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GIS approaches to evaluating renewable energy potential in the Ternopil and Ivano-Frankivsk territorial communities

*M. Lopushanska *(Professional Association of Environmentalists of the World (PAEW)*, L. Arkhypova *(Ivano-Frankivsk National Technical University of Oil and Gas)*, I. Barna *(Ternopil Volodmyr Hnatiuk National Pedagogical University)*, O. Savchenko *(Lviv Polytechnic National University)*, O. Lopushanskyi *(West Ukrainian National University)*

SUMMARY

This study investigates the renewable energy potential of two Ukrainian territorial communities – Ternopil and Ivano-Frankivsk – through geoinformation modelling of solar and wind resources. Using data from the Global Solar Atlas and the Global Wind Atlas for the period 1994–2024, together with the GIS software QGIS 3.34.3, long-term averages of solar irradiation and wind speed were analyzed. The results demonstrate that both regions possess favorable conditions for solar energy development. Global Horizontal Irradiation (GHI) ranges from 1150 to 1165 kWh/m², which is sufficient to ensure efficient photovoltaic performance. The wind energy assessment reveals greater variability between the two territorial communities. Although both communities exceed the critical threshold of 5.5 m/s required for wind turbine operation, Ternopil territorial community exhibits more favorable wind conditions, with average annual speeds of 6.1–7.1 m/s at 100 m. In contrast, the Ivano-Frankivsk territorial community shows lower values, averaging 5.5–6.1 m/s, which limits its wind energy potential compared to Ternopil territorial community. Overall, the findings confirm that geoinformation tools combined with climate datasets provide a reliable scientific basis for regional energy planning. The Ternopil territorial community demonstrates particularly strong potential for wind energy, while both regions offer significant opportunities for solar power development.

Keywords: renewable energy, solar energy, wind energy, renewable energy sources, GIS technologies, GIS mapping, Ternopil, Ivano-Frankivsk

Corresponding Author: mariialopushanska@gmail.com

Introduction

The modern stage of energy development is characterized by increasing attention to renewable energy sources, with solar and wind power playing a particularly important role. These areas are gaining relevance in the context of global climate change, the need to reduce dependence on fossil fuels, and the pursuit of sustainable development goals. For Ukraine, which possesses significant natural potential, the use of solar and wind energy represents a promising pathway to diversify its energy balance and strengthen energy security. An essential tool for assessing renewable energy opportunities is geoinformation modeling.

The use of international platforms such as The Global Solar Atlas and The Global Wind Atlas enables the analysis of long-term averages of solar radiation and wind speed. When combined with modern geographic information systems, such as QGIS, these data provide the basis for mapping the potential of specific regions and identifying optimal sites for new renewable energy projects.

Therefore, the integrated application of geoinformation technologies and climate databases makes it possible to justify the renewable energy potential of selected regions and provides a scientific basis for strategic decision-making in regional energy policy. Two territorial communities were selected for analysis: the Ternopil city territorial community (Ternopil region) and the Ivano-Frankivsk city territorial community (Ivano-Frankivsk region).

Method and Theory

For geoinformation modelling of the global horizontal irradiation data from online app, the long-term averages of solar resource and PV power potential data are calculated for the periods 1994-2024 for most of Europe (The Global Solar Atlas, 2025). For geoinformation modelling average annual wind speed, data from long-term monitoring from the open platform The Global Wind Atlas (The Global Wind Atlas, 2025) was selected. The GIS software QGIS 3.34.3 was used for mapping.

Research results and their discussion

Solar energy. Based on The Global Solar Atlas (The Global Solar Atlas, 2025), the flat territory of Ukraine has favourable conditions for the development of solar energy. An important indicator for the development of solar energy is global horizontal irradiation (GHI). The term solar irradiance represents the power from the sun that reaches a surface per unit area. Direct irradiance is the part of the solar irradiance that directly reaches a surface; diffuse irradiance is the part that is scattered by the atmosphere; global irradiance is the sum of both diffuse and direct components reaching the same surface/ (The Global Solar Atlas, 2025). According to The Global Solar Atlas (The Global Solar Atlas, 2025) (Fig.1) the global horizontal irradiation for the Ternopil territorial community is 1150-1160 kWh/m^2, and for the Ivano-Frankivsk territorial community – 1155-1165 kWh/m^2.

For photovoltaic modules to operate normally under NOCT conditions, insolation must exceed 800 W/m^2. In general, the amount of global horizontal irradiation is sufficient for the optimal operation of new solar power plants in territorial communities. Based on the annual reports on the state of the climate - The European State of the Climate, ESOTC (Copernicus Climate Change Service (C3S), 2025) for the period 2017–2024, the Ternopil and Ivano-Frankivsk territorial communities are characterised by anomalies in solar radiation on the surface.

In 2024, these anomalies accounted for up to 4% of the average values for the base period (1991–2020). The highest deviations are typical for May-July and September, with an increase in solar radiation to 30 W/m^2, as well as April, with a decrease to 30 W/m^2. For other months, this indicator ranges from -10 to +10 W/m^2.

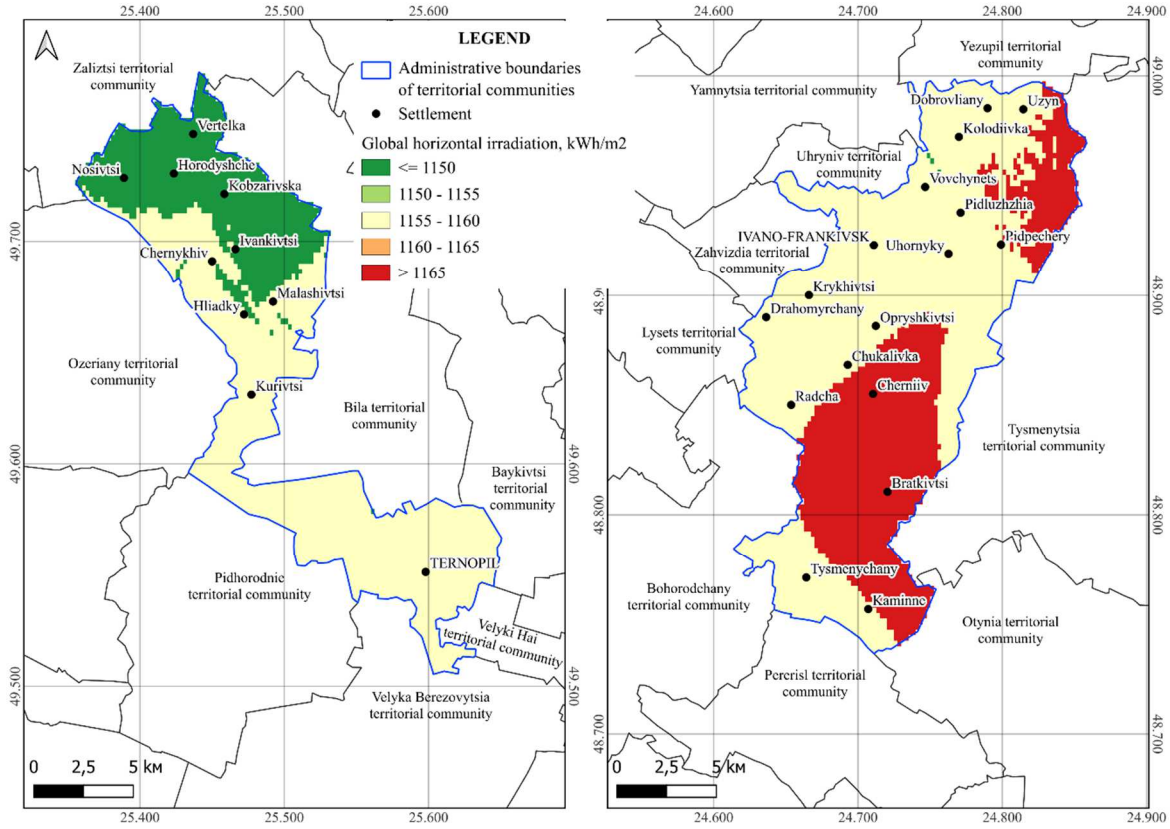

Figure 1. *Global horizontal irradiation in the Ternopil and Ivano-Frankivsk territorial communities (based on The Global Solar Atlas, 2025).*

Wind energy. Modern wind power plants operate within defined wind speed ranges: for the Danish manufacturer Vestas (Vestas, 2025), this range is 3–24 m/s; for the German company Nordex (Nordex, 2025), 3–20 m/s; and for the Dutch manufacturer Emergya Wind Technologies (EWT) (EWT Directwind, 2025), 3–25 m/s. The efficiency of electricity generation in wind power plants is directly determined by the prevailing wind speed. In 2023, average monthly wind speed anomalies at a height of 10 m were observed relative to the average values for the 1991–2020 observation period (from -20 to 30%). Thus, the largest anomalies with a decrease in speed compared to the average values are characteristic of June and September, and with an increase – for November (The Copernicus Climate Change Service (C3S) (2023).

According to The Global Wind Atlas (The Global Wind Atlas, 2025) (Fig.2) the annual mean wind speed at 100 m for the Ternopil territorial community is 6.1…7.1 m/s, and for the Ivano-Frankivsk territorial community – 5.5…6.1 m/s. Areas with an average annual wind speed of over 5.5 m/s are prospective for the use of wind turbines (Kudria, 2020). When selecting potential sites for wind energy projects, there are also other resources available: RE Data Explorer (RE Data Explorer, 2025) and The New European Wind Atlas (The New European Wind Atlas, 2025). According to data from The New European Wind Atlas (The New European Wind Atlas, 2025), a vertical wind profile has been created for the city of Ternopil according to which the average annual wind speed is 5.33 m/s (±1.47 m/s), at a height of 75 m/s – 5.88 m/s (±1.63 m/s), at a height of 100 m – 6.33 m/s (±1.79 m/s) (Lopushanska et al., 2024).

According to data from The New European Wind Atlas (The New European Wind Atlas, 2025), a vertical wind profile has been created for the city of Ivano-Frankivsk according to which the average annual wind speed is 4.02 m/s (±1.52 m/s), at a height of 75 m/s – 4.46 m/s (±1.71 m/s), at a height of 100 m – 4.83 m/s (±1.83 m/s). Based on the data obtained, more favourable conditions for the development of wind energy sources are available in the Ternopil territorial community.

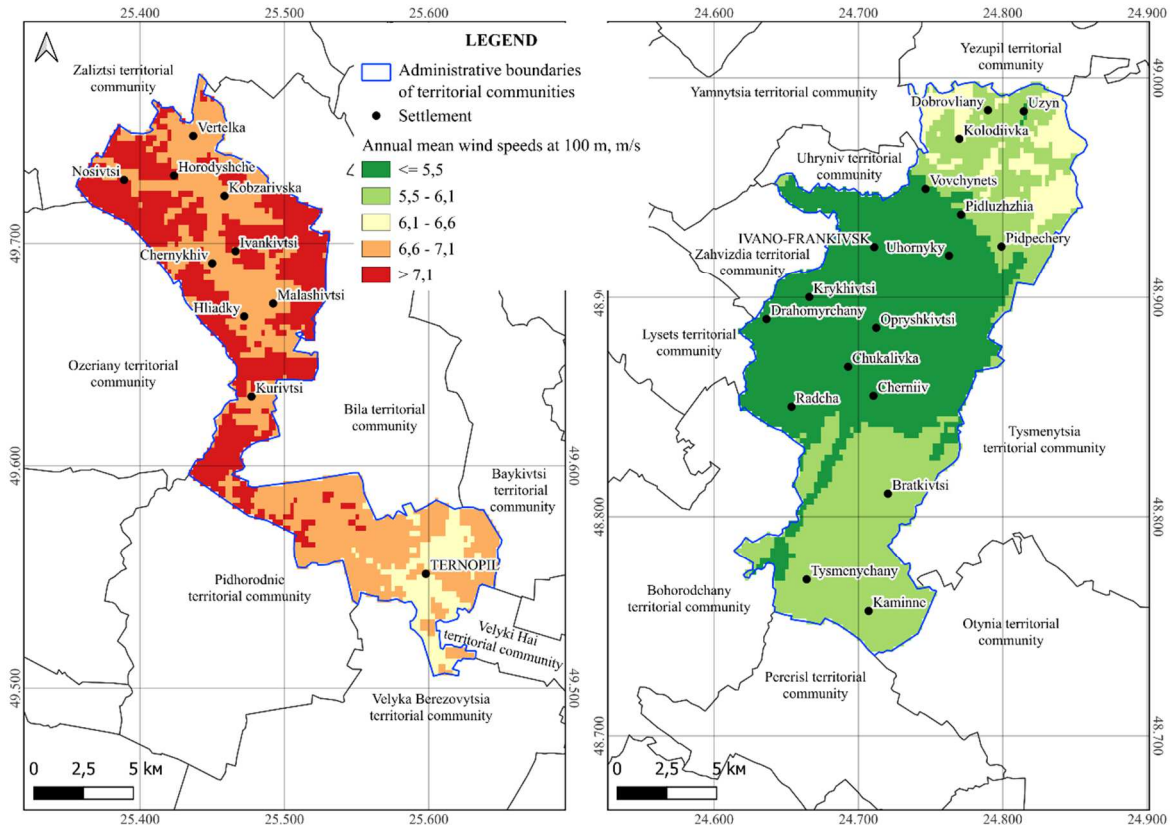

Figure 2. *Annual mean wind speed at 100 m in the Ternopil and Ivano-Frankivsk territorial communities (based on The Global Wind Atlas, 2025).*

Conclusions

The conducted analysis confirms that both the Ternopil and Ivano-Frankivsk territorial communities demonstrate favorable conditions for the development of renewable energy, with notable differences in their solar and wind potential. Solar energy indicators, particularly global horizontal irradiation values ranging from 1150 to 1165 kWh/m², ensure sufficient insolation for the effective operation of photovoltaic systems in both regions. Although climate anomalies during 2017–2024 influenced solar radiation by up to 4% compared to baseline values, these deviations remain within acceptable limits and do not significantly undermine the long-term prospects of solar power generation.

Wind energy assessment highlights greater regional variation. While both communities meet the basic threshold of 5.5 m/s annual mean wind speed required for wind turbine operation, the Ternopil community demonstrates a more favorable wind profile, with average annual speeds of 6.1–7.1 m/s at 100 m. By contrast, Ivano-Frankivsk shows lower values, making its potential less pronounced.

Overall, the integration of geoinformation modeling and climatic datasets provides a solid scientific foundation for regional planning and strategic energy policy. The results emphasize the importance of Ternopil as a priority area for wind energy development, while both regions remain promising for solar power investments.

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