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ECONOMIC AND ENVIRONMENTAL ANALYSES OF THE CONSTRUCTION OF ON-SITE, LARGE-SCALE PHOTOVOLTAIC FARMS

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ABSTRACT: This paper addresses the construction of large-scale photovoltaic farms. The paper describes the issues of the current overconsumption of energy from traditional sources and the associated overuse of fossil fuels. Alternatives to these processes are presented based on literature sources, and the use of renewable energy sources, focusing on solar energy, is recommended here. In the research section, attention was focused on the economic and environmental aspects of ventures involving the construction of large-scale farms by manufacturing companies with high monthly energy consumption. In the first stage of the work, economic analyses were carried out based on data obtained from photovoltaic installation companies. For the simulation, an assessment of the costs and benefits of building a photovoltaic farm for a steel construction company located in eastern Poland was used. Another element of the research part of the study was an analysis of the results of a questionnaire survey, which was conducted among people living in the vicinity of such farms. On this basis, the environmental impact of neighbouring areas of this type of investment was estimated. Positive conclusions from the analyses made it possible to recommend the construction of this type of facility, especially for manufacturing plants with high electricity consumption.

KEYWORDS: photovoltaic farms, renewable energy sources, photovoltaic panels, solar panels, environment, electricity, RES

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Introduction

Mastery over the forces of nature has been the domain of humankind since the dawn of time (Devauchelleet al., 2006). The ability to use fire contributed to social bonds and opportunities for expansion and gave advantages over other animal species (Pausas & Keeley, 2009). Conscious of using its heat and light opened the gates to the development of civilisation. As a result of progress, man learned to use not only wood energy but also other deposits of energy and raw materials found in the form of coal, oil, and natural gas deposits (Brownlie, 1922). The use of these raw materials on an ever-increasing scale has helped to accelerate technical progress in many industries (McCloskey, 1981). Today, however, mankind is also increasingly recognising the disadvantages that the consumption of fossil fuels brings (Olkuski, 2018). Their deposits are only found in certain countries that profit from them and use these resources to necessitate the economic and political dependence of other countries (Plewa & Strozik, 2019). The deposits of these raw materials are being depleted, and it is already indicated that in a few decades, it will only be possible and profitable to extract them in a few places in the world. However, the greatest threat to civilisation as a whole is the climatic effects of burning fossil fuels (Garrett, 1992). Indeed, this process is the main cause of the greenhouse effect (Mitchell, 1989). An increase in global temperature has been recorded for some time, contributing to an imbalance in the atmosphere (Kweku et al., 2018). This anomaly leads to numerous floods, droughts, hurricanes and rising sea levels. The consequence of this is massive damage to infrastructure (Mikhaylov et al., 2020). Countries located in hot climate zones suffer the most from the effects of these disasters. Despite the fact that they are classified as poor, developing countries, the disasters described cause additional huge economic losses and, during droughts, cause famines and migrations of unprecedented magnitude (Solomon et al., 2010). In this situation, it is increasingly pointed out that the era of fossil fuels should be coming to an end, and humanity should try to use energy from renewable sources (Nowicki, 2012).

Literature review

The increase in energy demand due to rapid economic development combined with the described conscious, limited use of fossil resources, as well as excessive environmental pollution, has resulted in a great deal of interest in alternative energy in recent years (Rehman, 2020). An increasingly popular topic is the use of renewable energy sources whose utilisation is not associated with their long-term scarcity (Rockett et al., 2011), as they renew themselves in a short period of time. Their raw materials are constantly replenished, and the replenishment process can occur spontaneously, i.e. without the need for human intervention (Dresselhaus & Thomas, 2001). Renewable energy is often referred to by the term "green energy" because its resources occur naturally in nature, and their use is the least harmful to the environment, as well as reducing emissions of greenhouse gases and other hazardous substances (Bakis, 2007). The Renewable Energy Sources Act of 20 February 2015 states that alternative energy sources are renewable and non-fossil energy sources, which include wind energy, solar energy, aerothermal energy, geothermal energy, hydrothermal energy, hydropower, wave, current and tidal energy, energy obtained from biomass, biogas, agricultural biogas and bioliquids (Act, 2015).

The share of renewable energy in the fuel and energy balance is steadily increasing (Pacesila et al., 2016). This is mainly due to the development of new technologies (Bernath et al., 2021), as well as the fact that these installations are often financed with the support of EU funds. The use of renewable energy sources brings many benefits to local communities (Nawrot, 2017). This increases energy security, promotes regional development or creates new jobs (Akellaet al., 2009). Increasing the share of renewable energy sources in the world's fuel and energy balance also brings environmental benefits (Midilli et al., 2007). There is an improvement in the efficient use and conservation of energy resources, as well as an improvement in the environment through a reduction in pollution to the atmosphere and water and a reduction in the amount of waste produced (Tytko, 2010).

One of the primary sources of renewable energy is the electromagnetic radiation of the sun (Saidi & Omri, 2020). According to literature sources, the amount of sunlight that reaches the Earth's surface in one hour would be sufficient for the world's energy consumption for a whole year. For this

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reason, the use of the sun's rays to generate electricity is considered a future technology that is currently being rapidly developed (Kabir et al., 2018). Solar energy (Gong et al., 2019) can be used in two ways: passive and active. The concept of passive use of solar energy is to use the most energy and prevent losses. This is done without special equipment, thanks to natural heat exchange phenomena. Passive systems are used, among other things, to heat buildings by means of appropriate siting, i.e. positioning in relation to the sides of the world and appropriate selection of materials for construction. Appropriate devices such as photovoltaic cells (Chenni et al., 2007) are already required to make active use of solar energy.

Photovoltaics is an innovative technology that enables the conversion of sunlight into electricity (Mathews et al., 2019). Recently, the concept has been associated with two important issues, namely energy and environmental protection. It provides an alternative to nature-destroying methods of producing electricity during ever-increasing demand (Saunder & Turner, 2008). Photovoltaics, as one of the few branches of electronics, is still developing rapidly despite decades of practical use (Grätzel, 2005). Its development is also accompanied by a steady decline in the price of the electricity received (Sibinski & Znajdek, 2016). Connected combinations that generate electricity from the sun are so-called photovoltaic farms (Brodziński et al.,2021). These are solar power plants, usually sited on the ground. They are specially delimited areas with chains of photovoltaic panels connecting to form a single system. They have a specific capacity to generate electricity in full sunlight, which depends on the number of solar panels installed (Ghaediet al., 2014). This type of power plant has great potential to meet most of the electricity needs of all mankind (Yang et al., 2017). These installations allow electricity to be consumed not only at its point of generation but also to be transmitted to the power grid for use by other consumers. The energy produced can also be stored in batteries for use during inferior solar radiation (Alva et al., 2017).

The last decade has seen a rapid development in the use of solar energy (Hou et al., 2011), primarily in the installation of solar panels and photovoltaic panels. It is believed that solar techniques will soon account for a significant proportion of global energy (Palacios et al., 2020). If these predictions are confirmed, it will mean that all the countries of the world will have access to clean, safe and free fuel. This will allow them to develop economically and civilisationally, ending any political conflicts over access and use of energy resources (Blaga et al., 2019). However, it should be remembered that currently, as mankind, we are only at the beginning of the road to the rational use of this energy source. Therefore, attention is also increasingly being drawn to the need to conduct both economic and environmental analyses in order to learn about the risks of this type of activity (Wolańczyk, 2019).

With this in mind, this paper focuses on the economic and environmental aspects of large-scale wind farm projects. The first stage of the work was to analyse the economics of such projects based on data obtained from companies involved in photovoltaic installations. Another element of the research part of the project was the analysis of the results of a questionnaire survey conducted among people living in the vicinity of the farms. On this basis, the environmental impact of the areas neighbouring such investments was estimated.

Research methods

In the first stage of the work, economic analyses were carried out for this type of project based on data obtained from photovoltaic installation companies. This was done using the cost-benefit analysis method. The data was obtained from surveys conducted by installation manufacturers, referring to the methods presented in (Tokarski & Zegardło, 2020). The cost-benefit analysis that was used is a comprehensive method for assessing the effectiveness of investments and projects, taking into account all expected benefits and costs, including qualitative and quantitative elements, to determine the degree of effectiveness of a given investment in the environment (Becla et al., 2012). In addition to the economic aspects of the project, the cost-benefit analysis also took into account the social, cultural and environmental areas considered in subsequent analyses (Boardman et al., 2006). The theoretical basis for the above analysis was welfare economics (Szot-Gabryś, 2013). An assessment of the costs and benefits that would be associated with the construction of a photovoltaic farm for a steel structure company located in eastern Poland was used for the simulation. With this type of production, all tools,

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such as welding machines, hydraulic presses, laser cutting machines, drilling machines, etc., run on electricity, which has so far consumed a very high level of energy, averaging 607361kWh per year. Electricity bills averaged 6398 EURper month, which amounted to 76 778 EUR in charges per year. It was assumed that the plant would be equipped with a photovoltaic installation, which would cover the full demand for electricity. According to the calculations, the electricity bill will therefore amount, after installation of the installation, to the equivalent of the fixed and handling charges: 48.54 EUR per year.

Three variants were considered for the calculation. The first option assumed the use of the cheapest materials available on the market, which would result in the fastest return on investment. However, this was related to the expected need to replace the electronic sub-assembly of the inverter between the 5th and 10th year of operation of the installation. This option also assumed that the photovoltaic panels would operate for a maximum of 25 years. The manufacturer's warranty was 15 years for the photovoltaic panels and 5 years for the solar inverter. Variant two involved the use of higher-quality components optimised in terms of value for money. In this case, the manufacturer's guarantee was 15 years for the photovoltaic panels and 10 years for the solar inverter. The need to replace the electronic component of the inverter was anticipated between 10 and 14 years of operation. It was also assumed that the photovoltaic panels would operate for more than 25 years. The last option assumed the highest quality components and the longest expected performance. In this case, the manufacturer's guarantee was as much as 30 years for the photovoltaic panels and 25 years for the microinverters. The microinverters were expected to need to be replaced between 25 and 30 years of operation. It was also assumed that the photovoltaic panels would operate for more than 25 years. The results of the analyses in which the costs of constructing the installation, the returns on electricity savings, an estimate of the payback time for the investment and the calculation of the returns on savings over a period of 25 years were estimated are summarised in a summary table.

The second part of the research was the analysis of the results of the questionnaire survey conducted. The object of the research, according to Apanowicz (2002), was to analyse the opinion of local residents concerning the impact of photovoltaic farms on the environment of their surroundings, and its aim, according to Skorny (1984), was to determine the degree of this impact. In accordance with Łobocki (2000), the research problem was formulated and defined by the question: "Does the photovoltaic farm have an impact on the environment?". Additionally, helpful specific questions were formulated: "Does the support for the development of photovoltaic farms depend on where they are located?", "Does a photovoltaic farm affect humans?", "Does a photovoltaic farm affect the environment and landscape?", and "Do the human-perceived effects of a photovoltaic farm depend on the distance, of the residence from the nearest photovoltaic farm?". The main hypothesis, according to Apanowicz (2002), was that the photovoltaic farm affects the environment, and the specific hypotheses were statements stating that the support of the development of photovoltaic farms depends on the location of the farm, the photovoltaic farm affects humans, the photovoltaic farm affects the environment and landscape, the effects of the photovoltaic farm perceived by humans depend on the distance and place of residence from the nearest photovoltaic farm. In this study, a diagnostic survey was used as the research method. The primary function of this method was to collect information about issues of interest to the researcher as a result of the verbal accounts of the people surveyed, called respondents. The technique used in the present study was a questionnaire targeted at people living near photovoltaic farms. The research tool, or object, that helped to realise the chosen research technique was a survey questionnaire containing questions related to photovoltaic farms. These allowed the collection of the data necessary to carry out the survey. The information collected from the survey questionnaire was presented in the form of graphs, which were then described and interpreted. Part of the data was also subjected to the calculation of a chi-square test of independence, which was used to assess the relationship between the frequency distribution of responses in terms of one variable in relation to another variable.

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Results of the research

Table 1 below summarises the necessary expenditure to be incurred, the payback period for the investment, and the savings to be achieved, projected over the next 25 years.

Table 1. Summary of expenditure required, payback period and savings over the next 25 years from the construction of a plant-based large-scale photovoltaic farm

Lp.	Description	VARIANT 1	VARIANT 2	VARIANT 3
	Objective	Lowest investment price	Cost-priceoptimisation	Use of the best materials available on the market
1	Projectedpower	607.8 kWp	607.5 kWp	607.7 kWp
Photovoltaicpanels				
2	Type of panels	Polycrystalline	Monocrystalline	Monocrystalline
3	Name / price	2210 x Jinko EAGLE JKM275PP-60 / 220 151 EUR	1841 x Q.Cells Q.PEAK DUO-G5 3301 / 326 246 EUR	1665 x LG NeON®2 365 W / 581 385 EUR
4	Product guarantee	10 years	12 years	25 years
5	Guarantee of energy yield after 25 years	80.7%	85.00%	88.4%
6	Estimated energy yield over 25 years	13500 mWh	13821 mWh	14084 mWh
7	Installation area	3694.06 m^2	3102.09 m^2	2875.79 m^2
8	Installation weight	41990 kg	34427 kg	30803 kg
Inverter				
9	Name / price	Delta RPI M30A_120 (30 KW) / 2 684 EUR	SMA Sunny Tripower 25000 (25 KW) / 3 344 EUR	SolarEdge SE27.6K (27.6 KW) / 1 908 EUR plus power optimizers / 8 729EUR
Other material costs				
10	Wiring, rack	117 308 EUR	103 766 EUR	97 307 EUR
Costs of execution works				
11	Labour	185 390 EUR	154 436 EUR	139 672 EUR
12	TOTAL COSTS	567 582 EUR	634 092 EUR	980 174 EUR
Savings				
13	Year to date electricity bill	76 778EUR	76 778 EUR	76 778 EUR
14	Expected electricity bill per year	48.54 EUR	48.54 EUR	48.54 EUR
15	Expectedannualsavings	76 729 EUR	76 729 EUR	76 729 EUR
Payback period and profits				
16	Payback period, understood as the ratio of costs incurred to annual savings	6.8 years	7.7 years	11.8 years
17	Expected savings over the 25-year lifetime of the installation	1392 712 EUR	1331 128 EUR	1010 682 EUR

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As was evident from the simulations presented, the differences in the anticipated installation costs differed significantly between the proposed variants. The total prices of the installation in the first – economic – variant were noticeably lower. This was mainly influenced by the value of components such as panels and the inverter. It is worth noting that the difference in the cost of the solar panels alone between the first and third variants was as much as 250%. The costs of ancillary materials such as wiring and racking and labour costs were higher for the economic variant than for the other cases. This is because the manufacturer assumed that with lower-quality main components, the assembly and ancillary work itself would be more costly. In the end, however, the values of the total investment differed significantly. The value of the installation in Variant 2 was 11% higher than in Variant 1, and in Variant 3, in which the most expensive components were used, it was approximately 17% higher. These calculations significantly affected the estimated payback period and projected savings gains. Assuming trouble-free operation of the installation, the payback period from the electricity savings for variant one was calculated to be 6.8 years. For the subsequent variants, the period was longer at 7.7 years for variant two and 11.8 years for variant three. Similarly, the projected profits over the 25-year period were highest for variant one and amounted to 1392712 EUR. For subsequent variants, the profit was lower by 4% for variant two and as much as 27.43% for variant three.

On the basis of the simulation carried out, it was therefore noted that assuming optimistic conditions and fault-free operation of the installation, it is most beneficial to build the installation on the basis of the cheapest components available on the market. This type of investment ensures the fastest return on the costs incurred and brings the highest expected long-term profits. It is also worth bearing in mind that in times of a rather unstable market, both in the consumer and energy markets, incurring very large costs for long-term investments is risky. However, the analyses carried out have shown a relatively quick payback period and, in economic terms, the investment has been found to be very profitable and worth recommending.

Another part of the research work consisted of survey analyses to answer the question of whether and how the construction of large-scale photovoltaic farms affects the environment surrounding this type of investment.

The questionnaire survey was conducted in January 2022 and targeted people living close to PV farms. The questionnaire was available online. The survey had 90 respondents who answered 18 questions, of which 15 were related to photovoltaic farms, and three questions were related to gender, age and education choices.

The surveyed group consists of both women and men. Women were more numerous and accounted for 53.33% of all respondents. Men were a slightly smaller group, comprising 46.67% of the total survey group. The largest number of respondents was in the 31-50 age range, and they accounted for 45.13% of all respondents. The smallest number of respondents were under 18 years of age, who accounted for 3.54% of all respondents, and people over 50 years of age, who accounted for 17.70% of all respondents. Those in the 18-30 age bracket accounted for 33.63% of all respondents. Most respondents had a high school education, which accounted for 41.11% of all respondents. Slightly less, or 34.45%, were those with a university education. The fewest respondents had primary and vocational education, who represented 12.22% of all respondents.

The first survey question was to establish how many people supported the development of renewable energy sources in the form of photovoltaic farms. The vast majority, or 83.33% of all respondents, were in favour of supporting the development of this energy. A small proportion, representing 11.11% of the total survey group, stated that they did not support the development of this type of energy.

The second question concerned the permission to locate a photovoltaic farm in their municipality. The majority of people, 82.22% of all respondents, allowed the construction of such a farm in their municipality. A small proportion of people, 13.33% of the total survey group, stated that they do not allow the location of a photovoltaic farm in their municipality. The remaining respondents, who accounted for 4.45% of all respondents, had no opinion on the subject.

The next question sought to establish how many people allow the location of a photovoltaic farm in their locality. The vast majority (Figure 1), or 73.33% of all respondents, stated that they allow the location of such a farm in their locality. A small part of the survey group, representing 15.56% of all respondents, does not allow the location of a photovoltaic farm in their locality. The remainder of all respondents had no opinion on the subject.

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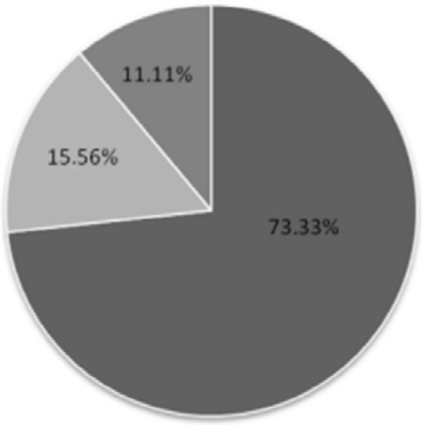

Figure 1. Percentage share of respondents in answer to the question: Do you allow the location of a photovoltaic farm in your village? Yes – 73.33%, No – 15.56%, I have no opinion – 11.11%

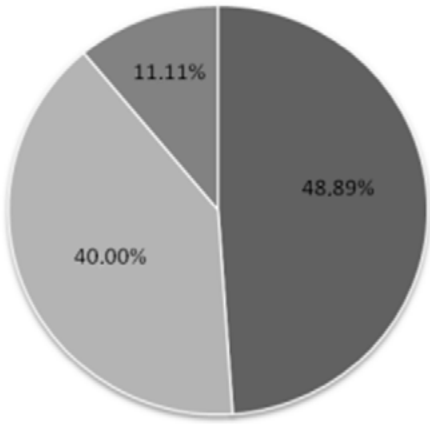

Figure 2. Percentage of respondents in response to the question: Do you allow a photovoltaic farm to be located on your land? Yes – 48.89%, No – 40.00%, I have no opinion – 11.11%

The next question concerned permission to locate a photovoltaic farm on a neighbour's land. The majority of respondents, as in the previous survey representing as much as 70.00% of the total survey group, allowed the construction of such a farm on a neighbour's land. A number ofrespondents, i.e. 17.78% of all respondents, do not allow the location of a photovoltaic farm on their neighbour's land. The rest of the respondents, who accounted for 12.22% of all respondents, had no opinion on the subject.

The next question (Figure 2) concerned the answer to the question: do you allow the location of a photovoltaic farm on your land?

Although the majority of respondents allowed for the location of a PV farm in their municipality, village or on a neighbour's land, this percentage was much lower for their own land, amounting to 48.89% of the total survey group. Almost 40.00% of the respondents did not allow a photovoltaic farm to be located on their land. The remainder of the respondents, or 11.11% of all respondents, had no opinion on the subject.

The next question sought to establish whether photovoltaic panels cause noise. The vast majority of people, or 88.89% of all respondents, stated that no source of noise is felt during the operation of the photovoltaic panels. A small proportion of the survey group, representing 3.33%, felt noise from the operation of the photovoltaic panels. The rest of the respondents, or 7.78% of all respondents, had no opinion on the subject.

Question eight (Figure 3) asked whether photovoltaic installations produce light reflections. The majority of people, or 60.00% of all respondents, assessed that photovoltaic panels do not produce light reflections. A portion of the respondents, which accounted for 14.44% of all respondents, believed that photovoltaic installations produce light reflections. The remainder of the survey group, or 25.56% of all respondents, had no opinion on the subject.

The answers to question nine showed how the environmental impact of photovoltaic farms was assessed. The majority of people, 44% of all respondents, stated that such farms have little impact on the destruction of natural habitats for plants and animals. Almost 30% of the respondents in the study group were of the opinion that these farms have no impact on nature. Those who stated a high and moderate degree of impact of photovoltaic farms on the destruction of habitats for living organisms each accounted for 10% of all respondents.

The next question was to establish whether photovoltaic farms cause a change in land values (Figure 4).

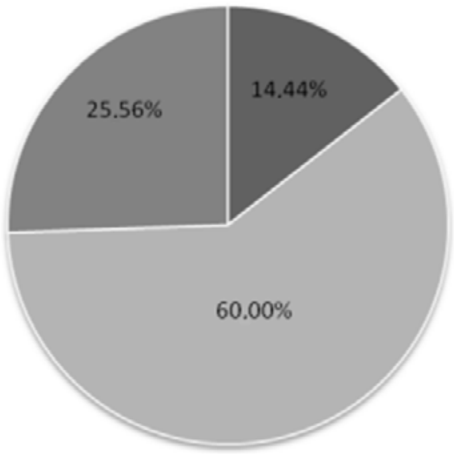

Figure 3. Percentage of respondents answering the question: do photovoltaic installations produce light reflections? Yes – 14.44%, No – 60.00%, I have no opinion – 25.56%

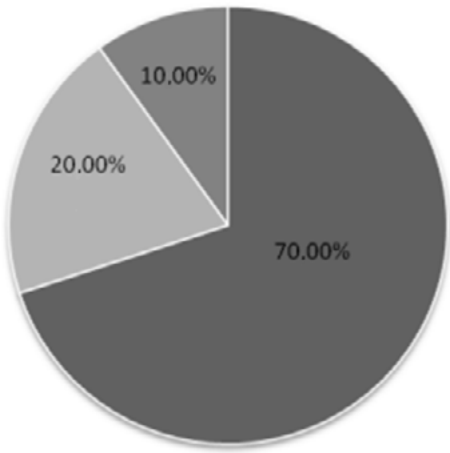

Figure 4. Percentage of respondents in response to the question: do photovoltaic farms cause a change in land value? Yes – 70.00%, No – 20.00%, I have no opinion – 10.00%

The vast majority of the survey group, which accounted for 70.00% of all respondents, stated that such farms affect the value of land plots. A small proportion of people, or 20.00% of all respondents, believed that photovoltaic farms do not cause a change in land values.

The answers to the next question were to show whether the location of the photovoltaic farm caused an increase or decrease in land values. The vast majority, or 77.78% of all respondents, assessed that there would be a decrease in the value of land plots as a result of the construction of this type of farm.

The next question sought to establish whether photovoltaic farms contribute to exclusion from potential development opportunities. The majority of people, 58.89% of the respondents, believed that the location of a photovoltaic farm causes a reduction in interest in building various types of buildings in its vicinity. A sizable proportion of respondents, representing 33.33% of the total survey group, stated that photovoltaic farms do not contribute to exclusion from potential development opportunities. The remainder of the respondents, who accounted for 7.78% of the total survey group, had no opinion on the subject.

The twelfth question asked whether the construction of a photovoltaic farm affects the aesthetics of the landscape. The majority of people, or 62.22% of respondents, stated that the location of these farms affects the appearance of the space. A small part of the survey group, which accounted for 20.00% of all respondents, assessed that photovoltaic farms do not affect landscape aesthetics. The remainder of the people, or 17.78% of all respondents, had no opinion on the subject.

The next question (Figure 5) was to establish whether the construction of a photovoltaic farm would improve or worsen the attractiveness of the landscape.

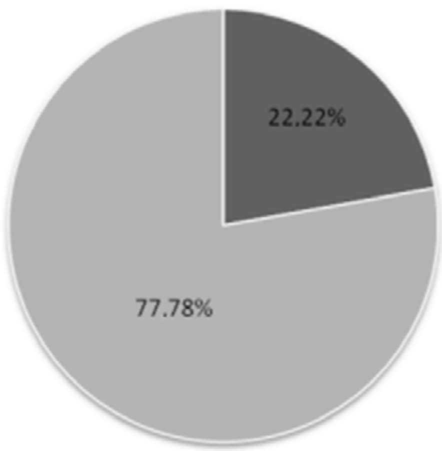

Figure 5. Percentage of respondents answering the question: do photovoltaic farms cause beautification or disfigurement of the landscape? Disfigurement – 77.78%, Beautification – 22.22%

The vast majority of people, or 77.78% of those surveyed, stated that the environment had been disfigured following the location of the farm. The remainder of the survey group, which accounted for 22.22% of all respondents, assessed that the construction of the photovoltaic farm had improved the attractiveness of the landscape.

The last question was intended to show whether there had been any health damage and failures related to photovoltaic panels in the area. Almost all of the survey group, or 98.89% of the respondents, answered that there had been no incidents or accidents related to photovoltaic systems in their vicinity. Only 1.11% of the respondents reported that there had been a dangerous incident related to photovoltaic panels in their neighbourhood, which was an installation fire.

Part of the data was also subjected to the calculation of a chi-square test of independence, which was used to assess the relationship between the frequency distribution of responses in terms of one variable in relation to the other variable. The first analyses were carried out to illustrate the dependence of the place of residence from the nearest PV installation in relation to the perception of light reflections produced by the PV panels. Most people living less than 1 km from the PV installation thought that the PV panels did not produce light reflections, and they represented 59% of all respondents living at this distance. 15% thought that the PV installation produced light reflections, and 26% had no opinion. The majority of respondents who live between 1.0 and 1.9 km from a photovoltaic installation believed that this installation does not produce light reflections, and they represented 70% of all respondents living at this distance. 10% of people thought that the PV panels produce light reflections, and 20% had no opinion on this question. The largest number of people living between 2.0 and 2.9 km from a PV installation believed that PV panels do not produce light reflections, and they accounted for 70% of all respondents at this distance. 5% thought that the PV installation produced light reflections, and 25% had no opinion. The majority of respondents who lived more than 3 km from a PV installation thought that the installation did not produce light reflections, and they accounted for 48% of all respondents living at this distance. 17% of people thought that the photovoltaic panels produced light reflections, and 35% had no opinion in relation to this question. As the empirical value of the chi-square test ($\chi 2$) was below the cut-off value, it could be concluded with a probability of 95% that the distance from the residence to the nearest PV installation did not depend on the perception of light reflections produced by PV panels.

Another test looked at the distance from the residence to the nearest PV installation in relation to the perception of noise resulting from the operation of the PV panels. The largest number of people living less than 1 km from a PV installation did not feel any noise resulting from the operation of the PV installation, and they accounted for 88% of all respondents living within this distance. 4% of people felt noise from the operation of the PV panels, and 8% had no opinion on this issue. The majority of respondents living at a distance of 1.0-1.9 km from the PV installation did not experience noise from the PV panels, accounting for 85% of all respondents living at this distance. 5% of people felt noise from the PV panels, and 10% had no opinion. The largest number of people living between 2.0 and 2.9 km from a PV installation felt no noise from the PV installation, and they made up 80% of all respondents living at this distance. 5% of people felt noise from the operation of the PV panels, and 15% had no opinion. The majority of respondents living more than 3km from the PV installation did not experience noise from the operation of the PV panels, and they made up 82% of all respondents living at this distance. Those who felt noise from the operation of the PV panels and those who had no opinion on this question were 9% each. As the empirical value of the chi-square test ($\chi 2$) was again below the cut-off value, it could be concluded with a probability of 95% that the distance from the residence to the photovoltaic installation does not depend on the perception of noise from the operation of the photovoltaic panels.

Conclusions

On the basis of the analyses carried out, it was concluded that the construction of large-scale photovoltaic farms is the most economically viable project. The construction of a solar plant to ensure that electricity needs are fully met is particularly beneficial for production facilities that consume large amounts of energy. Despite the fact that this is an expense of several million Euros for a production plant, economic calculations prove that the investment will pay for itself within six to seven years

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from the moment of its creation. The economic analyses carried out, taking into account the variants for this type of project in terms of the quality of the components used for construction, showed that the most favourable, in economic terms, is the construction of the installation from the cheapest available components. This is because the payback period is much shorter than the warranties offered on the components.

Conclusions drawn from the survey-based analyses of the environmental impact of the installation on the surroundings of this type of facility have shown that the photovoltaic farm does not have a significant impact on its surroundings. Its impact is most evident in terms of landscape changes following the introduction of photovoltaic panels into the surroundings. Respondents living in the vicinity of the farms mostly supported the development of renewable energy sources in the form of the construction of such facilities. It is worth noting, however, that support for the construction of such an investment depends on where it is located. The closer to the respondents' land a photovoltaic farm was to be built, the support for the construction of this type of energy source decreased. In the case of the construction of a photovoltaic farm in the respondent's municipality, support was very high. Respondents were slightly less likely to support the construction of such an investment in their municipality and even less likely to support it on their neighbour's land. The least support was declared by respondents for the construction of a photovoltaic farm on their own land. It is also worth noting that respondents mostly believed that the construction of a photovoltaic farm would cause a decrease in the value of the land after its construction and would reduce potential development opportunities. The above survey also showed that photovoltaic farms do not affect human health. After examining the respondents' opinions on the perception of noise and light reflections, it could be concluded that the effects of photovoltaic panels are not felt by people. For the two effects surveyed, light reflections appeared to be more perceptible. Noise, on the other hand, was felt by a small number of people. The survey showed that there was little or no impact of photovoltaic farms on the destruction of natural habitats of organisms. In contrast, the impact on the landscape was different. Respondents felt that the construction of photovoltaic farms significantly affects the environment in a negative way. Most people say that PV farms disfigure the landscape. It is also worth noting that, in general, there were no health hazards or accidents associated with PV farms. The survey also showed that the human-perceived effects of a PV farm do not depend on the distance of the residence from the nearest PV farm. This was due to the fact that noise and light reflections were not felt at all by the majority of people taking part in the survey.

The positive conclusions of the analyses made it possible to recommend the construction of this type of facility, particularly for generating plants with high electricity consumption.

The contribution of the authors

Conception, B.Z. and N.P.; literature review, B.Z.; case study, B.Z. and N.P.; investigation, B.Z. and N.P.; formal analysis, B.Z. and N.P.; editing, B.Z.; conclusions, B.Z. and N.P and A.B.

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ANALIZY EKONOMICZNE I ŚRODOWISKOWE BUDOWY PRZYZAKŁADOWYCH, WIELKOPOWIERZCHNIOWYCH FARM FOTOWOLTAICZNYCH

STRESZCZENIE: W artykule niniejszym podjęto problematykę budowy wielko powierzchniowych farm fotowoltaicznych. W pracy opisano zagadnienia dotychczasowego nadmiernego zużycia energii pochodzącej ze źródeł tradycyjnych i wiążące się z tym nadmierne wykorzystanie paliw kopalnianych. Na podstawie źródeł literaturowych przedstawiono alternatywy dla tych procesów oraz zarekomendowano wykorzystanie w tym miejscu odnawialnych źródeł energii koncentrując uwagę na energii słonecznej. W części badawczej uwagę skoncentrowano na aspektach ekonomicznych i środowiskowych przedsięwzięć polegających na budowie wielko powierzchniowych farm przez firmy produkcyjne o wysokim miesięcznym zużyciu energii. W pierwszym etapie prac bazując na danych pozyskanych z firm wykonujących instalacje fotowoltaiczne dokonano analiz ekonomicznych. Do symulacji posłużono się oceną kosztów i zysków jakie wiązałyby się z budową fermy fotowoltaicznej dla firmy wytwarzającej konstrukcje stalowe zlokalizowanej we wschodniej Polsce. Kolejnym elementem części badawczej była analiza wyników przeprowadzonego sondażu ankietowego, który został wykonany wśród osób zamieszkujących sąsiedztwo takich farm. Na jego podstawie oszacowany został wpływ na środowisko terenów sąsiadujących tego typu inwestycji. Pozytywne wnioski płynące z przeprowadzonych analiz pozwoliły na zarekomendowanie budowy tego typu obiektów w szczególności dla zakładów wytwórczych o wysokim zużyciu energii elektrycznej.

SŁOWA KLUCZOWE: fermy fotowoltaiczne, odnawialne źródła energii, panele fotowoltaiczne, solary, środowisko, energia elektryczna, OZE