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SZYMON PELCZAR, MAŁGORZATA ŚLIWKA

AGH University of Science and Technology, Faculty of Civil Engineering and Resource Management, email*: pelczipelczar@gmail.com, sliwka@agh.edu.pl*

DEVELOPMENT OF RENEWABLE ENERGY SOURCES INVESTMENTS IN THE CONTEXT OF SPATIAL ORDER AND THEIR IMPACT ON THE LANDSCAPE

Although installations to convert renewable energy sources into electricity respond to the challenges of sustainable development, their operation is not without their impact on the environment. The landscape is one of environment components on which renewable energy sources (RES) infrastructure effects. The article presents a possible location for investments in wind and photovoltaic power plants based on legal requirements. The areas in which they are most frequently carried out are also mentioned. It was indicated how the infrastructure of photovoltaic and wind power plants affects spatial order and landscape.

Key words: RES, landscape, rural areas, environmental impact assessment

I. INTRODUCTION

The use of fossil fuels to meet humanity's energy needs has a significant impact on the environment [Darkwah et al. 2018]. Therefore, energy transformation measures are being taken to make energy production more environmentally and climate friendly [Kurtyka 2021, Soliński et al. 2017]. A way to reduce emissions from the burning of fossil fuels is the continued development of renewable energy sources. However, RES investments also have some environmental impact during the operational phase of the infrastructure that comprises them. One impact is the transformation of landscape form, particularly by photovoltaic and wind power plants . It can also be pointed out that RES development is a kind of challenge for spatial management, as all spatial components should be interconnected in a harmonious way, creating spatial order. The paper focuses on determining how these two types of RES projects (which are developing dynamically) affect the spatial order of municipal areas in Poland. Their visual impact on the landscape is also indicated [Badora 2011].

II. RESEARCH MATERIAL AND METHODS

In order to determine the place of photovoltaic and wind power investments in spatial planning, the current legislation in this area was showed. After that, by analysing publicly available databases, the most optimal location of projects (photovoltaic and wind power plants) realized and planned in Poland was determined. On this basis, their impact on spatial order and landscape changes was indicated. It was proposed a new type of landscape developed as a result of indicated renewable energy sources investments. The paper also notes one possible way to predict the impact of the implementation of these investments on spatial order and landscape by using geoinformatics modeling.

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III. RESULTS OF THE ANALYSIS

3.1. Legal conditions

The main legal act determining the location of wind power plants is the Act of 20 May 2016 on wind power investments [Dz. U. 2021 poz. 724 consolidated text, Hektus 2020]. This piece of legislation specifies that the location of a wind power plant shall only take place on the basis of a local development plan (art. 3). Moreover wind turbines may only be located at a distance of ten times their height from residential buildings or buildings with a mixed function which includes a residential function (art. 4(1-2)). The indicated distance must also be kept from the following forms of nature protection: national parks, reservations, landscape parks and Natura 2000 areas. Also the way from promotional forest complexes must equals ten times of wind turbines hight (art. 4(2)). The implementation of the aforementioned projects is only possible if they receive an environmental approval (which must be obtained prior to the construction permit). This administrative decision requires investors to carry out an EIA [Łaguna and Łaguna 2012, Korona and Harasymiuk 2018, Michalski 2013, Niedziela 2020, Dz. U. 2022 poz. 916 consolidated text].

The picture (Fig. 1) taken in the Barzowice (a village in Poland, in the Zachodniopomorskie Voivodship) shows an example of a wind power plant.

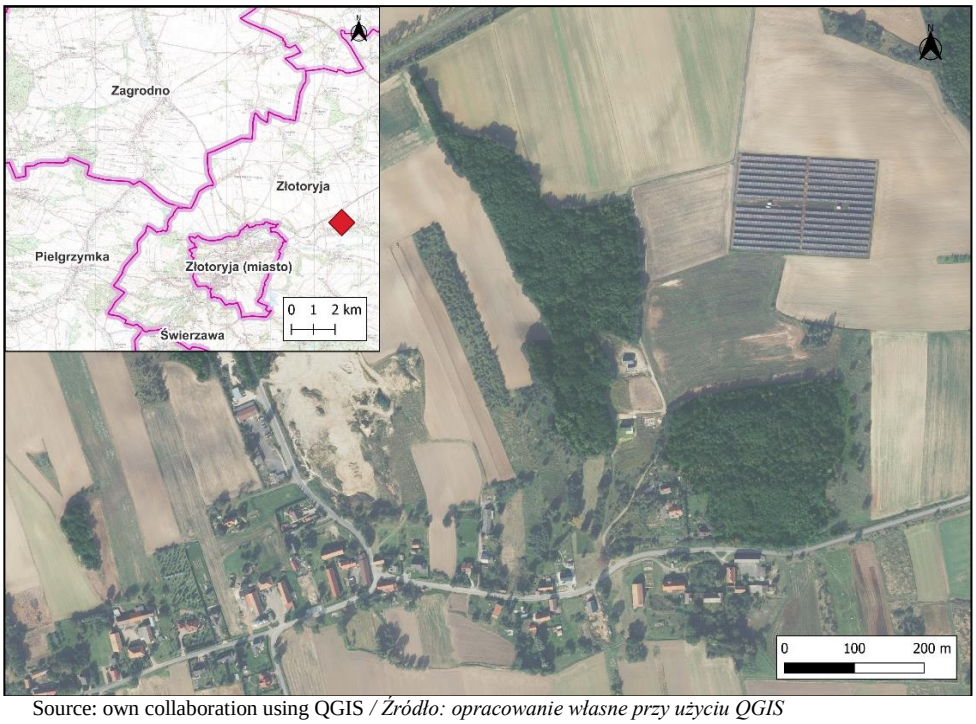
Source: own photo / Źródło: zdjęcie własne

Fig. 1. Example of a wind power plant
Rys. 1. *Przykład elektrowni wiatrowej*

Unlike wind power plants, the second type of enterprises under discussion - photovoltaic plants - do not need to be located on the basis of a local development plan. It is sufficient for the entrepreneur to obtain a zoning approval (in accordance with the provisions of the Planning and Spatial Development Act [Dz. U. 2022 poz. 503 consolidated text].

In accordance with the legal acts relating to environmental impact assessment [Dz. U. 2022 poz. 1029 consolidated text, Dz. U. 2019 poz. 1839 as amended] this kind of investments must obtain environmental approval only if their building surface area exceeds 0,5 ha in areas covered by forms of nature protection (or buffer zones of national parks, reservations and landscape parks) or 1 ha in other areas [Niedziela 2020].

The map (fig. 2) shows 2,65 ha photovoltaic power plant located in Kozów village (Dolnośląskie Voivodship).



Source: own collaboration using QGIS / *Źródło: opracowanie własne przy użyciu QGIS*

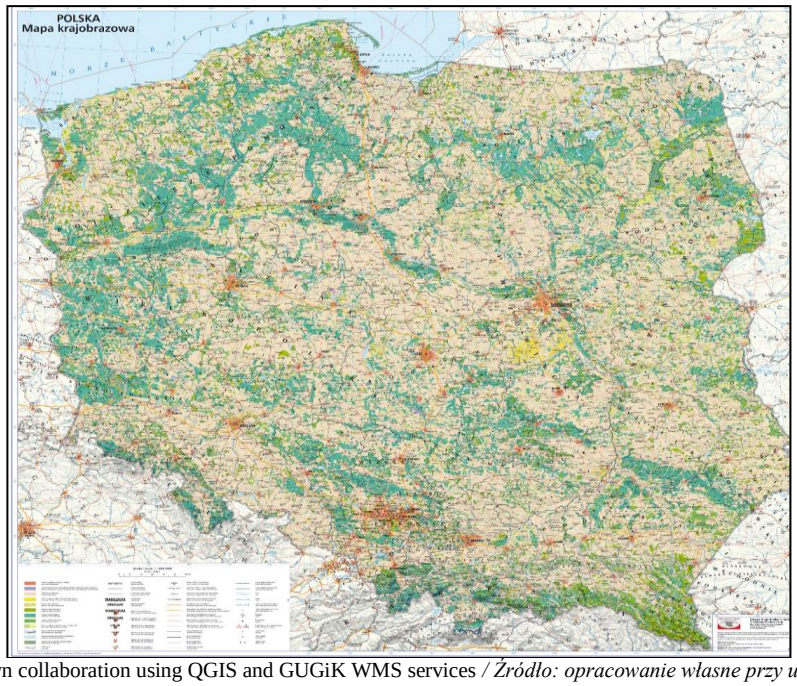
Fig. 2. Example of large (2,65 ha) power plant
Rys. 2. *Przykład rozległej (2,65 ha) elektrowni fotowoltaicznej*

Furthermore, the Planning and Spatial Development Act also specifies what spatial order and landscape is. Throught spatial order should be understood as a spatial arrangement which forms a harmonious whole and takes into account, in an orderly relationship, all the conditions and requirements of the functional, socio-economic, environmental, cultural and compositional aesthetic (art 2(1)). On the other hand the landscape is the space perceived by people, that contains natural elements or the creations of civilisation. This space may be shaped by natural factors or human activity (art. 2(16e).

3.2. Localisation of the enterprises under consideration

The largest part of Poland's area is covered by agricultural land, which accounts for 60.54% of the total country's area [GUS 2021]. This makes that landscapes of cultivated fields and permanent crops cover a large part of the country, what was showed on Landscape Map of Poland (Fig. 3). The largest areas of land are characterised by the indicated landscape types (brown and yellow colours respectively).

The analysis of the EIA database [Baza OOŚ] and the building permit database [Wyszukiwarka publiczna RWDZ] shows that the vast majority of large-scale solar power and wind power investments are carried out in rural areas (rural municipalities and rural areas of urban-rural municipalities).



Source: own collaboration using QGIS and GUGiK WMS services / *Źródło: opracowanie własne przy użyciu QGIS oraz usługi WMS GUGiK*

Fig. 3 Landscape Map of Poland
Rys. 3. *Krajobrazowa Mapa Polski*

The development of these enterprises is causing a change of land use forms. Previously functioning directions of spatial development (usually agricultural areas) are being transformed as a result of location new landscape components in these areas. This is exemplified by the changes, that have taken place in the landscape of parts of the Wicko (pomorskie voivodship) municipality following the introduction of the wind turbines (fig. 4)

The location of photovoltaic power plants in rural areas also influences changes in the landscape and the interconnectedness of space components. The picture (fig. 5) shows the infrastructure of such a power plant, which creates a new viewing foreground [Drapińska-Bysiek 2019].

Wind turbines have a major impact on spatial order due to their height (thus having a visual impact over considerable distances). They create a new anthropogenic landscape dominant. They also change the so-called 'sky line' (the apparent contact between the sky and landscape elements). It was previously outlined by tree canopy, rural buildings and natural relief. With the introduction of a new spatial component (wind turbines), its dynamics are different and somewhat disturbed. The space into which such infrastructure has been introduced creates new links between natural elements (woodland, lower vegetation, wooded areas in the form of rows, copses) and anthropogenic elements (arable fields, rural buildings). In a way, a correspondence is taking place between the old, 'traditional' elements of the rural landscape and the new component of wind turbines.

Source: own collaboration using QGIS / *Źródło: opracowanie własne przy użyciu QGIS*

Fig. 4. Changes in development of municipality of Wicko affecting the spatial order and the rural landscape
Rys. 4. *Zmiany w zagospodarowaniu Gminy Wicko wpływające na ład przestrzenny i krajobraz wiejski*


Source: own photo / Źródło: zdjęcie własne

Fig. 4. Example of a photovoltaic power plant in a rural area
Rys. 5. *Przykład elektrowni fotowoltaicznej na obszarze wiejskim*

3.3. Spatial order and cultural landscape vs implementation of selected RES investments

In contrast to the previously identified developments, the visual impact of PV power plants on space users only occurs in relation to the nearest, neighbouring areas [Badora 2011]. They change the previous forms of view foregrounds (cultivated fields, fallow land, wasteland) to the anthropogenic type of this landscape element. The infrastructure that makes up these power plants is characterised by considerable spatial extent. This has a significant impact on the local landscape by introducing a large-scale anthropogenic element into the rural space.

3.4. Predicting the impact of projects under discussion on the rural landscape and spatial order

The use of geoinformatics tools (for example, using QGIS, a program widely used for spatial analysis purposes) is one of possible method for predicting the visual impact on space users and spatial linkages of proposed developments.

Using a Digital Surface Model (DSM) and mathematical modeling, it is possible to analyse whether a given element of space to be introduced into it will be visible from a given observation point. Modeling results take into account view obstructions (which are part of the DSM) such as buildings and higher vegetation. In addition, ground surface denivelations that may significantly affect the extent of the visual impact of a project are also taken into account. The modeling result should be interpreted accordingly, assessing the validity of the results beforehand.

IV. CONCLUSIONS

Formal-legal requirements, which have been indicated, have the greatest influence on the choice of location for future wind and photovoltaic plants. Most of the developments in question are designed in rural areas, which affects spatial order. It also causes a transformation of the landscape, as new forms of land use are introduced.

The indicated changes in the landscape and the structure of the interrelationships of the spatial components do not necessarily involve a disturbance of the spatial order and a negative impact on the space perceived by people. It is worth noting, that the spatial changes described are the result of the energy transition and of conducting spatial planning in a way that meets the challenges of sustainable development. Indeed, the shaping of spatial order should take into account not only environmental but also economic and social requirements.

The infrastructure of the RES types in question creates new links between elements of the rural space. The cultural landscape is being transformed, what follows from a process of crystalization of a new type of landscape. It can be suggested that this is the *agricultural landscape with RES infrastructure*. Furthermore this suggesting type of a landscape could be divided into groups which will be reliant on RES types present in a landscape.

In addition, it is important that each investment is treated individually. It is crucial that the impact of projects on different environmental elements, including the landscape, would be assessed properly. It may be useful to use indicated GIS modeling in this case.

Also administrative authorities should take into account the idea of spatial order and landscape protection in administrative decisions, in particular by environmental permit. On the other hand, investors should project enterprises to have regard to spatial interconnections of local rural space. This approach to investment development will then be compatible with corporate social responsibility (CSR).

In connection with the above it can be stated that development of the investments in question impact on spatial order by introducing a new, anthropogenic elements into landscape. The characteristics of the landscape are changing, taking on more anthropogenic

features. However, it seems well-based to propose that both photovoltaic and wind power plants do not disrupt the spatial order, responding to the requirements of the green transition. Investors should be required to ensure that the way in which the land is developed through renewable energy sources infrastructure meets aesthetic requirements.

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ROZWÓJ INWESTYCJI W ODNAWIALNE ŹRÓDŁA ENERGII W KONTEKŚCIE ŁADU PRZESTRZENNEGO I WPŁYW OZE NA KRAJOBRAZ

Streszczenie

Pomimo, że instalacje przetwarzające odnawialne źródła energii na energię elektryczną odpowiadają na wyzwania zrównoważonego rozwoju, to ich funkcjonowanie nie pozostaje bez wpływu na środowisko. Krajobraz stanowi jeden z komponentów środowiska, na który oddziałuje infrastruktura odnawialnych źródeł energii (OZE). Artykuł przedstawia możliwości lokalizacji inwestycji z zakresu elektrowni wiatrowych i fotowoltaicznych w oparciu o wymogi prawne. Zaprezentowano również obszary, na których są one najczęściej realizowane. Wskazano też sposób w jaki infrastruktura elektrowni fotowoltaicznych i wiatrowych wpływa na ład przestrzenny i krajobraz.

Słowa kluczowe: OZE, krajobraz, obszary wiejskie, ocena oddziaływania na środowisko