ІНЖЕНЕРІЯ СЕРЕДОВИЩА ТА БЕЗПЕКА ЖИТТЄДІЯЛЬНОСТІ

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FACTORS OF SPATIAL CONSTRAINTS AND OPPORTUNITIES IN THE CARPATHIAN REGION OF UKRAINE FOR RENEWABLE ENERGY PROJECTS

The article substantiates the use of renewable energy sources in the sustainable tourism development of the region. Sustainable development of tourism in the Carpathian region is considered taking into account the energy and environmental impact of the traditional Ukrainian energy sources. The developed approach combines the economic profits of the tourism industry with the benefits of society since it takes into account the ecological situation and provides measures for its improvement.

It is determined that selecting areas that are suitable for renewable energy consuming projects should consist of three stages: selecting potentially suitable areas, considering exclusion criteria, and an in-depth assessing potential sites or territories. The factors determining spatial constraints and providing essential resources for the construction of wind and solar power plants and small hydropower plants are defined, with the parameters of sustainable tourism development of the Carpathian region in view. Factors that are common to different types of power plants are as follows: availability of wind, solar or hydrological resources, local topography and existing obstacles, accessible terrain, available infrastructure, network service access point, soil properties and composition, the proximity of inhabited areas, surface openness and steepness of slope, environmental constraints, land tenure analysis, proximity of protected nature and landscape areas.

Based on these studies, the GIS map of the Carpathian region is compiled showing the spatial distribution of the solar potential on a horizontal surface. Solar radiation varies with the height, steepness of the mountain slopes and other meso and micro factors, but over the examined territory the annual insolation is not less than 1000 kW/m^2. The work contains recommendations related to the use of solar energy as the innovation of the tourist infrastructure; they aim at the further developing of major tourist centres and isolated settlements in the Carpathian region.

Key words: sustainable development, sustainable tourism development, renewable energy sources, landscape, spatial constraints.

Formulation of the problem. Sustainable development meets the present day needs and guarantees the same opportunity to future generations. The following interrelated components should be considered with sustainable development: social, economic, environmental and political development. According to the definition developed by the World Tourism Organization (WTO) in 1996 and changes made in 2004, sustainable tourism is a tourist activity, which should keep the cultural component, environmental condition, biodiversity and life support system. And the development of sustainable tourism is seen as a process that, in addition to meeting the needs of tourists and places that receive them, maintains and develops opportunities for the future. According to this definition, sustainable tourism development, taking into account the situation in the country regarding energy and environmental impact of traditional energy sources, should serve the interests of tourists in the economy, society and take into account the ecological environment and use measures for its preservation.

Carpathian region has great potential, the wealth of natural resources is one of the main reasons tourists travel, and all the preconditions for sustainable tourism and recreation development. The use of renewable energy sources (RES), which have recently gained popularity because of the individual economic and political factors prevailing in the country fully meets the criteria of modern energy ecological tourism development in the region.

Analysis of previous research. The rationality of usage of renewable energy sources was based by S. H. Plachkova, I. V. Plachkov, E. T. Bazeiev, V. I. Bondarenko, T. O. Buriachok [1], N. M. Mkhytarian, S. A. Kudria, V. F. Reztsov, T. V. Surzhyk, L. V. Yatsenko [2], O. M. Adamenko, V. V. Vysochanskyi, V. V. Lotko, M. I. Mukhailiv [3, 4], researching methods of increasing the efficiency of the development of alternative and renewable energy sources were considered by S. M. Bevz, A. K. Shydlovskyi, Bondarenko [5] and other scholars and researchers. Among the issues raised by scientists is the question of implementation problems of renewable energy projects, the projects realization.

Selection of previously unsettled parts of the general problem. But for the future there is an issue of rational argumentation for selection the space for projects concerning renewable energy sources, such as taking into account factors that need to be considered when choosing such areas, given the parameters of sustainable development in tourism.

The objectives of setting. During development phase and implementation of projects of renewable power sources, the essential component is the site finding, which consists of three stages:

- selection of potentially suitable area;
- consideration of the exclusion criteria;
- detailed assessment of potential sites or areas.

Presentation of the main material. For all projects in which renewable power sources are used, they all have many potential overall impacts on the landscape, biodiversity and the local population, which should be considered during selecting a suitable site for the project. These general potential impacts may include:

- negative impacts of new energy-generated constructions and ancillary facilities such as transmission lines and access roads, on the quality of the landscape, environment and aesthetic appearance;
- loss of habitat, habitat fragmentation and simplifying of the ecosystem which were caused by the influence of site developments, and related thereto potential adverse impacts on the fauna and flora that exist in this natural environment;
- changes in land use and the formation of business struggle because of valued lands use (e.g., lands withdrawal from agricultural production);
- impacts on protected areas or sensitive areas and objects of cultural heritage or archeological monuments;
- impacts on local infrastructure facilities and personal property.

Finding the suitable site for wind power station is essential for the success and economic viability of the project. The main aim in site finding is to determine potential wind regions that are also characterized by other parameters which are necessary for wind energy projects implementation. The project developer may be interested in only those areas that are at his disposal or if he selects district or municipality has larger area.

At the first stage, the potential sites for wind power are determined by taking into account the wind resources at the height of the hub. This process covers quite a large area (e.g., district or territory which is served by public utility) to determine areas with necessary wind resources on the basis of information which is contained in sources such as maps of wind resources, satellite wind data, time series of design winds, wind data from airport, topography and other indicators.

It is necessary to take into account following restrictions which are related to the site finding. The main factors to be taken into account during site finding include:

- initial assessment of wind conditions by using available public data which are related to potential site or nearby located place, although the obtained results, cannot be quite correct and reliable, but they will get an idea how this terrain can be potentially favorable;
- overall assessment of the site, including topography and existing obstacles, such as buildings or woods and their potential effect on productivity and project value;
- location accessibility by taking into account access roads, their condition and distance from potential site, the size of components and quality specifications for necessary roads;
- availability of node for the planned wind power station and the network power of node in relation to the planned capacity and cost of additional electrical grid by taking into account network operation and adequate legislation;
- soil quality and work related to foundation plan and construction, as well as costs and their impact on the possibility of realization of wind power station;

- accounting of residential areas, infrastructure and potential effect of wind power station on the following factors: shade, noise, visibility, microwave data transferring, interference in radars, airports, etc.;
- openness of terrain, to prevent wind current diffusion uplands must be separated by a distance at least 2-3 km;
- uplands should be in terms of columnar, cone shape;
- slopes must be low-sloped with incline not above 20.

At the second stage exclusion criteria are used to determine if this place is suitable for wind power stations exploitation.

Exclusion criteria which are used for site finding for wind power stations include:

- districts near communities;
- industrial and commercial sites;
- hamlets, farms or detached houses;
- infrastructural areas where construction is prohibited;
- transportation infrastructure;
- overhead transmission lines;
- airports;
- mining areas ;
- national parks, natural monuments, biosphere reserves, reserves, habitats which are protected by law;
- ponds.

At the third stage in conducting assessment of the site potentially suitable areas are tried out by taking into account technical and layout (ecology and land use) aspects:

- site topography, location of obstacles;
- access to transmission systems;
- maximum installed capacity;
- access to the site;
- land ownership;
- distance to populated localities;
- environmental constraints;
- layout of visually sensitive objects;
- the reliability of mobile telephony for data transfering;
- restrictive factors associated with communication signals such as microwave communication corridors, if applicable.

Construction of wind farms negatively affects the quality of the landscape and the aesthetic appearance of high quality landscapes on large areas of land. They are perceived as new, unnatural vertical structures that are not in harmony with most landscapes. Visibility of such facilities may be limited on the landscapes with wedged elements, but on the flat, steppe, and arable landscapes they will be especially noticeable. High quality landscapes and environmentб which surrounds areas, namely, environmental facilities, may be especially vulnerable to these effects.

All potentially suitable sites must be visited if possible in order to verify their existing conditions.

Depending on the available land and topography first wind-power station chart and balance settings can be designed.

Area’s estimation results in ranking of sites-candidates.

The key characteristics of solar electricity technologies and their advantages and disadvantages, which are taken into account when assessing the project, are attributed to the location of the site (external shading and spatial constraints) [7].

Choosing the site for photovoltaic power-station is essential for the success and economic viability of the project. The main factors which are taken into account while choosing the site include:

- initial assessment of solar resources in the form of global horizontal irradiation using publicly available data about potential site or place next to the site;
- assessment of the site including the area, topography and existing obstacles, such as buildings or trees, and their potential impact on productivity associated with shading;
- availability of water for the construction and operation phases;
- analysis of land use that affects the cost of the land;

- the availability of areas on the basis of existing access roads, their condition and distance from a potential site. Proper condition of roads is required to avoid damage mainly inverters and photovoltaic modules during their transportation;

- existence of point attaching to the main for scheduled solar power-station and capacity of this main in relation to the planned capacity, and cost of necessary additional electricity with account of operator and relevant legislation;

- seismic risk, groundwater, soil resistivity are equal pH and bearing capacity. The last options are especially important for assessing the type of possible foundations of mounting system;

- consideration of environmental and social sensitivity, vizual and potential impacts of solar system;

- the possibility of rational use of territories which are situated under the station.

At the second and third stages while evaluating the site, potentially suitable areas are studied in detail considering technical and planning (ecology and land utilization) aspects and conduct ranking of sites. It is necessary to take into account the force that the placement of photovoltaic panels and ancillary facilities on a flat area can affect the landscape character, replacing the existing picturesque landscape on areas of panels which can be perceived as significant unnatural objects. Conservation areas and high quality landscapes and their environment may be especially vulnerable to these influences. However, solar energy facilities are likely to be low-lying, thus the impact on scenic views will be mostly noticeable if only observing from the hill or close to the facilities.

Projects of small hydroelectric power stations differ with their significant flexibility. There may be aligning for small hydropower plants (SHPP) which are characterized by great diversity. Areas of Highlands and fast waterways in the Carpathian region create the necessary conditions for the construction of hydroelectric power plants (HPP) with medium or high pressure. Lowlands with wide rivers provide conditions for the construction of low-pressure SHPP. Most SHPP are channel stations, thus they produce electricity depending on the availability of water in the river, which varies depending on the weather. Therefore, they cannot be used for the production of peak electricity, and can only work in basic mode, the overall energy system.

Depending on the topography of the site, medium-, high- and low-pressure SHPP can be applied for power generation..

Medium- and high-pressure HPP usually have in their schemes channel-forcing pipe or its variants. The channel track depends on the form of terrain. If the construction of the channel includes difficulties, or it can be completely avoided, only the pressure pipeline is used. In especially sensitive from an environmental point of view places the only solution may be to lay-down pressure pipeline in the ground to minimize its impact on the environment.

Low-pressure SHPP may be built according to two schemes: with the derivative channel and dike dam.

Planning and development of small hydropower stations must be brought out due to prevailing environmental conditions with simultaneous consideration of the possible impact on the environmental and social ambient which may be caused by its construction and operation. Therefore, on the first phase the basic requirements to the selection of the territory relating to the following data:

- topographical;
- hydrological;
- geological.

Determining of the confines and especially the existing pressure are the mandatory data for designing of MHEP. The data submitted in topographic map of a certain scale and a digital elevation model.

Possible costs for water intake combined with hydraulic pressure are the most important parameters for design MHEP. Typically, regional authorities of water resources measure water consumption on the most important rivers and streams, so these data can be obtained from them. As a rule, the assumption of water in alignment does not take place except cases when there's water gauge installed post. Therefore it is necessary to transfer data of already existing water stage gauge on characteristics of water consumption in MHEP alignment. For this purpose, measurement data are used, obtained at the nearest water stage gauge along the same river, or if it is possible, the data of water stage gauge, located near MHEP. Data on the cost of water should cover the time period equal to at least 15 years in a row, if it is possible, to get statistically justified conclusions.

For the proper design of the engineering structures foundation it ie necessary to get as detailed geological data as possible:

- the first assessment of the dominant species can be made with the help og geological maps that may exist at the district level;
- estimates are indicative and should be complemented by further studies (eg geological mapping), during which quite detailed map of the project area is prepared;

At the second stage of choosing the territory the accuracy should be raised and considered in more detail. Before the evaluation stage, it is necessary to carry on geological studies with further laboratory analysis of the samples. These tests are conducted to determine the parameters of rocks and soil on which the project of MHEP will be based. It must be emphasized that without adequate information of the geological parameters of rock and soil, MHEP design contains a large number of unknown variables, which is a significant source of risk. Therefore, proper geological studies are a prerequisite for the proper MHEP design.

It is necessary to exclude the territory with:

- low or unregulated river flow;
- restricted or prohibited zones of economic activity;
- very steep slopes.

When evaluating areas for ranking it is necessary to consider a few key points:

- compliance with national legislation on environmental and social aspects;
- loss of habitats for local animals and plants;
- passes for fish and other aquatic organisms;
- rare species that are at risk of extinction.

Often the most attractive from an economic and technical point of view platforms for small hydropower plants are also less suitable in terms of ecology and tourism. For example, while the mountainous Carpathian region has the highest potential for small hydropower in Ukraine, he is also the richest in terms of clean, valuable and vulnerable areas. The presence of new dams, derivative pipes (if they are not underground), power lines and flooded areas may adversely affect the landscape character and high quality environment, which in turn may adversely affect on tourism and recreational potential of the area.

Conclusions and prospects of research. In the work proposed recommendations for pre-innovation segment of the tourism infrastructure to future development as the major tourist centers and isolated settlements as part of the Carpathian region on the example of solar energy. Grounded objects implementing solar energy as an innovative component of sustainable tourism in the Carpathian region. Solar radiation depends on altitude, slope orientation and other meso and microfactors, but throughout the Carpathian region will exceed 1,000 kWh per 1 m^2 of a year. That enables active in "green" tariff for electricity build as industrial, cost-effective solar power, as the source and use of solar energy for tourist complexes, private rural estates "green tourism", street lighting, etc. of local communities. Specific investments make $ 1500-1800 / kW of installed capacity (fig.1).

The Ivano-Frankivsk region is convenient for solar energy usage (table 1). Annual solar radiation flux for the Ivano-Frankivsk region is 1200 kW per hour/m^2, which is very suitable for solar energy facilities as well as for the industrial scale which would relatively raise the infrastructural level of tourism in the region.

The analyzes of operation of such power plant units in Lviv, Ivano-Frankivsk and Zakarpattia regions showed that solar photovoltaic power plant units (capacity of 1 megawatt) may generate nearly 1 mil. kW of energy per year. It may take near 7 years to pay off the investment of 1mln euro for 1megawatt of SEP (Solar Electric Plant) peak power. The establishment of local energy source as the element of tourist infrastructure in certain Carpathian regions will enable reliable and effective electricity supply to local consumers.

Estimated monthly volume of electricity production by photovoltaic solar power panels installed at a maximum of 2,8 MW of electric power (table 2).

For the development of tourism infrastructure it is proposed to use solar panels, which are based on photovoltaic cells and renewable energy sources for street lighting in villages (fig. 2).

Technical parameters:

- Fully automatic operation control.
- Vertical ground level of illumination can reach 10-12 Lx.
- 10 hours lighting every day. 4-10 hours lightening in a bad weather.

- 7 m height . Operating temperature from -30 ° C to 45 ° C.
- It is appropriate to use LED lamps for the effective implementation of street lighting powered by photovoltaic solar cells.

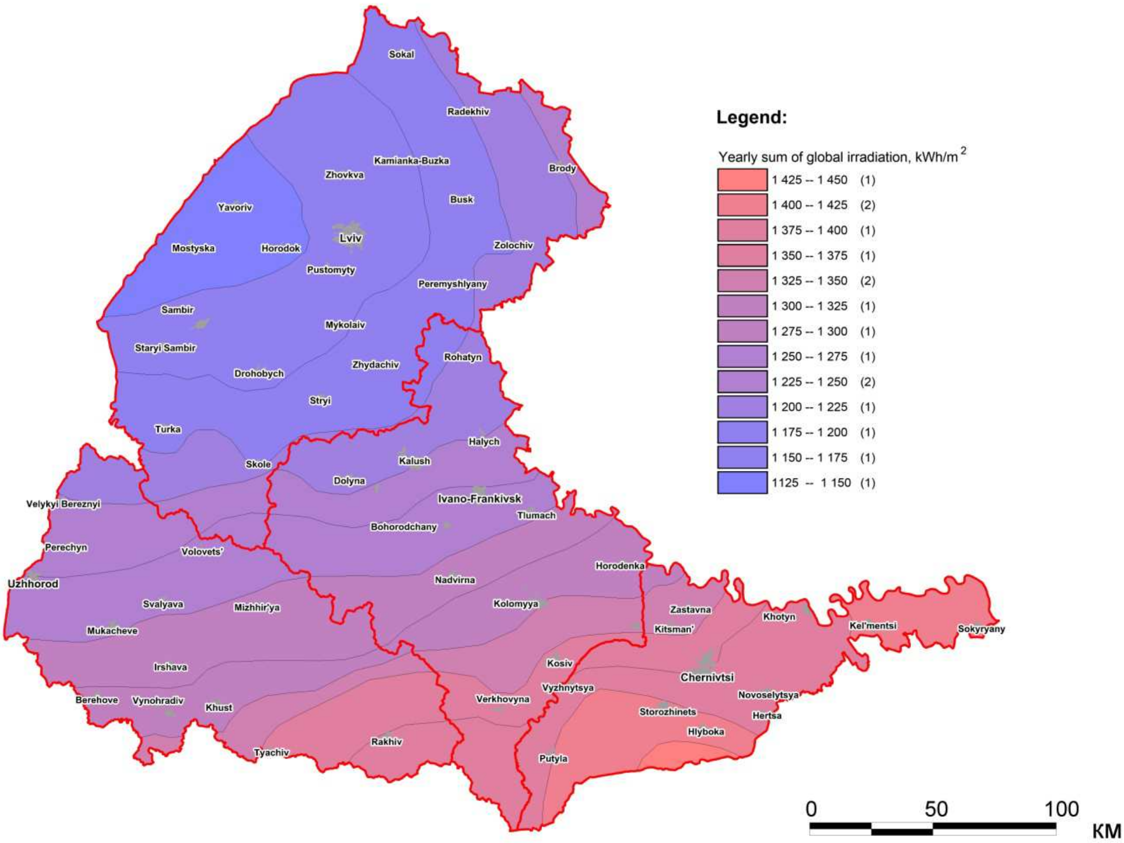

Fig. 1. Total annual potential of solar energy

Table 1

Monthly meteorological data (Ivano-Frankivsk)

Month	Global horizontal emission, Kw·h/m^2	Temperature, °C	General emission per area kW·h/m^2	Effective global emission, kW·h/m^2
January	21,9	-3,98	46,4	44,9
Fabruary	39,9	-2,77	59,8	57,8
March	77,9	0,96	109,9	106,6
April	124,9	7,92	145,6	141,1
May	162,9	14,65	167,0	161,0
June	177,8	16,75	159,9	154,3
July	172,8	18,87	169,2	163,5
August	135,9	17,85	153,8	148,7
September	89,9	12,32	123,1	119,1
October	59,9	7,66	87,6	84,8
November	28,9	2,35	55,5	53,7
December	14,9	-3,53	41,3	39,9
YEAR	1108,0	7,3	1319,1	1275,3

When operating facilities using solar energy produces electricity without using fossil (or nuclear) fuel, providing a corresponding decrease fuel consumption for conventional thermal or nuclear power plants. Energy savings through the use of renewable, environmentally-friendly sources of energy is a promising innovative segment in the development of tourism infrastructure, development of green tourism in the Carpathian region, which provided more investment in the future will result in increased tourist demand.

Table 2

Estimated monthly volume of electricity production by photovoltaic solar power panels installed at a maximum of 2,8 MW of electric power

Month	Efficient production on output of modules, MWt per hour	The volume of supply to the network, MWt per hour	The efficiency degree of generation, %	The degree of the system effectiveness
January	68,3	66,25	13,3	12,8
Fabruary	137,0	132,89	13,5	13,2
March	219,5	214,01	13,2	12,9
April	346,7	339,77	12,7	12,5
May	404,0	395,92	12,2	12,0
June	410,9	402,68	12,0	11,8
July	395,9	387,98	11,9	11,7
August	371,3	363,87	12,0	11,8
September	250,0	243,75	12,3	12,1
October	185,9	182,9	12,6	12,3
November	99,4	96,42	13,0	12,6
December	69,0	66,93	12,9	12,4
Year	2 957,9	2 893,37	12,4	12,2

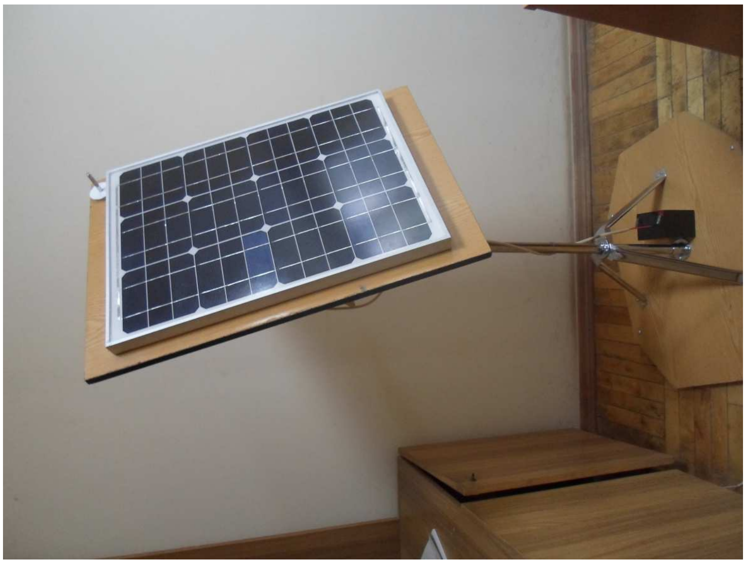

Fig. 2. Technical parameters of solar panels

On the basis of the carried research it is proposed to conduct a comprehensive assessment of environmental safety based on the current organizational structure of the environmental monitoring and information model by involving specially formulated environmental indicators and indices of quality.

The establishment of local energy source as the element of tourist infrastructure in certain Carpathian regions will enable reliable and effective electricity supply to local consumers.

Solar panels based on photovoltaic and renewable energy sources are proposed to be used to develop the tourism infrastructure for street lighting in villages.

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ЧИННИКИ ПРОСТОРОВИХ МОЖЛИВОСТЕЙ ТА ОБМЕЖЕНЬ ДЛЯ ПРОЕКТІВ ВІДНОВЛЮВАНОЇ ЕНЕРГЕТИКИ У КАРПАТСЬКОМУ РЕГІОНІ УКРАЇНИ

В статті обгрунтовано використання відновлювальних джерел енергії в сталому туристичному розвитку регіону. Сталий розвиток туризму в Карпатському регіоні розглядається з урахуванням ситуації в країні щодо енергетичного та екологічного впливу традиційних джерел енергії, що має забезпечувати інтереси туристичної галузі в економіці, суспільстві та враховувати екологічну ситуацію й застосовувати заходи для її покращення.

Виділено три етапи вибору територій під реалізацію проектів відновлювальних джерел енергії: підбір потенційно придатної території; врахування критеріїв виключення;детальна оцінка потенційних майданчиків чи територій. Визначено фактори впливу на визначення просторових обмежень та можливостей для будівництва вітрових, сонячних електростанцій та малих гідроелектростанцій по параметрах сталого туристичного розвитку Карпатського регіону. Загальними для всіх є відповідні вітрові, сонячні та гідрологічні ресурси, топографічні умови та наявні перешкоди, доступність місцевості, наявність інфраструктури, наявність точки приєднання до мережі, якість і склад ґрунту, врахування житлових районів, відкритість місцевості, крутизна схилів, екологічні обмежуючі фактори, аналіз землекористування, наявність природоохоронних територій та ландшафтів.

На основі проведених досліджень представлена ГІС карта просторового розподілу сонячного потенціалу на горизонтальну поверхню для Карпатського регіону. Сонячне випромінювання залежить від висоти, орієнтації схилу та інших мезо- і мікрофакторів, але по всій території сумарна сонячна радіація перевищує 1000 кВт-год на 1 м^2 на рік. У роботі запропоновано рекомендації щодо інноваційного сегмента туристичної інфраструктури для подальшого розвитку як основних туристичних центрів та ізольованих населених пунктів у складі Карпатського регіону на прикладі сонячної енергії.

Ключові слова: сталий розвиток, сталий туристичний розвиток, відновлювальні джерела енергії, ландшафт, просторові обмеження

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