES, it became possible to use lands unsuitable for economic needs.

The solar energy potential and the wind energy potential of external dumps in the context of effective use of the natural potential of man-made landscape objects are determined.

The possibility of using the natural potential of man-made landscape objects for recreational purposes was considered, based on the Institute's obtained experience in creating natural reserves on the territories of developed quarries.

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About authors

Kopach Pavlo Ivanovych, Candidate of Technical Sciences (Ph.D.), Senior Researcher, Senior Researcher in Department of Ecology of mastering Natural Resources, Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine (IGTM NAS of Ukraine), Dnipro, Ukraine, kopach.pavlo@gmail.com

Yakubenko Leonid Viktorovych, Candidate of Technical Sciences (Ph.D.), Senior Researcher, Senior Researcher in Department of Ecology of mastering Natural Resources, Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine (IGTM NAS of Ukraine), Dnipro, Ukraine, lalex-pod@i.ua

Mormul Taras Mykolaiovych, Candidate of Technical Sciences (Ph.D.), Senior Researcher, Senior Researcher in Department of Ecology of mastering Natural Resources, Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine (IGTM NAS of Ukraine), Dnipro, Ukraine, mormult33@gmail.com

Danko Tamara Timofiivna, Senior Engineer in Department of Ecology of mastering Natural Resources, Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine (IGTM NAS of Ukraine), Dnipro, Ukraine, lalex-pod@i.ua

Gorobets Natalia Vasyliivna, Senior Engineer in Department of Ecology of mastering Natural Resources, Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine (IGTM NAS of Ukraine), Dnipro, Ukraine, natgor490@gmail.com

Halchenko Zariana Serhiivna, Senior Engineer in Department of Ecology of mastering Natural Resources, Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine (IGTM NAS of Ukraine), Dnipro, Ukraine, zorichka85@gmail.com

ОЦІНКА ПРИРОДНО-РЕСУРСНОГО ПОТЕНЦІАЛУ ПОРУШЕНИХ ГІРНИЧИМИ РОБОТАМИ ТЕРИТОРІЙ В КОНТЕКСТІ ЕФЕКТИВНОГО ВИКОРИСТАННЯ ПОСТЕХНОГЕННИХ ЛАНДШАФТІВ

Копач П.І., Якубенко Л.В., Мормуль Т.М., Данько Т.Т., Горобець Н.В., Гальченко З.С.

Анотація. У статті наведено визначення понять природно-ресурсного потенціалу, постехногенного ландшафту, антропогенної трансформації. Розглянута різниця між кількісними і якісними змінами в природній екологічній системі. Проаналізовані перспективні до використання види ресурсних відходів і природних ресурсів. Дана оцінка природно-ресурсного потенціалу порушених гірничими роботами територій. Оцінка проведена на прикладі Криворізького залізорудного комплексу. Розглянуто використання відновлюваних джерел енергії, як найважливіших перспектив освоєння постехногенних ландшафтів у гірничодобувних регіонах, визначені основні переваги використання відновлювальних джерел енергетики. В контексті ефективного використання постехногенних ландшафтів досліджено потенціал сонячної енергетики і вітроенергетичних установок (вітряків). Наведені розрахунки ефективності використання відновлювальних джерел енергетики на порушених гірничими роботами територіях. Зроблено порівняння ефективності роботи вітряків (виробництва електроенергії) в умовах відвалів Кривбасу вертикальними та горизонтальними вітроенергетичними установками з урахуванням висоти розташування. Наведені докази щодо доцільності використання вітряків із вертикальною віссю обертання турбіни. Встановлено, що вертикальні вітроенергетичні установки можуть виробляти електроенергії більше ніж в 7 разів за традиційні (горизонтальні). Визначені основні чинники, що визначають необхідність розвитку нетрадиційних джерел енергетики в Україні. Розглянута можливість використання постехногенних ландшафтів для природоохоронних, рекреаційних і туристичних цілей. Дані приклади використання природно-ресурсного потенціалу порушених гірничими роботами територій при відкритих гірничих роботах і розглянуто використання порушених земель у вугільній промисловості. Досліджені можливості залучення постехногенних ландшафтів у господарській діяльності гірничодобувних регіонів. У статті доведено, що ступінь трансформації природно-ресурсного потенціалу порушених гірничими роботами територій визначає можливість рекультивації чи використання цих території для потреб суспільства.

Ключові слова: природно-ресурсний потенціал, порушені гірничими роботами території, трансформація ландшафту, відновлювальні джерела енергії, сонячна енергетика, вітроенергетичні установки, вертикальні вітряки, горизонтальні вітряки, рекультивація територій, використання постехногенних ландшафтів.

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