Renewable energy sources for sustainable tourism in the Carpathian region

O M Mandryk¹, L M Arkhypova², O V Pobigun² and O R Maniuk¹

¹Ivano-Frankivsk National Technical University of Oil and Gas, Institute of Environmental Engineering, Department of Ecology, Karpatska str., 15, 76018, Ivano-Frankivsk, Ukraine
²Ivano-Frankivsk National Technical University of Oil and Gas, Institute of Architecture, Construction and Tourism, Department of Tourism, Karpatska str., 15, 76018, Ivano-Frankivsk, Ukraine

E-mail: konsevich@ukr.net

Abstract. The use of renewable energy in sustainable tourism development of the region is grounded in the paper. There are three stages of selecting areas for projects of renewable energy sources: selection of potentially suitable area; consideration of exclusion criteria, detailed assessment of potential sites or areas. The factors of impact on spatial constraints and opportunities for building wind, solar and small hydro power plants on the parameters of sustainable tourism development in the Carpathian region were determined.

1. Introduction

Considering the energy potential of the Carpathian region, it is expedient to implement such types of renewable energy sources like wind, solar and small hydroelectric power plants [1]. The basic condition for the stages of development and implementation of renewable energy sources is consideration of spatial constraints and opportunities of their implementation, taking into account all the parameters of sustainable regional development, particularly touristic.

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.

2. Finding the suitable site

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.

2.1. Wind power station
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.

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.

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

2.2. Solar electricity technologies
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) [2].

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, visual 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.

2.3. Small hydroelectric power stations

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 [3].

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 is necessary to get as detailed geological data as possible.

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.

3. Results

In the work proposed recommendations for pre-innovation segment of the tourism infrastructure to future development as the major tourist centres 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 micro factors, 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. Figure 1 shows specific investments make $1500-1800 / kW of installed capacity.

The Ivano-Frankivsk region is convenient for solar energy usage in 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 in 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.

It is proved that the development of solar energy in the recreational and tourism development in the Carpathian region is not objective resource, technical, operational, environmental and economic obstacles. 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.
Figure 1. Total annual potential of solar energy

Table 1. Monthly meteorological data (Ivano-Frankivsk)

| Month       | Global horizontal emission, Kw·h/m² | Temperature, °C | General emission per area kW·h/m² | Effective global emission, kW·h/m² |
|-------------|--------------------------------------|-----------------|-----------------------------------|------------------------------------|
| January     | 21,9                                 | -3,98           | 46,4                              | 44,9                               |
| February    | 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                             |
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                                   |
| February| 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                                   |

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 [4], [5].

4. Conclusions

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.

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