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The Challenges for Social and Economic Policy Related to the Energy Transformation - Analysis of Profitability and Minimizing the Risk of Deciding to Invest in a Home Micro-Installation

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Abstract:

Purpose: *The aim of the article is to analyze the profitability and minimize the risk of making a decision in the investment of a home PV micro-installation. Particular emphasis was placed on the determinants of the boundary conditions at which there is an investment and economic justification for potential investors to make business decisions in the implementation of the project of electricity production for their own needs.*
Approach/Methodology/Design: *The research was carried out using the NPV - Net Present Value of Investment and IRR - Internal rate of Return methods. These methods allowed the authors to calculate the market value of investments with the assumed boundary criteria and to determine the economic efficiency of the investment. The research was carried out in April-March 2021-2022 on a test PV installation in a household.*
Findings: *Installing a photovoltaic system in your household brings many benefits. It should be noted that each kWh produced in a PV installation makes the investor independent of the grid distributor, reduces the consumption of energy from conventional sources, minimizes the emission of pollutants into the atmosphere and favors economic development. In addition, investment in such installations allows for obtaining income from the sale of surplus energy produced.*
Practical implications: *The presented models have shown that the project for their implementation is fully economically justified and will allow investors to make a rational investment decision. These models can be effectively used in other countries, and can also be a starting point for a discussion on the direction of energy development.*
Originality/Value: *Obtaining this data allowed the authors to indicate the directions of improvements that may contribute to obtaining a more reliable assessment of the profitability of the tested installations.*

Keywords: *Profitability account, economic analysis, energy analysis, renewable energy sources, photovoltaic panels.*

JEL Classification: *D12, O29, P18, Q20.*
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1. Introduction

In recent years, changes in the energy sector in Poland have been observed in many aspects. First of all, there is a continuous increase in electricity prices (Derski, 2019; Olczak *et al*., 2020). Secondly, "green energy sources", such as solar radiation, are becoming more and more popular and, above all, profitable. Within solar energy, there are new, more modern and efficient elements of the system that participate in the process of converting solar radiation into electricity without emitting pollutants into the atmosphere (Directive of the European Parliament and of the Council 2009/28/EC 2009).

Poland's energy policy must ensure the security of energy supply in a balanced way, increase the use of its own resources and promote the sustainable development of various electricity generation technologies (Benalcazar *et al*., 2020). It will be difficult to achieve the assumed goals of the climate and energy policy without the participation of effective technologies based on distributed generation (Niekurzak *et al*., 2022). In this context, the development and use of photovoltaic systems is becoming increasingly important.

Photovoltaics is one of the most promising technologies, and the possibilities of its use in energy systems of various scales mean that in the future it may become an effective and safe source of energy and an important element of a stable and independent energy mix (Eurostat 2020; Hayibo; Pearce, 2021). One of the main problems associated with the production of energy based on solar radiation is the high variability of its production volume, resulting from the dependence of the amount of energy produced on current weather conditions (Green *et al*., 2020; Modanese *et al*., 2018).

On the one hand, this translates into the uncertainty of energy estimates for planned installations, and on the other hand, constant variability over time, which makes it necessary to balance it. An important assumption determining the profitability of investing in a photovoltaic installation is the level of insolation. Each region of Poland has different conditions, such as cloud cover, topography, latitude and longitude (Niekurzak, 2021). Since Poland is a country with a relatively small latitudinal and meridional spread, the differences in insolation are not large and range from 1000 kWh/m^2 in northern Poland to 1150 kWh/m^2 in south-eastern Poland (SolarPower Europe, 2020).

The development of renewable energy in Poland is a result of both global trends and the need to achieve the share of energy from sources required by EU legislation renewables in gross final energy consumption (Chakraborty *et al*., 2019). Based on the draft Energy Policy of Poland until 2040, it can be concluded that the development of renewable energy will be largely based on photovoltaics (IEA, 2019; IEO, 2019; CIRE.PL, 2020). This is the result of a deliberate and responsible government policy aimed at ensuring energy security and stable energy supplies to end users. Therefore, the question of the economic viability of such an investment becomes reasonable.

The traditional approach to assessing the profitability of investment projects is characterized by a static approach (Newseria BIZNES, 2020). It consists in the fact that once adopted assumptions, already at the stage of calculations and all calculations related to the investment, are assumed to be permanent and cannot be changed (Tomasik *et al*., 2018; Kowalski, 2020). This approach seems unjustified from the point of view of time. The static approach to assessing the profitability of investment projects should be accepted only when it is considered impossible to reliably estimate, for example, how the market will behave in the next 5 years, which has direct consequences in generating future cash flows, which are the basis for calculations of all methods profitability of investment projects (Höfer and Madlener, 2020; Rouzbahani, Karimipou, and Lei, 2021).

The profitability analysis of the photovoltaic installation was carried out in the work based on the cash flow model for a classic investment project (Bhuiyan *et al*., 2021; Borowski, 2019). The factors determining the level of profitability of PV investments by households are, the level of electricity prices and electricity distribution prices (Sawin *et al*., 2016). The most accurate tool for assessing the profitability of an investment project are discount methods of economic calculation (Kreft *et al*., 2020).

They take into account, in contrast to simple assessment methods, the distribution over time of the expected inflows and expenses related to the examined investment. This is achieved by using the discounting technique, which makes it possible to compare expenditures and effects realized in equal periods of time (Calise *et al*., 2019; Burgio *et al*., 2020). Determining their present value, i.e. updated at the time of the assessment, is the basis for further inference.

2. Research Approach

2.1 Energy Analysis of a Photovoltaic Installation

The energy analysis is part of the efficiency assessment for a photovoltaic installation. It gives the opportunity to check the previous selection of modules, the specific power and efficiency of the installed modules. Appropriate selection of the size of the photovoltaic installation is the basis for achieving the greatest possible energy self-sufficiency and savings. The research of the photovoltaic installation was carried out on the example of a single-family house inhabited by 3 people. Demand was determined by energy consumption based on bills - the monthly energy cost was around EUR 35.

Due to the obtained energy cost, an installation with a total power of 3.92 kWp was designed. Then, the system was dimensioned for the operating parameters of the batteries, maintaining the interdependence between the demand for energy and its consumption on a daily or annual basis. The tested installation will be located on the roof of the building and covers an area of approximately 24 m^2. Polycrystalline modules with a power of 280 Wp will be mounted on a specific surface at an angle of inclination of 35°.

The installation will be an on-grid network, so the system will be connected to an external power grid. The space around the installation is not shaded - there are no trees or other structures nearby that may limit the contact between the module and solar radiation. In the first place, the installation will power household devices, while surpluses will be discharged to the grid. The installation will consist of 14 PV panels connected in parallel, located on the roof on the south side.

The installation will include: photovoltaic module 280 Wp - 14 pieces, grid inverter with a power of 4 kW (Growatt),protection system on the DC side,protection system on the AC side - in the form of overvoltages and current circuit breakers with IP65 tightness class (set), assembly system, the installation will start with the start of the monitoring system - inverter with Internet access,reporting the installation to the Power Plant,wiring and plugs.

The tested installation works with the Growatt 4000TLS3-S inverter. Its selection was determined by the maximum power of photovoltaic panels. A three-phase inverter was selected because the installation power exceeds 3.68 kWp. Based on these parameters, research was conducted.

2.2 Economic Analysis of Return on Investment

Static and dynamic decision criteria are criteria that facilitate decision-making during the analysis of investment profitability. The static criteria do not take into account the change in the value of money over time and therefore can only be used for preliminary estimations of investment profitability or for short-term investments (Zdyb and Gulkowski, 2020; Zamasz *et al.*, 2020). Among the static criteria, the simple payback period is most often used, and among the dynamic criteria - the net present value (NPV) and the internal rate of return (IRR).

In order to thoroughly examine the economic efficiency of the analyzed photovoltaic installation, the IRR method was used, which was used to determine the internal rate of return on investment and the NPV method - concerning the net present value. The discount rate was set at 2.5% - in line with the interest rate on long-term treasury bonds.

It is difficult to find the interest rate for the period of the assumed operation of such an installation, while 12-year bonds are shaped at the level of approx. 2%, hence the value of the relationship was slightly higher due to economic changes and lower interest rates on the economic market - amounting to 2.5%. The value of the rate will be used in two methods of profitability calculation. The NPV method is based on the discounted cash flow methodology. The NPV calculations were made according to the following principle: the present value (ie for year "0") of cash flows discounted in each period at the cost of capital (discounting rate) was determined; the obtained sum of discounted cash flows was defined as the NPV of the project and if the NPV obtained a positive value - the project was accepted, if negative - it should be rejected. The *NPV* equation on the basis of which the calculations were made has the following form (Niekurzak; Kubińska-Jabcoń, 2021):

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+k)^t} \quad (1)$$

where: *CF* - expected cash flow in the period *t* (*t* - next years: 0, 1 ,2 ...), *k* - assumed cost of capital of the project.

An *NPV* of zero means that the cash flow is exactly sufficient to pay back the capital invested and bring the required rate of return on capital. When an investment (project) has a positive *NPV* - then cash flows provide additional income The *NPV* method is supplemented by the *IRR* method (internal rate of return), defined as the discount rate, which equates the present value of expected cash flows with the present value of expected costs (investment) (Janoś, 2020).

The calculations were based on the formula: The *NPV* method is supplemented by the *IRR* (internal rate of return) method, defined as the discount rate, which equates the present value of expected cash flows with the present value of expected costs (investment expenditures). Calculations were made on the basis of the formula:

$$IRR = \sqrt[n]{\frac{\sum_{t=0}^{n} CF_t (1+IRR)^{(n-t)}}{CF_0}} \quad (2)$$

The internal rate of return (*IRR*) can be interpreted as the expected rate of return on a given project and compared with rates of return from other, alternative ways of allocating investment outlays, e.g. with bank deposits. Investments in which the *IRR* is higher than the assumed level should be considered satisfactory.

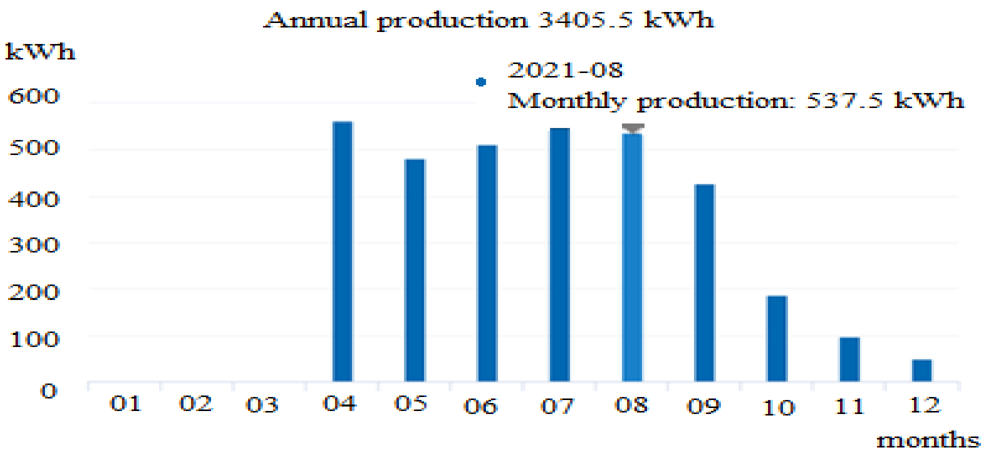
3. Results and Discussion

3.1 Energy Gains of the Tested Installation

The annual power yield with which the installation was designed is 4000 kWp. Energy gains reflect the accuracy of the installation design - a correct design will not generate energy losses or shortages. For research purposes - to illustrate power gains, data was collected from April 2021 to May 2022. The presented data come from the system to which the inverter is connected via WiFi. Data was recorded on a daily/monthly/yearly basis. Figure 1 shows energy yields from April to December

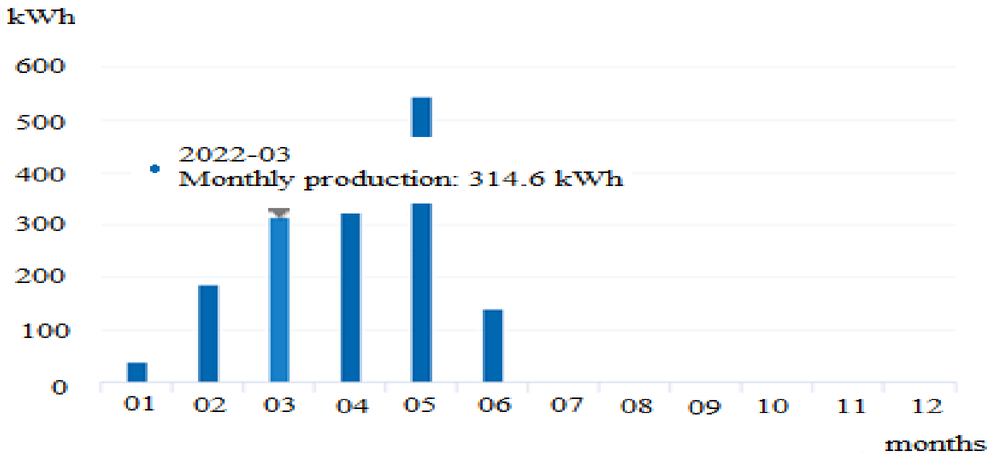
2021. Figure 2 shows energy yields from January to March 2022. Each month from which power readings were obtained was analyzed.

Figure 1. *Electricity production: April - December 2021*



Source: *Own elaboration.*

Figure 2. *Electricity production: January - June 2022*



Source: *Own elaboration.*

As part of the research, daily, monthly and annual power yields from solar radiation were collected. The annual value of these tests was 3405.5 kWh - with the assumed estimated yield of 4000 kWh. It can be concluded that the difference in the reported assumed value is small. The installation in use did not generate any additional charges by users for energy consumption during the analyzed year.

The generated energy fully covered the household's demand. In addition, it can be concluded that the autumn/winter months are characterized by a lower recorded power yield than the spring/summer months. The reason for this phenomenon was the presence of significant cloudiness in the period under study. Little cloud cover in the summer period resulted in higher values of the power output of the analyzed installation. For example, for the month of August, the power yield from the installation was 537.5 kWh. This is only 15% of the annual yield. On the other hand, the power yields look different if we take into account the yields relative to the seasons (Table 1).

Table 1. *Electricity production by seasons*

Months	Power, kWh	Sum of power, kWh	**Percentage, %**	**Season**
December	49.5	272.1	7	Winter
January	37.5			
February	185.1			
March	314.6	1358.8	34	Spring
April	561.7			
May	482.5			
June	512.1	1601.9	41	Summer
July	552.3			
August	537.5			
September	426	709.9	18	Autumn
October	186.7			
November	97.2			
Annual sum of yield power		3942.7		

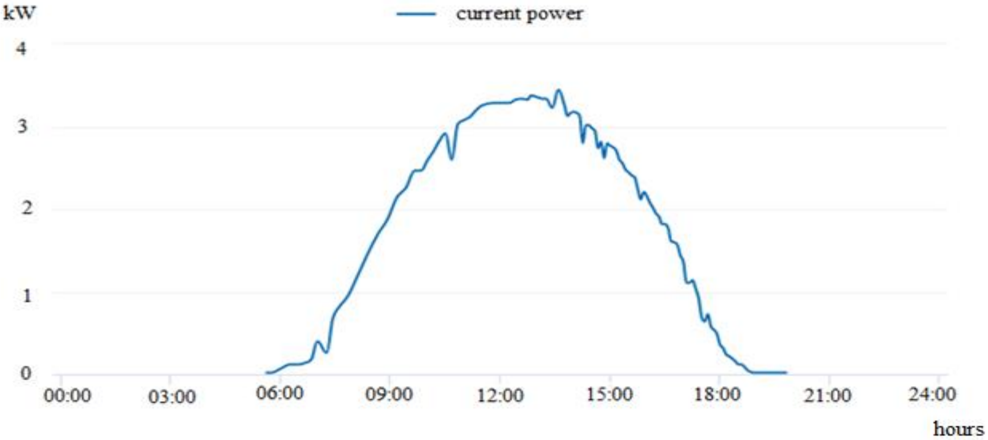
Source: *Own elaboration.*

The data presented in Table 1 shows that most of the power generated by the photovoltaic installation is generated in the spring and summer months - as much as 75%, the remaining 25% falls on the autumn and winter months. For comparison, Figures 3 and 4 show the daily electricity production for an example spring day in April and a summer day in August.

From the analysis of Figures 3-4, reading fluctuations can be observed - there are minimal decreases and increases of received power. These disturbances are caused by weather conditions, which reduce the amount of radiation reaching the surface of the modules.

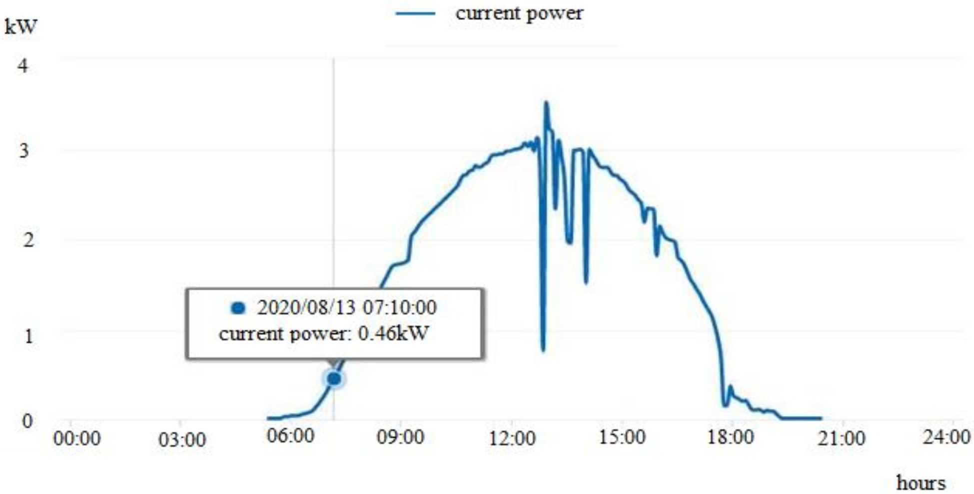
The power yield in April was 25.5 kWh, while in August it was 23.7 kWh. These differences were caused by the presence of clouds, and additionally - photovoltaic cells work more efficiently in conditions of lower temperatures. Overheating of the module reduces its efficiency. The highest power yields occurred in the afternoon hours. Table 2 presents the total value of power yield in the analyzed research year.

Figure 3. *Daily electricity production - April 13, 2021*



Source: *Own elaboration.*

Figure 4. *Daily electricity production - August 13, 2021*



Source: *Own elaboration.*

Table 2. *Monthly energy yield from the photovoltaic installation in the research year*

Month	Power, kW	Month	Power, kW
April	561.7	March	314.6
July	552.3	October	186.7
August	537.5	February	185.1
June	512.1	November	97.2
May	482.5	December	49.5
September	426	January	37.5

Source: *Own elaboration.*

The analyzed photovoltaic installation gained energy independence. The costs incurred for the purchase of energy were reduced before the investment was made in its entirety. In addition, the installation produced surpluses that can be sold to the power utility. When analyzing the energy yield of the panels, one should also take into account their lifetime, i.e., the decrease in energy production, which is noticeable every year.

Panel manufacturers assume that visible drops in power will be visible only after 20 years of use. Additional guarantees for the long-term use and profits from the installation are also provided by the inverter warranty. From the documentation attached to the inverter, it can be read that the efficiency guaranteed by the manufacturer is at the level of 98%. Of course, the manufacturers' guarantees alone will not ensure long-term efficiency of the systems - the operation and maintenance of the panels is important.

3.2. Economic Analysis of Return on Investment

The percentage share of costs incurred by the investor for the purchase of the installation at the current prices in Poland is: 40% PV modules, 23% inverter, 10% steel structure, 10% protection and cables, 15% assembly and 2% transport. The cost of a photovoltaic module depends on its power and manufacturer. Currently, there are a number of companies dealing with the production and distribution of photovoltaic modules on the market. Therefore, their price range is quite wide.

After calculating all the components of the analyzed investment, the total installation cost is EUR 4,450. In addition to the incurred costs, the investment in a micro-installation also generates revenues. The basis of revenues is the sale of the surplus energy produced to the grid. The economic analysis was carried out for the designed installation consisting of 14 photovoltaic modules. As part of this part of the research, the following were adopted:

- the price of energy at the level of EUR 0.15/1 kWh in the zero period of use, while later periods were subject to inflation at the level of 5%,
- operating costs depend on the market situation, therefore the inflation rate was assumed at the level of 3.5% per annum,
- energy consumption, as well as energy transferred to the grid will be determined on the basis of the efficiency of photovoltaic modules, starting from the original values,
- savings will be determined on the basis of the energy generated by the photovoltaic installation depending on energy prices in a given period.

As part of this part of the study, the cumulative cash flow was calculated for each of the 20 useful lives of the installation - including the zero period, where all original costs incurred for the investment were included. Calculations in accordance with the formula (1) and (2) were made in order to indicate the actual state of investing money throughout the entire period of operation. Table 3 shows the cumulative cash flow calculations based on the NPV method.

$$NPV = \frac{-4430.72}{(1+r)^0} + \frac{445.82}{(1+r)^1} + \frac{464.94}{(1+r)^2} + \frac{484.86}{(1+r)^3} + \frac{505.61}{(1+r)^4} + \frac{527.24}{(1+r)^5} + \frac{549.76}{(1+r)^6} + \frac{573.23}{(1+r)^7}$$

$$+ \frac{597.67}{(1+r)^8} + \frac{623.14}{(1+r)^9} + \frac{649.66}{(1+r)^{10}} + \frac{677.28}{(1+r)^{11}} + \frac{706.05}{(1+r)^{12}} + \frac{736.02}{(1+r)^{13}} + \frac{767.22}{(1+r)^{14}}$$

$$+ \frac{799.71}{(1+r)^{15}} + \frac{833.54}{(1+r)^{16}} + \frac{868.78}{(1+r)^{17}} + \frac{905.45}{(1+r)^{18}} + \frac{943.64}{(1+r)^{19}} + \frac{983.40}{(1+r)^{20}}$$

Table 3. *Recognition of cash flow based on the NPV method for the marginal rate of return*

Period	**Cash flow, EUR**	**Net present value based on 2.5% return, EUR**	
0	-4 430.72		- 4 430.72
1	445.82		434.95
2	464.94		442.54
3	484.86		450.24
4	505.61		458.06
5	527.24		466.00
6	549.76		474.06
7	573.23		482.24
8	597.67		490.54
9	623.14		498.96
10	649.66	**NPV_t**	507.51
11	677.28		516.19
12	706.05		524.99
13	736.02		533.92
14	767.22		542.98
15	799.71		552.17
16	833.54		561.50
17	868.78		570.95
18	905.45		580.55
19	943.64		590.27
20	983.40		600.14
		NPV	**5 848.05 EUR**

Source: *Own elaboration.*

The investment evaluation criterion based on the NPV method is based on the value of this indicator. The values that can be taken are (Olczak *et al*., 2018; Żołądek *et al., 2019*):

- NPV > 0, then the project can be implemented,
- NPV = 0, then the decision is ambiguous, the project may or may not be implemented, everything depends on the decision based on other information collected so far, on the basis of which the investor can make the final decision,
- NPV < 0, then the investment should not be implemented.

In the case of the NPV value obtained for the analyzed data, it amounted to EUR 5848.05, so the value is greater than 0. It follows that the investment can definitely be implemented, because there are visible benefits from it. Then, the internal rate of return (IRR) was calculated, i.e. the value determining the discount rate r, at which discounted proceeds are equalized with discounted expenses. The internal rate of return IRR was calculated for the investment in question from formula (2), and its results are presented in Table 4.

Table 4. *Cash flow recognition based on the IRR method*

Period	**Cash flow, EUR**	**Internal rate of return**	
0	-4 430.72	**IRR**	**11.86 %**
1	445.82		
2	464.94		
3	484.86		
4	505.61		
5	527.24		
6	549.76		
7	573.23		
8	597.67		
9	623.14		
10	649.66		
11	677.28		
12	706.05		
13	736.02		
14	767.22		
15	799.71		
16	833.54		
17	868.78		
18	905.45		
19	943.64		
20	983.40		

Source: *Own elaboration.*

Calculations were made using a spreadsheet. The IRR value was 11.86%. The interpretation of the IRR value relates to the rate of return on the capital that has been invested, so the obtained value indicates that the investor covered the entire investment costs and additionally gained from it. An investment is considered profitable if, IRR > the assumed cut-off rate, i.e., 2.5%. The calculated value is several times higher than the assumed rate, so it can be concluded that the investment will bring great financial benefits in the future, and allocating money for these expenses is safe.

Since the obtained IRR value differs from the investor's rate of return *r*, the NPV analysis was repeated in the further part of the research, replacing the value r with the newly calculated IRR = 11.86%. The results of the calculations are presented in Table 5.

Table 5. *Recognition of cash flow based on the NPV method for rate of return=IRR*

Period	**Cash flow, EUR**	**Net present value based on IRR = 11.86 %, EUR**	
0	-4 430.72		-4 430.72
1	445.82		398.55
2	464.94		371.58
3	484.86		346.41
4	505.61		322.94
5	527.24		301.05
6	549.76		280.62
7	573.23		261.58
8	597.67		243.82
9	623.14		227.25
10	649.66	**NPV_t**	211.81
11	677.28		197.40
12	706.05		183.97
13	736.02		171.44
14	767.22		159.76
15	799.71		148.87
16	833.54		138.72
17	868.78		129.25
18	905.45		120.43
19	943.64		112.20
20	983.40		104.53
		NPV	**1.45 EUR**

Source: *Own elaboration.*

Calculation of the NPV value for IRR = 11.86% gives more approximate values for the investment in question, because the rate of return is selected directly from the analyzed data. As in the previous interpretation of this indicator, there are 3 possible readings. In this case, the NPV value is also greater than 0, which indicates the profitability of the investment, while this value is much lower than in the previous calculations.

This may indicate lower returns on investment than in the case of a rate of return of 2.5%. Comparing the calculated NPV_r and NPV_IRR indicators, it can be concluded that the NPV value calculated on the basis of IRR is negligible and practically unnoticeable.

The calculations simulate the costs and profits incurred by the investor. It has been proven that the investment definitely pays off - the greatest benefit from a photovoltaic installation is obtained when as much energy as possible is consumed at the time of its production, the rest of the energy is discharged to the grid. In the case of energy consumption or sale to the grid, does the investor benefit from it - in the former case, he saves, in the latter, he earns.

Based on calculations of profits from energy consumed and sold, as well as financial outlays incurred at the beginning and during the use of the investment, the result of full cost recovery was obtained, and additionally generating pure revenues already in the 9th year of installation. Calculations of NPV and IRR indicators confirm the profitability of the investment.

4. Conclusions

When making a decision to invest in RES, it should be remembered that only a complete and correctly carried out analysis of the profitability of RES investments, which was presented in a given work, allows you to make an informed and appropriate decision regarding the commencement or abandonment of the planned project.

The results of such an analysis depend strictly on the values of individual parameters, which should be selected very carefully and thoughtfully. This applies in particular to the assumptions regarding the cost of equity (including the assumed level of investment risk) and the time value of money (inflation rates, income reinvestment rates, etc.). Based on the analysis of the research problem, the following conclusions were drawn:

1. Problems and limitations related to the use of conventional energy sources, and thus the emission of harmful substances into the environment, are becoming more and more common. This is the basis for the use of alternative sources - renewable, which are the future of combating environmental barriers.
2. Solar radiation is one of the most beneficial and prosperous renewable sources. The possibilities of its use are enormous and inexhaustible.
3. Photovoltaics is an extensive and wide field in the field of both energy and environmental protection. The possibilities of its use are wide, the only limitation is the area on which the installation can be made, as well as the financial capital available to the investor.
4. The constant development of photovoltaics is related to the search for newer and newer technological and production solutions in order to create cells

with high efficiency, decent price, and the material that will support the operation of the cells.

5. The efficiency of energy yields from photovoltaic panels depends on many factors. The quality and quantity of produced power is influenced by, among others, area shading, angle of arrangement of photovoltaic modules, geographic location, as well as module servicing.
6. Energy analysis allows you to examine the distribution of energy required in a given building, and then translate the obtained data into the input elements of the installation project. On this basis, the power of the planned installation can be determined. The presented power yields from the modules confirm the sufficiency of production in relation to its consumption.
7. The economic analysis shows the cash flow - costs and profits generated by the photovoltaic installation. Thanks to this, it is possible to simulate the development of expenses in subsequent years. Based on the presented analysis, the annual profit is visible - caused by increasing electricity prices every year, and the high IRR and NPV confirm the legitimacy of the investment.

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