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ECONOMIC PROFITABILITY OF INVESTMENT IN A PHOTOVOLTAIC PLANT IN SOUTH-EAST POLAND

Key words: economic efficiency, renewable energy sources, photovoltaics, South-East Poland

ABSTRACT. The goal of the conducted research was to assess the economic profitability of investment in a photovoltaic power plant located in south-east Poland, taking into consideration the whole invested capital, regardless of its origin. To determine such profitability, the NPV (Net Present Value) was used as well as the DPBT (Dynamic [Discounted] Pay Back Time). Empirical data was obtained from Energia Dolina Zielawy Sp. z o.o., with its registered office in Wisznice, which owns a photo-voltaic farm with 1.4 MW power, located in Bordziłówka (commune of Rossosz, province of Lublin). In accordance with the adopted assumptions described in the methodology section, the net present value of the investment in both variants was above zero, thus being economically efficient. The discounted period of payback time DBPT for the version with a subsidy was 9 years, whereas the option without subsidy extended that period to 13 years, and in the case of not taking the PMSPE into account – 18 years, still significantly shorter than the assumed 25-year period of use.

INTRODUCTION

In 2011-2017 the Polish photovoltaic sector experienced very high growth dynamics. The power of photovoltaic systems connected to a power grid increased from 1 MW to 287 MW, whereas the amount of produced electric energy grew from approximately 0.01 GWh to 165.5 GWh [GUS 2018]. "The photovoltaic market in Poland" report [IEO 2017, 2019] reveals that the above tendencies will be even more dynamic in the next years. In 2018 (31st December), the total power installed in photovoltaic sources amounted to around 500 MW, whereas in May 2019 it exceeded 700 MW. The above numbers describing the sector confirm the accuracy of forecasts included in "Solar Energy Production in the European Union – the State and Development Tendencies" study [Gradziuk 2017]. The key factor behind such significant growth in use of solar energy was, on one hand, subsidies to the renewable energy sector and, on the other hand, relatively simple procedures for obtaining permission for their installation and use, compared to, for example, wind, water or bio-gas power plants. Moreover, close observation of this market reveals decreasing investment costs and increasing energy efficiency of photovoltaic installations. Research conducted by Barbara and Piotr Gradziuk and Anna Us [2018] shows that, in

the group of prosumer projects, average investment costs in 2018 were nearly five times lower than those recorded in 2011. The declining tendency was also observed in costs for commercial installations. The above research findings were convergent as to the described tendencies with those presented in the following reports: "The Development of the Polish Photovoltaic Market in 2010-2020" [Polska PV 2016] and "The PhotoVoltaic Market in Poland" [IEO 2019], as well as some foreign reports [Fu et al. 2017, Feldman 2015, Hermandez-Moro, Martinez-Duart 2013, Mayer et al. 2015]. The aim of the conducted research was to assess the economic efficiency of the investment in the photovoltaic power plant located in south-east Poland, taking into account the whole invested capital, regardless of its origin.

RESEARCH MATERIAL AND METHODS

The research constituted a continuation of long-lasting analyses concerning the efficiency of using renewable energy sources, mainly bio-mass and solar power [Gradziuk 2006, 2012, 2014, P. Gradziuk, B. Gradziuk 2016, 2019]. This time, research focused on the efficiency of the photovoltaic investment understood as "capital (own and borrowed) outlay on the long-term investment venture, carrying risk, aimed at building and maintaining the photovoltaic installation in order to achieve future results – benefits from produced electric energy" [Wiernik 2013]. In order to determine this, the net present value (NPV) and the dynamic (discounted) payback time (DPBT) were used. Empirical data was obtained from Energia Dolina Zielawy Sp. z o.o., with its registered office in Wisznice, the owner of a photovoltaic farm with 1.4 MW power, located in Bordziłówka (commune of Rossosz, province of Lublin) and the Department of Regional Operational Programme Management in the Province of the Lublin Governor Office in Lublin. On the basis of these data, the total investment cost, the sources of financing and the revenues and costs for the period of 2014-2017 were determined. The years covered the first four years of operation, while the volume of generated energy also covered 2018. Due to the fact that the predicted period of use of the examined investment is 25 years, in order to conduct a reliable analysis, certain assumptions concerning revenue and costs in the future period (2018-2038) were adopted. Assumptions were based on historical data from the first years of use, the experience and observations of employed staff or providers of services for Energia Dolina Zielawy Sp. z o. o., market forecasts of electric energy prices as well as subject literature. The analyzed object operates within a system of property rights to certificates of energy origin (Polish abbreviation: PMSPE). Based on the above, the following assumptions were adopted:

– the decline in power of photovoltaic modules – 0.5%, starting from 2019, the reference level was the average annual volume of generated electric energy in 2015-2018 (1,435.01 MWh),
– the growth in electric energy prices – 3% per year (the reference level – PLN 300.00/ MWh in 2019),
– the growth in prices of property rights to certificates of energy origin – 2% per year (the reference level – PLN 140.00/MWh in 2019), the period when they are granted – 01.10.2014 – 30.09.2029,

– the growth of the costs of use – 3% per year, the reference level was their average annual value in 2015-2017 (PLN 83,605.48),
– discount rate – 2,5%.

THE CHARACTERISTICS OF THE OBJECT OF STUDY

Energia Dolina Zielawy limited liability company, with its registered seat in Wisznice, was established by local authorities of five partner communes in the Valley of Zielawa. The agreement was entered by 3 communes from the Biała district, namely: Rossosz, Wisznice, Sosnówka, and 3 from the Parczew district – Milanów (it is not a shareholder in the company), Jabłoń and Podedwórze. As an independent economic entity, the company was registered in the District Court in Lublin, VI Economic Division – National Court Register, on 15th November 2012. The shares in the company were allocated proportionally to the number of inhabitants and the size of each commune. The core activity of the Company is the production of electric energy in the photovoltaic installation with a power of 1.4 MW and its sale. The investment was completed in 2014, part of the financing required to build the plant was obtained from the Regional Operational Programme of the Lublin Province 2007-2013. Opened in 2014, the Company was then the biggest plant of this type in Poland. Now, it is one of the biggest plants in the province of Lublin. It occupies an area of 3.5 hectares and the total surface area of installed photovoltaic panels amounts to 8,400 m^2.

The photovoltaic farm consists of 5,560 polycrystalline photovoltaic modules Renesola JC250M-24/Bb each having 250 W power, and 104 thin-layer photovoltaic modules, including:
– modules made from cadmium telluride (CdTe) Calyxo CX3, each having 75 W power,
– modules from copper indium gallium selenide (CIGS) Solar Frointier SF155S, each with 155 W power,
– modules from silicon anamorphic (a-Si) NexPower NH-100AX, with 95 W power each.

Their specific parameters are included in the report titled "Experimental Efficiency Analysis of a Photovoltaic System with Different Module Technologies under Temperate Climate Conditions" [Gulkowski et al. 2019]. Polycrystalline modules work with 70 Delta Solivia 20TLS inverters of 20 kW power, thin layer modules with 3 Delta Solivia 3.3 TR p inverters of 3.3 kW power. All inverters in the power plant are divided into 11 low voltage switchgears, from which energy is transferred to the transforming station. NN switchgears contain "green energy" meters.

Photovoltaic panels were installed on a steel structure, hammered 1.30 m into the ground, without any concrete foundations. The structure is located so as the rows of modules do not shadow neighboring modules. The solar panels are bent at a 35° angle to the level of the ground.

The farm also has a transforming station, where the system of steering and monitoring the work of the power plant is located. The station has a transformer, thanks to which it is possible to transform low voltage into medium voltage and put electric energy into the network via a power connection.

THE RESULTS OF THE RESEARCH

The total investment costs of the analyzed photovoltaic system amounted to PLN 7.64 million, which, calculated for 1 MW_e of installed power was PLN 5.46 million. The structure of investment costs (Table 1) is dominated by the purchase of PV panels (49.59%), followed by the wiring system (14.57%), inverters (11.52%) and the construction of the transforming station (5.38%).

Total expenditure on these appliances and materials exceeded 80% of total gross costs in this investment. The investment was financed by a subsidy (PLN 2.6 million) from the Regional Operational Programme of the Province of Lublin (RPO WL 2007-2013), VI Priority Axis. Environment and clean energy, Action 6.2. Environment friendly energy (contract RPLU.06.02.00-06-086/12-00) and a bank loan (PLN 4.6 million), granted initially for a period of 10 years, and then prolonged for 1 year. The change in the credit

Table 1. The structure of investment costs of the photovoltaic power plant in Bordziłówka

No	Item	Structure of costs			
		Net cost [PLN]	VAT [PLN]	Gross cost [PLN]	[%]
1.	Purchase of land	123,750.00	0.00	123,750.00	1.62
2.	Feasibility study	23,000.00	0.00	23,000.00	0.30
3.	Project documentation	30,000.00	6,900.00	36,900.00	0.48
4.	Project promotion	4,830.08	1,110.92	5941.00	0.08
5.	Public tender procedure	5,841.00	0.00	5,841.00	0.08
6.	Construction of the energy connection	49,833.75	11,461.76	61,295.51	0.80
7.	Structure and installation	602,567.14	138,590.45	741,157.59	9.70
8.	Transforming station and wire	334,362.89	76,903.46	411,266.35	5.39
9.	PV panels	3,080,041.70	708,409.60	378,8451.30	49.59
10.	Inverters	715,623.51	164,593.41	880,216.92	11.52
11.	Technical audit	3,800.00	874.00	4,674.00	0.06
12.	Wiring	904,914.35	208,130.35	1,113,044.70	14.57
13.	Investment supervision	65,000.00	14,950.00	79,950.00	1.05
14.	Geodesic and geological work	7,455.28	1,714.71	9,169.99	0.12
15.	Electric installation – tests	76,650.00	17,629.50	94,279.50	1.24
16.	Monitoring and lighting	55,485.67	12,761.70	68,247.37	0.89
17.	Fencing and ground work	130,010.04	29,902.31	159,912.35	2.09
18.	Earthing of the structure	22,500.00	5,175.00	27,675.00	0.36
19.	Project promotion	3,100.00	0.00	3,100.00	0.04
20.	Geodesic and geological work	1,200.00	0.00	1,200.00	0.02
21.	Total	6,239,965.41	1,399,107.17	7,639,072.58	100.00

Source: own elaboration based on information obtained from Energia Dolina Zielawy sp. z o.o.

Tabela 2. Production, price and sale of electricity generated in the photovoltaic power plant of Energia Dolina Zielawy Sp. z o. o.

Month	Electricity production [MWh]				Price of electricity sales [PLN/MWh]				Value of electricity sales [PLN]			
	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
I	14,251	16,651	27,303	27,386	130.00	157.93	211.37	200.00	1,852.63	2,629.69	5,771.04	5,477.20
II	61,893	44,723	30,005	41,065	177.35	150.67	145.66	200.00	10,976.72	6,738.41	4,370.53	8,213.00
III	128,027	109,499	96,461	109,277	146.65	156.17	146.97	200.00	18,775.16	17,100.46	14,176.87	21,855.40
IV	170,672	151,313	155,612	200,323	149.88	176.38	165.66	200.00	25,580.32	26,688.59	25,778.68	40,064.60
V	180,198	214,303	216,496	234,054	182.47	195.94	163.92	200.00	32,880.73	41,990.53	35,488.02	46,810.80
VI	209,564	218,933	208,567	198,773	186.78	320.46	193.35	200.00	39,142.36	70,159.27	40,326.43	39,754.60
VII	218,924	182,356	187,295	170,990	195.66	189.51	170.83	300.00	42,834.67	34,558.29	31,995.60	51,297.00
VIII	226,663	196,928	194,285	199,434	193.82	148.89	200.00	300.00	43,931.82	29,320.61	38,857.00	59,830.20
IX	121,215	167,7	106,489	150,621	206.87	191.34	200.00	300.00	25,075.75	32,087.72	21,297.80	45,186.30
X	117,037	68,259	60,071	117,291	180.53	196.77	200.00	300.00	21,128.69	13,431.32	12,014.20	35,187.30
XI	40,154	32,525	28,737	33,805	164.78	203.54	200.00	300.00	6,616.58	6,620.14	5,747.40	10,141.50
XII	30,074	12,526	10,566	17,722	148.06	173.04	200.00	300.00	4,452.76	2,167.50	2,113.20	5,316.60
I-XII	1,518,672	1,415,716	1,321,887	1,500,741	179.93	200.25	180.00	250.00	273,248.19	283,492.53	237,936.78	369,,134.50

Source: own elaboration based on information from Energia Dolina Zielawy sp. z o.o.

terms was due to lower than assumed revenues from the sale of property rights to certificates of energy origin in 2015-2017. Part of this loan (PLN 1.4 million) was allocated to financing the VAT tax, which will be regained in the next years and allocated to the repayment of this commitment.

The analyzed farm was put into operation in October 2014. Tables 2, 3 and 4 and Figures 1 and 2 below present the basic information concerning the volume of generated electric energy, granted property rights to certificates of energy origin, selling prices of energy and PMSPE and exploitation costs. The information included in them demonstrates that the production of electric energy in the analyzed years fluctuated slightly, from 1,322 MWh (0.94 MWh/MW of installed power) in 2017 to 1,519 MWh in 2015 (1.09 MWh/MW), whereas there were significant differences between November-February and May-September periods. Much bigger fluctuations could be observed in the selling prices of

Table 3. The number, price and value of granted and sold property rights to certificates of energy origin in 2015-2018

Year	Number of granted PMSPE	Number of sold PMSPE	Value of sales [PLN]	Price [PLN]	Estimated value granted PMSPE [PLN]
2014	76,530	-	-	111.08	8,501
2015	1,518,670	400	42,824.00	107.06	162,589
2016	1,415,720	800	30,768.04	38.46	54,449
2017	1,321,887	3,132,807	115,534.66	36.88	48,750
2018	1,500,741	1,500,741	194,075.83	129.32	194,076
Total	5,833,548	5,833,548	383,202.53	65.69	379,863

Source: own elaboration based on information from Energia Dolina Zielawy sp. z o.o.

Table 4. Exploitation costs of the photovoltaic farm in 2014-2017

Item	Exploitation costs [PLN]			
	2014	2015	2016	2017
Use of materials and energy	8,805.93	25,264.38	14,456.74	12,574.96
External services	6,161.73	11,683.31	4,256.52	3,558.90
Taxes and fees	4,163.50	23,472.00	24,663.18	24,659.55
Remuneration	32,391.00	26,536.32	27,452.00	16,947.00
Social security and other contributions	-	615.09	930.95	762.58
Other costs in kind	2,296.50	19,232.12	7,038.40	6,712.44
Total costs of operational (core) activity	53,818.66	106,803.22	78,797.80	65,215.43

Source: own elaboration based on information from Energia Dolina Zielawy sp. z o.o.

electric energy and property rights to certificates of energy origin. From the 4th quarter of 2017 to the 2nd quarter of 2019, the average selling prices of electric energy in the competitive market grew by over 60%, whereas PMSPE by approximately 190% (Figure 2). In the 1st quarter of 2018 the average wholesale price of electric energy on the Next Day Market (Polish abbreviation: RDN) was PLN 184/MWh and was 19% higher than the average price quoted in the same period of the previous year. In the 2nd quarter of 2018, energy prices, in specific term contracts, for August, September and the whole 3rd quarter of 2018 exceeded PLN 330 per one MWh. This was mainly caused by growing prices of coal (80% of electric energy is generated from coal in Poland) and the rights to CO_2 emission [Wiśniewski et al. 2017].

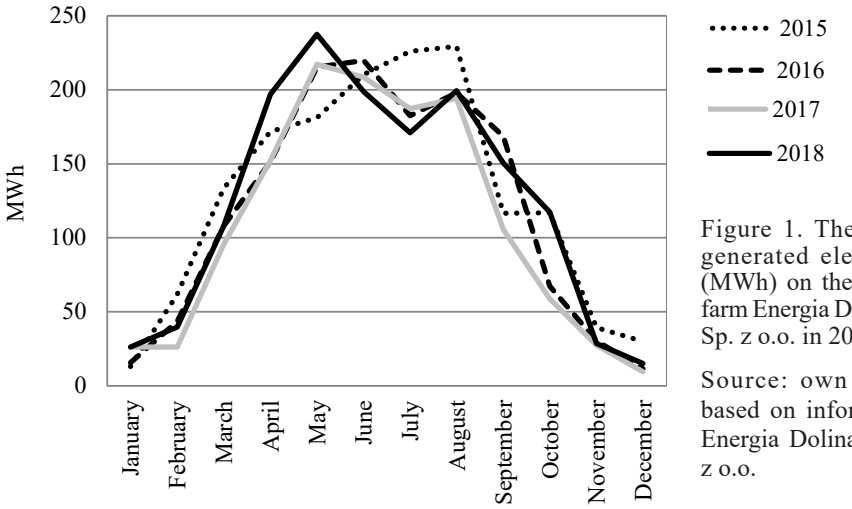

Figure 1. The quantity of generated electric energy (MWh) on the photovoltaic farm Energia Doliny Zielawy Sp. z o.o. in 2015-2018

Source: own elaboration based on information from Energia Dolina Zielawy sp. z o.o.

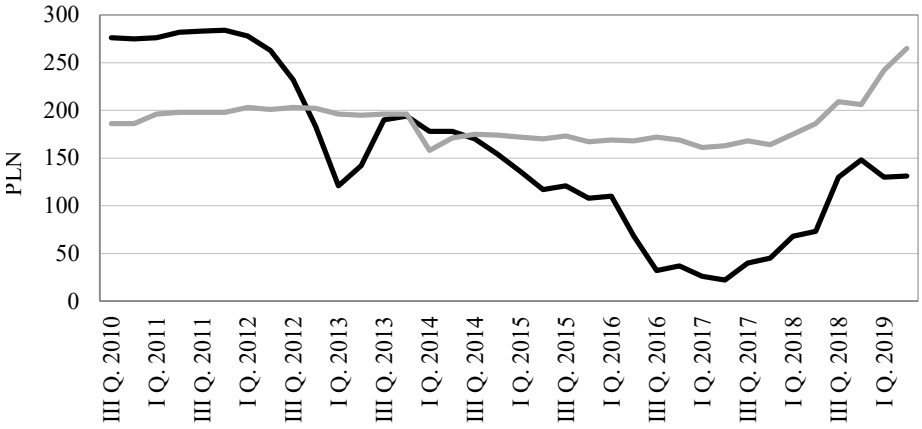

Figure 2. Prices of property rights to certificates of origin and electric energy in the years 2010-2019

Source: based on The Energy Regulatory Office (URE) and the Power Exchange date

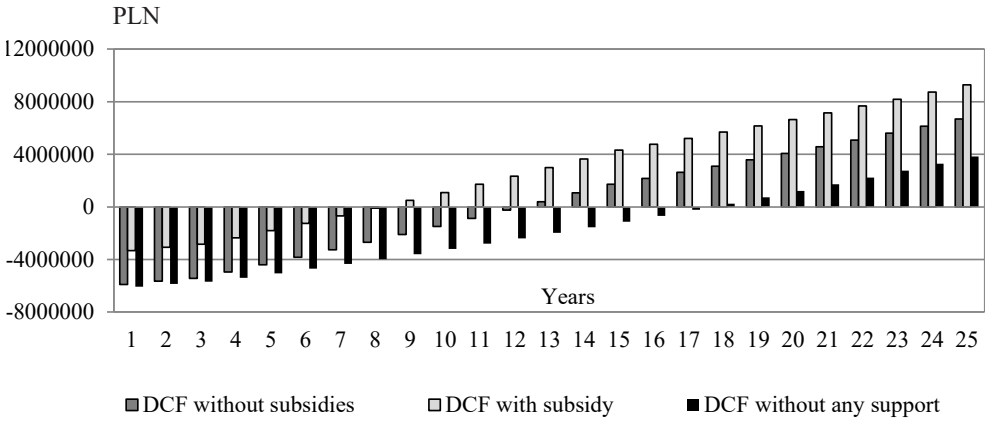

Figure 3. The sum of discounted cash flows (DCV) at the end of each year for the Photovoltaic Farm Dolina Zielawy sp. z o.o.

Source: own elaboration

The criteria for the assessment of economic efficiency of the analyzed investment was based on net present value (NPV) and discounted payback time (DPBT). Calculations were conducted in three variants: with subsidy, without subsidy, and also without taking into account the PMSPE. Results are presented in Figure 3.

With the adopted assumptions described in the methodology section, the net present value (NPV) in both variants was above zero, which means it was economically efficient. The discounted payback time (DPBT) period for the version with subsidy was 9 years and without subsidy – 13 years, whereas in the version not taking into account the PMSPE – 18 years, thus significantly shorter than the assumed period of 25 years of farm exploitation. These results are convergent with the results of research conducted by Anna Klepacka and Kamil Pawlik [2018] for the scenario in which the operating photovoltaic farm used support in the shape of PMSPE.

CONCLUSIONS

On the basis of the conducted analysis of how the photovoltaic farm of Dolina Zielawy sp. z o.o. operates, and on the basis of adopted assumptions, it can be concluded that the vision described by Ryszard Manteuffel [1987] came true. He claimed that, "raw materials used liberally by the industry is a limited resource and all important sources of energy today are non-renewable sources. And this is the nightmare which will bother humankind until the human genius finds a way of using solar power without any limitations". The "without limitations" phrase used in the article is interpreted as "used in an economically efficient way". Nevertheless, investment in generating electric energy from renewable sources of energy carries a high degree of risk, both of market and legal nature. With prices of selling electric energy and property rights to certificates of energy origin obtained in the first 4 years of operation, there was a serious risk that the whole investment in the photovoltaic

farm would turn out to be unprofitable for the investor. It was only when the above prices increased significantly beginning from the 3rd quarter of 2018, did the financial results forecast improve. In the analyzed period, the Act on renewable sources of energy has been amended five times, negatively affecting investment processes in this sector.

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EKONOMICZNA EFEKTYWNOŚĆ INWESTYCJI W ELEKTROWNIE FOTOWOLTAICZNE W POŁUDNIOWO-WSCHONIEJ POLSCE

Słowa kluczowe: efektywność ekonomiczna, źródła energii odnawialnej, fotowoltaika, południowo-wschodnia Polska

ABSTRAKT

Celem przeprowadzonych badań była ocena ekonomicznej efektywności inwestycji w elektrownię fotowoltaiczną zlokalizowaną w południowo-wschodniej Polsce, z uwzględnieniem całego zainwestowanego kapitału, niezależnie od źródła jego pochodzenia. Do jej określenia wykorzystano wartość bieżącą netto NPV (*Net Present Value*) oraz dynamiczny (zdyskontowany) czas zwrotu nakładów DPBT (*Dynamic Pay Back Time*). Dane empiryczne uzyskano z przedsiębiorstwa Energia Dolina Zielawy Sp. z o.o. z siedzibą w Wisznicach, która jest właścicielem farmy fotowoltaicznej o mocy 1,4 MW położonej w miejscowości Bordziłówka (gm. Rossosz, woj. lubelskie). Przy przyjętych założeniach opisanych w metodyce wartość bieżąca inwestycji netto NPV w obu wariantach miała wartości większe od zera, a zatem była efektywna ekonomicznie. Zdyskontowany okres zwrotu nakładów DBPT dla wersji z dotacją wynosił 9 lat, bez uzyskanej dotacji 13 lat, w przypadku nieuwzględnienia także PMSPE 18 lat, a więc znacznie krótszy od założonego 25-letniego okresu eksploatacji.

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