

# Profitability analysis of a PV micro-installation in a single-family house in Sulejów

Analiza opłacalności mikroinstalacji PV w budynku jednorodzinnym w Sulejowie

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Photovoltaics remains the clear leader among all renewable energy sources in our country with a 60% share of installed capacity in this sector. The most important criterion for investing in a photovoltaic installation is determining the net profit over the entire life cycle. The article describes an existing PV micro-installation in a single-family house located in Sulejów, designed and installed by a company specializing in this field. The conducted considerations analyzed the production of electricity from PV installations, which is sold in its entirety to the grid at a 20% reduced price per 1 kWh of energy. The calculations assumed a 5% discount rate for the price of 1 kWh of electricity and an increase in demand for electricity of 1% year-on-year. In this paper, the analysis was carried out to check the profitability of the above-mentioned installation and to compare other possibilities of using the financial resources needed for its construction. This analysis includes the investment in long-term funds, the amount allocated for the purchase of PV panels and determines the profit that can be obtained by exploiting PV panels and the money saved thanks to this, to be invested. A safe long-term fund with an average annual return of 7% was adopted for the analysis. Each of the analyzed variants brings financial benefits, but the option that takes into account investing the money saved thanks to the PV installation allows for almost doubling the profit over the life cycle of the micro-installation. *Keywords: PV micro-installation, return on investment, RES, European Green Deal, investment fund, subsidy program.*

Fotowoltaika pozostaje zdecydowanym liderem wśród wszystkich OZE w naszym kraju z 60% udziałem mocy zainstalowanej w tym sektorze. Najważniejszym kryterium inwestycji w instalację fotowoltaiczną jest określenie zysku netto w całym cyklu życia. W artykule opisano istniejącą mikroinstalację PV w budynku jednorodzinnym zlokalizowanym w Sulejowie, zaprojektowaną i zamontowaną przez specjalizującą się w tej dziedzinie firmę. W prowadzonych rozważaniach analizowano produkcję energii elektrycznej z instalacji PV, która w całości sprzedawana jest do sieci po obniżonej o 20% cenie za 1 kWh energii. Do kalkulacji przyjęto 5% stopę dyskonta dla ceny 1 kWh energii elektrycznej oraz założono wzrost zapotrzebowania na energię elektryczną 1 % rok do roku. W niniejszej pracy przeprowadzono analizę, której celem jest sprawdzenie opłacalności w/w instalacji oraz porównanie innych możliwości wykorzystania środków finansowych potrzebnych do jej budowy. Analiza ta obejmuje inwestycję w długookresowe fundusze, kwoty przeznaczoną na zakup paneli PV oraz określa zysk, jaki można uzyskać eksploatując panele PV i zaoszczędzone dzięki temu pieniądze, inwestować. Do analizy przyjęto bezpieczny długookresowy fundusz ze średnioroczną kwotą zwrotu na poziomie 7%. Każdy z analizowanych wariantów przynosi korzyści finansowe, jednak opcja uwzględniająca inwestowanie zaoszczędzonych dzięki instalacji PV pieniędzy, pozwala prawie dwukrotnie zwiększyć zysk w okresie cyklu życia mikroinstalacji. *Słowa kluczowe: mikroinstalacja PV, opłacalność inwestycji, OZE, Zielony Ład, fundusz inwestycyjny, dofinansowanie.*

## Introduction

Climate change and environmental degradation pose a threat to Europe and the rest of the world [13]. To counter these challenges, in December 2019, the European Commission president Ursula von der Leyen presented the European Green

Deal [17] which includes a set of policy initiatives to reach climate-neutrality and make the EU economy sustainable. The European Green Deal targets climate neutrality by 2050, and aims to support companies to become world leaders in clean products and technologies, as well as to ensure a just and inclusive transition. As for

many Western countries, in the European Union, the Green Deal has been welcomed as a new package of policy interventions, having the main goal to foster sustainable development strategies with a focus on energy emissions and climate change mitigation [7]. Energy system modelling shows that achieving the updated targets

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will require large quantities of renewables deployed at an unprecedented pace. To achieve the EU's 2030 energy and climate targets, EU countries need to establish their 10-year integrated national energy and climate plans for 2021-2030 [20].

The national energy and climate plans (NECPs) were introduced by the Regulation on the governance of the energy union and climate action (EU)2018/1999, agreed as part of the Clean energy for all Europeans package [19] which was adopted in 2019. The national plans outline how the EU countries intend to address the 5 dimensions of the energy union: decarbonisation, energy efficiency, energy security, internal energy market, research, innovation and competitiveness.

Over the past 10 years solar PV has achieved the technological and market maturity to spearhead EU efforts to reach the energy and climate targets [9].

The increasing production of different forms of energy from renewable energy sources means that conventional power plants, on which energy security depends, produce less and less energy, being mainly a reserve for renewable energy sources. Reduced energy production in conventional power plants and lower sales revenues make it necessary to subsidize them. In 2019, a system of such subsidies was introduced in Poland, called the capacity market, which will operate until 2030, charging energy consumers with costs of over PLN 5.5 billion per year (2021). Contracts concluded on the capacity market will be implemented until the early 2040s. The capacity market is an indirect subsidy for renewable energy sources paid to conventional power plants for reserving their production [12].

The PGE Group is the largest producer of electricity in Poland, whose share in the domestic electricity production market is approximately 39%, with an installed capacity of 16.2 GW. Currently, the structure of fuels and other primary energy carriers used to generate electricity in 2022 is presented in Table 1.

The Green Deal strategy also envisages decoupling economic growth from resource-intensive use, while ensuring that no person or region is left behind. To achieve the assumed goals, the European Commission adopted a package of legislative proposals adjusting the EU's climate, energy, transport and tax policies. The goal is to reduce greenhouse gas emissions by at least 55% by 2030 compared to the 1990 level [21]. Table 2 shows the impact of electricity generation on the environment in terms of emission levels for indi-

**Tab.1. The structure of fuels and other primary energy carriers used to generate electricity sold by PGE Obrót S.A. in 2022 [24]**

**Tab.1. Struktura paliw i innych nośników energii pierwotnej wykorzystywanych do produkcji energii elektrycznej sprzedanych przez PGE Obrót S.A. w 2022 roku [24]**

No.	Energy source	Percentage [%]
1.	Renewable Energy sources including:	15,99
	Biomass	2,98
	Geothermal	-
	Wind energy	6,08
	Solar energy	4,90
	Large hydropower	1,70
	Small hydropower	0,33
2.	Coal	48,27
3.	Lignite	28,72
4.	Natural gas	6,78
5.	Nuclear energy	-
6.	Others	0,24
	<b>TOTAL</b>	<b>100,00</b>

**Tab.2. The impact of generating electricity on the environment in terms of emissions for individual fuels and other primary energy carriers used to generate electricity sold by PGE Obrót S.A. in 2022 (As of March 28, 2023) [23]**

**Tab.2. Wpływ wytwarzania energii elektrycznej na środowisko w zakresie emisji dla poszczególnych paliw i innych nośników energii pierwotnej wykorzystywanych do wytwarzania energii elektrycznej sprzedanej przez PGE Obrót S.A. w 2022 roku (Stan na 28.03.2023) [23]**

No.	Fuel type	CO <sub>2</sub>	SO <sub>2</sub>	NO <sub>x</sub>	Pyły	Radioactive waste
		[Mg/MWh]				
	coal	0,71378	0,00049	0,00050	0,00003	-
	lignite	1,00807	0,00091	0,00073	0,00003	-
	natural gas	0,28271	0,00005	0,00019	0,00001	-
	biomass	0,27859	0,00002	0,00019	0,00001	-
	other	0,00000	0,00000	0,00000	0,00000	-
	<b>TOTAL</b>	<b>0,66158</b>	<b>0,00050</b>	<b>0,00047</b>	<b>0,00002</b>	<b>-</b>

vidual fuels and other primary energy carriers used to generate electricity sold by PGE Obrót S.A. in 2022.

Review of the results of LCA analyzes electricity production from the combustion of fossil fuels is accompanied by the emission of many pollutants. When you look at a given electricity-generating system through the prism of its entire life cycle, solar energy also burdens the natural environment with certain harmful compounds. However, in the case of solar energy, this emission results from the use of energy from the combustion of fossil fuels to produce individual components of the photovoltaic

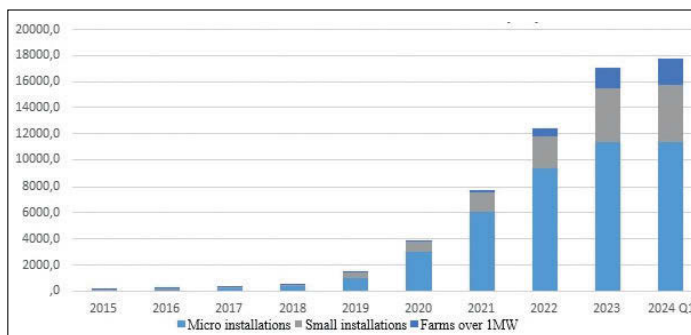
system. It is logical that the amount of this emission will depend mainly on the energy mix of the country where PV modules are produced.

One of the most important events for the Polish market is the change in the Construction Law regarding the increase from 50 to 150 kW of the power of photovoltaic installations, for which no building permit or notification is required. This opens up the industrial installations market significantly. Additionally, one of the most important events is the acceptance of the National Reconstruction Plan by the EU, thanks to which we can expect the release of large funds for green investments in the coming years. However, the events that had the greatest impact on the industries in 2023 alone were rising electricity prices and the launch of another recruitment drive in the

„My Electricity” program, because thanks to these two factors, photovoltaics accelerated again in Poland.

In 2022, almost 75% of all PV capacities were installed in prosumer micro-installations, but this time they were not only home installations, but also a large share of installations belonging to companies, installed in various types of service, commercial and religious buildings, with which were used by the so-called self-producers. In 2022, there were also more small installations (according to the definition of the RES Act) with a capacity of up to 1 MW, which do not require obtaining a license

**Fig. 1. Cumulative installed capacity in PV in Poland in years 2015-2024, according to [6]**  
**Rys.1. Skumulowana moc zainstalowana w PV w Polsce w latach 2015-2024, wg [6]**



for electricity generation. These installations amounted to almost 2.5 GW (1.5 GW a year earlier), which constituted 20% of the total PV capacity. At the end of 2022, the share of large PV farms above 1 MW in PV capacity exceeded 5% [6].

At the end of 2023, the installed capacity in PV installations in Poland reached 17.08 GW, and at the end of the first quarter of 2024, 17.73 GW, showed on Fig. 1.

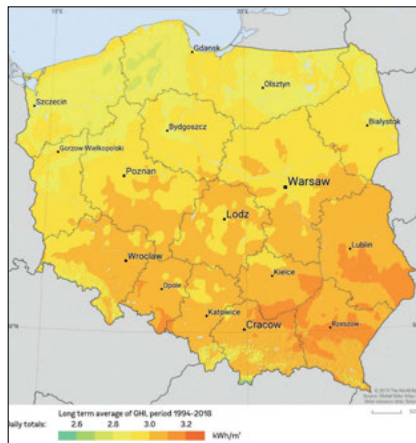
Photovoltaics still remains the clear leader among all other renewable energy sources in our country, with a 60% share of installed capacity in the entire renewable energy sector. In 2023, we took fourth place in terms of PV capacity growth in the EU and moved up to sixth place in terms of cumulative installed capacity. An analysis by Rystad Energy shows that in 2030 the PV recycling market will be worth as much as USD 2.7 billion. At this point, its value is only \$170 million, which shows the scale. In turn, in 2050, this market is expected to reach USD 80 billion [21].

In the article, after a detailed description of the existing PV installation, its operating principles and the analysis of the savings achieved, one made the estimation of the profits obtained in the PV installation life cycle. Then, a profitability analysis of the above installation was carried out over a period of 30 years. The results of the analysis were compared with solutions available on the market to check whether it is possible to achieve better financial results with the same investment amount. The last option compared is to check whether investing in the installation and reinvesting the resulting savings will be a more beneficial solution for the investor. The above considerations assume an investment in a long-term investment fund based on the S&P500 American stock exchange index, whose average annual rate of return is 7%. This solution was adopted because it is an option for beginners who want to benefit from the general economic development in a passive way [26].

Other publications on micro-installations, such as [2], [3] or [15] usually refer to the simple payback time (SPBT) of the PV investment. The publications do not refer to a comparison of investments in PV panels with investment funds.

## Construction of PV systems

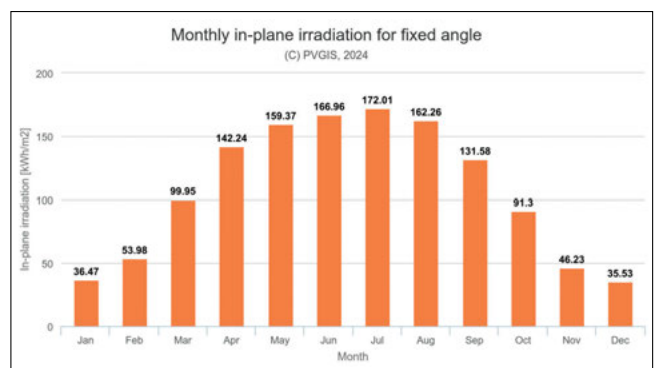
The efficiency of a PV installation depends on many factors such as the level of sunlight, shown on the Fig. 2, location, type, loss (in cables, inverter, modules, bypass diodes) and shading, ambient temperature, wind and frontal contamination.



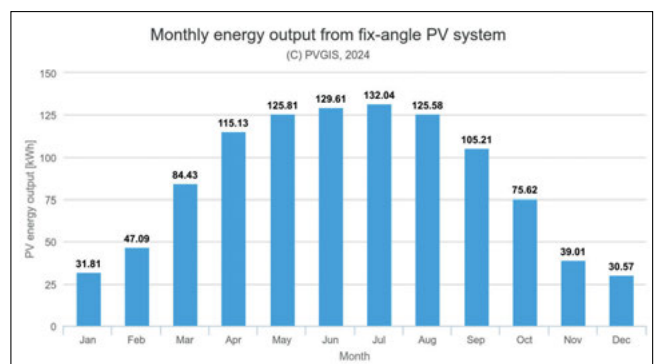
**Fig. 2.** Global Horizontal Irradiation in Poland [22]  
**Rys. 2.** Globalne napromieniowanie poziome w Polsce [22]

Moreover, the great impact on the efficiency of the installation is the way the PV panels are placed, namely the angle of inclination relative to the ground, the orientation towards the south and depends on a day of the year. According to this, they are able to produce more energy than installations which are not optimized in this field. For example, modules positioned perfectly towards the south and tilted at an angle of 60° (angle corresponding to winter conditions) would achieve approximately 93% of their maximum efficiency. If placed at the same angle but facing east, they would only achieve 76% of their maximum efficiency [1]. According to the analyzed case, presented monthly in-plane irradiation for fixed angle in Sulejów

**Fig. 3.** Monthly in-plane irradiation for fixed angle in Sulejów city for slope 30° (the angle of the PV modules from the horizontal plane) [14]  
**Rys. 3.** Miesięczne napromieniowanie płaszczyznowe dla stałego kąta 30° (kąt nachylenia modułów fotowoltaicznych od płaszczyzny poziomej) dla miasta Sulejów [14]



**Fig. 4.** Monthly energy output from fix-angle PV system in Sulejów city for slope 30° (the angle of the PV modules from the horizontal plane) [14]  
**Rys. 4.** Miesięczna produkcja energii z systemu fotowoltaicznego o stałym kącie 30° (kąt nachylenia modułów fotowoltaicznych od płaszczyzny poziomej) dla miasta Sulejów [14]



city for slope 30° (Fig. 3.) and monthly energy output from fix-angle PV system (Fig. 4.).

Photovoltaic installations can be divided into three basic variants:

- operating with the power grid (on grid) – they consist of the following elements: photovoltaic panels, a grid inverter and a bidirectional meter (measuring the electricity consumed and released to the grid). This system returns surplus electricity that was not used for self-consumption purposes to the power system. It also works the other way round – if the user is unable to produce enough electricity to meet his needs, he can download the missing amount of electricity from the grid,
- independent of the power grid (off grid) – the composition of such an installation differs from the previous one in that it is necessary to equip the system with an energy storage and a charging controller. The advantage of this system is complete independence from the grid, while the disadvantage is the need to install an appropriate number of batteries to be able to meet your own needs 24 hours a day.
- hybrid (mixed) – have elements from the two previous types. Similarly to the on-grid system, it involves giving away surplus generated energy that the prosumer is unable to use, but in this case the system has two or more energy sources. The first is the power grid, and the second is energy stored for personal

use in a home energy storage facility in the form of e.g. batteries [4].

PV system with options that allow consumers to generate electricity at the point of consumption, and send any excess into the grid, are emerging as an attractive option for households around the world, more so in countries where retail electricity prices are high [8].

Despite PV's "emission-free conversion" of sunlight into electricity, PV electricity still causes environmental impacts during the extraction of raw materials, their processing and assembly into PV systems. These embedded impacts need to be accurately quantified to understand the overall environmental profile of PV technologies and to allow for a meaningful comparison with other RES technologies.

The life cycle of a photovoltaic cell can be divided based on three basic processes that occur in it. The first is the manufacturing process, which includes activities related to the extraction of natural raw materials, production of materials, production of photovoltaic modules and other system elements (BOS – balance of system) and installation (construction) of a PV power plant. The next one is a process related to the main phase of the life cycle, which is the operation of the PV system; the main energy input in this phase is related primarily to maintenance activities, replacement of components that have failed or worn out, and the operation of follow-up systems. The last process is related to the disassembly of the installation and the recycling and disposal of individual system components [10]. This is important due to the expenses that must be incurred over the entire life cycle of the PV installation.

In conclusion, it should be noted that the use of photovoltaic panels brings many benefits. These include: no exhaust emissions (except for the production and disposal of PV panels), no noise, no need to transport minerals, significant efficiency of energy production, sufficient raw materials necessary for the production of photovoltaic panels, decreasing costs of their purchase and the possibility of using from EU and national financial programs.

However, we must not forget about negative effects on humans and the environment associated with construction and operation of photovoltaic panel systems. The following can be distinguished: use of toxic elements in the production process of such installations, problem with their storage, the disorienting effect of the reflection of photovoltaic panels on flying animals, which may cause bird collisions and bats with surface of the panels, shading the

area beneath them, which is unfavorable affects the species living there [11].

### Analyzed PV micro-installation

The analyzed building is located in Sulejów, Łódź Voivodeship, and corresponds to climate zone III, according to PN-EN 12831:2006 [18].

Heat in the house is provided by the Buderus dual-function non-condensing boiler with a capacity of 15 kW, powered by fuel oil. The central heating circuit is only a radiator circuit, there is no surface heating. Hot utility water was originally supplied from a boiler, currently in summer and winter it is heated in a 10-liter boiler powered by electricity from PV. Therefore, the boiler operates in single-function mode.

In the single-family house, in year 2021, 16 units of Ja Solar JAM60S10-340/MR photovoltaic panels were installed [17]. All 16 units were mounted on the roof of a single-family house facing south at an angle of 30 degrees (Fig.5. and 6.).



**Fig.5.** PV units installed on the roof – east side (pic. Ewelina Różycka-Wrońska)  
**Rys.5.** Jednostki fotowoltaiczne zamontowane na dachu – strona wschodnia (fot. Ewelina Różycka-Wrońska)



**Fig.6.** PV units installed on the roof – west side (pic. Ewelina Różycka-Wrońska)  
**Rys.6.** Jednostki fotowoltaiczne zamontowane na dachu – strona zachodnia (fot. Ewelina Różycka-Wrońska)

The total cost of the PV installation and assembly was PLN 22 100. The installation included:

- 16 pcs. Ja Solar JAM60S10-340/MR photovoltaic panels (specification shown in Table 3),

- SOLIS-3P6K-4G inverter (product features in Table 4) with switchgear, connectors, cable, mounting system and auxiliary materials.

**Tab.3.** The Ja Solar JAM60S10-340/MR photovoltaic panels specification [25]

**Tab.3.** Specyfikacja techniczna paneli fotowoltaicznych marki Ja Solar typ JAM60S10-340/MR [25]

JAM60S10-340/MR Specification		
1	Cell	Mono
2	Weight	18,7kg±3%
3	Dimensions	1689±2mmx996 +2mmx35±1mm
4	Cable Cross Selection Size	4mm <sup>2</sup>
5	No. Of cells	120(6x20)
6	Junction Box	IP68, 3 diodes
7	Connector	QC 4.10-35
8	Cable Length (Including Connector)	Portrait: 300mm(+)/400mm(-); Landscape: 1000mm(mm)/1000mm(-)
9	Packaging Configuration	30 Per Pallet
Electrical Parameters at STC		
1	Rated Maximum Power(Pmax) [W]	340
2	Open Circuit Voltage(Voc) [V]	41,55
3	Maximum Power Voltage(Vmp) [V]	3,73
4	Short Circuit Current(Isc) [A]	10,46
5	Maximum Power Current(Imp) [A]	9,79
6	Module Efficiency [%]	20,2
7	Power Tolerance	0±5 W
8	Temperature Coefficient of Isc(α <sub>Isc</sub> )	+0,044% /°C
9	Temperature Coefficient of Voc(β <sub>Voc</sub> )	-0,242% /°C
10	Temperature Coefficient of Pmax(γ <sub>Pmp</sub> )	-0,350% / °C
11	STC	Irradiance 1000W/m <sup>2</sup> , cell temperature 25°C, AM1.5G
Electrical Parameters at NOCT		
1	Rated Max Power (Pmax) [W]	257
2	Open Circuit Voltage (Voc) [V]	38,9
3	Max Power Voltage (Vmp) [V]	32,4
4	Short Circuit Current(Isc) [A]	8,35
5	Max Power Current(Imp) [A]	7,93
6	NOCT	Irradiance 800W/m <sup>2</sup> , ambient temperature 20°C, wind speed 1 m/s, AM1,5G

The diagram of connecting the micro-installation to the power grid is shown in the diagram below, Fig.7.

When installing the PV installation, the assumed power consumption was 250 kWh/ month.

**Tab.4. The SOLIS-3P6K-4G product features [24]**

**Tab.4. Dane techniczne inwertera SOLIS-3P6K-4G [24]**

SOLIS-3P6K-4G features:	
1	Max. efficiency of 98.3%
2	Type-II over-voltage surge protection for both DC and AC
3	Wide voltage range – Ultra low start-up voltage of 180V and max PV input voltage of 1100V
4	16A PV string input x 2
5	Maximum AC output power of 6.6kW
6	Max PV DC Power of 9kW
7	Integrated AFCI (DC arc-fault circuit protection)
8	IP66 Rated
9	DC reverse-polarity protection
10	5-year standard warranty (10-year standard warranty for the Netherlands, Belgium, France, Germany, Poland, Italy)

analysis of typical warranties for photovoltaic modules (which assume, for example, 80% efficiency after 25 years) and the claim that the modules continue to function after the warranty expires. For inverters used in small (home) installations, a 15-year lifespan is assumed, while for those used in large PV farms – 30 years, assuming replacement of 10% of elements every 10 years [5].

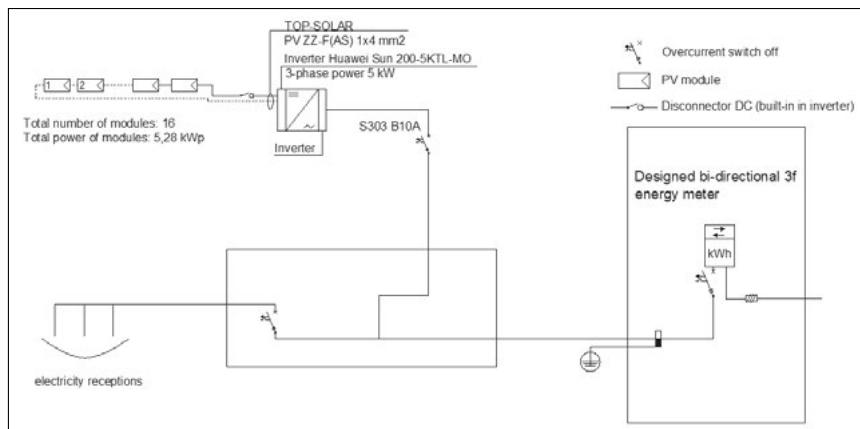
Throughout the life cycle of a PV installation, the following costs may occur:

- mandatory 5-year inspections. According to Polish regulations, all electrical installations must be thoroughly inspected at least once every 5 years. This rule also applies to photovoltaic installations. Some photovoltaic contractors

**Tab.5. Costs related to PV installation in specific years**

**Tab.5. Koszty związane z instalacją PV w poszczególnych latach**

Year	costs related to PV installation			
	technical inspection of the installation	disposal costs	inverter replacement costs	investment costs
	[PLN]	[PLN]	[PLN]	[PLN]
2020				19100
2026	1000			
2028				
2031	1276,28			
2036	1628,89		12000	
2041	2078,93			
2046	2653,30			
2050		3166,04		



**Fig.7. Connection the PV micro-installation to the energy system diagram. (in accordance with the project of connecting the micro-installation to the power grid carried out by Termer-MCM Sp. z o.o.)**

**Rys.7. Schemat podłączenia mikroinstalacji PV do systemu energetycznego. (zgodnie z projektem przyłączenia mikroinstalacji do sieci energetycznej wykonanym przez Termer-MCM Sp. z o.o.)**

According to the agreement concluded with the electricity supplier, the entire amount of electricity produced from the PV installation is sold to the grid at a market price reduced by 20%, while the current electricity consumption is purchased at the current price per 1 kWh.

The „My Electricity” subsidy program, edition III, was used and the investment costs incurred for the installation of a PV installation were reimbursed in the amount of PLN 3 000. The funds were disbursed half a year after the investment was completed.

recommend that the period between technical inspections of photovoltaics should not be longer than 2 years. During the service inspection, one should check, among others: condition of modules, inverter, structure, cabling, terminals, DC and AC protection. In addition, it is necessary to carry out control measurements – including: open circuit voltage, short-circuit current, insulation resistance,

- performing inspections that are a condition for maintaining, e.g., the warran-

ty for the installation of a photovoltaic installation, performed once every 2 years. Installation warranties usually last from 2 to 15 years,

- cost of module disposal. Currently, the price for recycling depends on the weight of the module. The cost also includes the costs of delivering the module to the disposal site,
- washing modules and clearing snow (The impact of photovoltaic panels is of significant importance to designers and users of photovoltaic systems, their performance results, interaction, and that the arrangement of panels influences their performance) [16],
- optional insurance of the PV installation against dangers related to, among others: weather conditions (wind, hail, storms), but also the actions of third parties (destruction, theft).

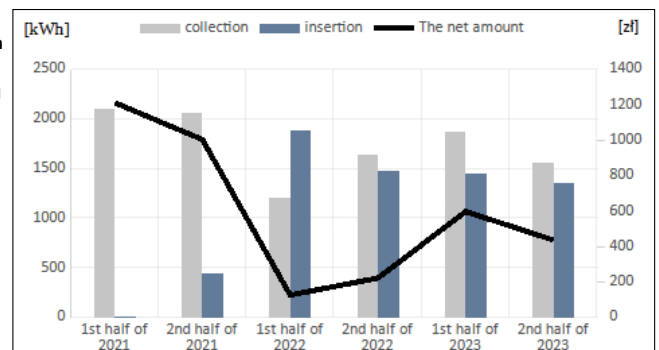
However, it should be noted that operating costs change from year to year due to the increasing prices of energy carriers and the changing value of money in a dynamic or less dynamic way. Moreover, the prices also depends on the PV installation location in the country.

The analysis took into account only 5-year inspections of the electrical installation, the costs of disposal of the installation after 30 years at the level of PLN 40/PV module (price for 2023) plus transport costs and inverter replacement once in

## Analysis & results

Life cycle assessment of photovoltaic systems requires making certain assumptions that will affect the final result of the considerations. These assumptions apply to the photovoltaic installation and determine its technical parameters. The assumed lifespan of photovoltaic modules made using glass-glass or glass-Tedlar technology is 30 years. This statement is based on an

**Fig.8. Statement of production and consumption in years 2021-2023 along with the net price resulting from the difference Rys.8. Zestawienie produkcji i zużycia w latach 2021-2023 wraz z ceną netto wynikającą z różnicy**



a life cycle. The above-mentioned costs included a discount rate of 5%. (Tab.5.)

Total costs related to the life cycle of a PV installation PLN 42 903,45.

Based on available settlements, the values of electricity production from PV and energy demand are shown. For individual years, the net amounts payable resulting from the difference between demand and production were read from the available invoices, Fig.8. It should be noted that the PV installation was installed at the end of 2020, but during the first half of 2021 the installation did not work due to incorrect connection.

**Tab.6. Net profit throughout the life cycle of PV installation**  
**Tab.6. Zysk netto w całym cyklu życia instalacji PV**

Year	5% discount rate	1% increase	average energy production from PV [kWh]	net cost without PV installation [PLN]	difference between demand and production [kWh]	average energy production from PV - 20% [kWh]	difference between energy demand and reduced PV production [kWh]	average annual net cost with PV [PLN]	net profit [PLN]
	unit price for 1kWh [PLN/kWh]	energy consumption [kWh]							
2021	0,581	2109,0	442	1225,90	1667,00	353,6	1755,40	1020,36	205,54
2022	0,699	3027,0	3354	2115,47	-327,00	2683,2	343,80	240,27	1875,20
2023	0,683	3439,0	2812	2350,52	627,00	2249,6	1189,40	812,94	1537,58
2024	0,718	3473,4	3083	2492,73	390,39	2466,4	1006,99	722,68	1770,05
2025	0,754	3508,1	3083	2643,54	425,12	2466,4	1041,72	784,99	1858,55
2026	0,791	3543,2	3083	2803,47	460,21	2466,4	1076,81	851,99	1951,48
2027	0,831	3578,6	3083	2973,08	495,64	2466,4	1112,24	924,03	2049,05
2028	0,872	3614,4	3083	3152,95	531,42	2466,4	1148,02	1001,45	2151,50
2029	0,916	3650,6	3083	3343,71	567,57	2466,4	1184,17	1084,63	2259,08
2030	0,962	3687,1	3083	3546,00	604,07	2466,4	1220,67	1173,97	2372,03
2031	1,010	3723,9	3083	3760,53	640,94	2466,4	1257,54	1269,90	2490,63
2032	1,060	3761,2	3083	3988,04	678,18	2466,4	1294,78	1372,88	2615,16
2033	1,113	3798,8	3083	4229,32	715,80	2466,4	1332,40	1483,40	2745,92
2034	1,169	3836,8	3083	4485,20	753,78	2466,4	1370,38	1601,98	2883,22
2035	1,227	3875,2	3083	4756,55	792,15	2466,4	1408,75	1729,17	3027,38
2036	1,289	3913,9	3083	5044,32	830,90	2466,4	1447,50	1865,57	3178,75
2037	1,353	3953,0	3083	5349,50	870,04	2466,4	1486,64	2011,82	3337,69
2038	1,421	3992,6	3083	5673,15	909,57	2466,4	1526,17	2168,58	3504,57
2039	1,492	4032,5	3083	6016,37	949,50	2466,4	1566,10	2336,57	3679,80
2040	1,567	4072,8	3083	6380,36	989,82	2466,4	1606,42	2516,57	3863,79
2041	1,645	4113,6	3083	6766,38	1030,55	2466,4	1647,15	2709,40	4056,98
2042	1,727	4154,7	3083	7175,74	1071,69	2466,4	1688,29	2915,91	4259,83
2043	1,814	4196,2	3083	7609,87	1113,23	2466,4	1729,83	3137,05	4472,82
2044	1,904	4238,2	3083	8070,27	1155,20	2466,4	1771,80	3373,81	4696,46
2045	1,999	4280,6	3083	8558,52	1197,58	2466,4	1814,18	3627,24	4931,28
2046	2,099	4323,4	3083	9076,31	1240,38	2466,4	1856,98	3898,47	5177,85
2047	2,204	4366,6	3083	9625,43	1283,62	2466,4	1900,22	4188,69	5436,74
2048	2,315	4410,3	3083	10207,77	1327,28	2466,4	1943,88	4499,19	5708,58
2049	2,430	4454,4	3083	10825,34	1371,39	2466,4	1987,99	4831,33	5994,00
2050	2,552	4498,9	3083	11480,27	1415,93	2466,4	2032,53	5186,57	6293,71
Total [PLN]				<b>165726,62</b>					<b>100385,20</b>

The most important criterion for the profitability of investing in photovoltaic panels was determining the net profit over the entire life cycle, as shown in Table 6. When calculating the price for 1 kWh of

electricity, a 5% discount rate was taken into account, while the assumed demand for electricity assumed an increase in demand over the years by 1% year to year.

Summarizing the entire case analysis, a net profit of PLN 57 481,75 was achieved over the entire life cycle of the PV installation.

If the decision was not to install the PV system, the total costs of electrical energy buying over the 30-year period would amount to PLN 165 726,62, assuming, as before, a 1% increase in energy demand year-on-year and a discount rate of 5% over the 30-year period.

The second analysis allowed to determine the amount of money saved if the investment amount of PLN 19 100 (investment amount reduced by the refund of funding from the „My Electricity” program)

was invested in the fund. One resigned to install a PV system in a single-family house. The savings achieved in this variant are presented in Table 7.

**Tab.7. Net profit from investment fund after 30 years in second analysis**  
**Tab.7. Zysk netto z funduszu inwestycyjnego po 30 latach w drugiej analizie**

Lp	Year	net profit
		[PLN]
1	2021	20 437
2	2022	21 867,59
10	2030	37 572,59
15	2035	52 697,50
20	2040	73 910,97
25	2045	103 663,96
30	2050	145 394,07

Based on the above calculations, it was determined that the gross profit in 2050 will amount to PLN 145 394,07. However, the total net profit that we will obtain after deducting investment costs and paying income tax at the rate of 19% on the profit will amount to PLN 102 298,198. Investing in long-term funds allows to save almost twice as much as the amount obtained with the above-described PV micro-installation in a single-family house. It follows that investing PLN 19 100 for 30 years gives better financial results than the above-mentioned installation.

The last calculation variant was the option of investing in a PV micro-installation, and the savings obtained from it were reinvested in the long-term S&P500 ETF fund. The analysis assumed that all installation costs occurring over a period of 30 years will be covered from funds paid out from the fund account. In this variant, the investor does not incur additional costs from current own funds. Final profits are shown in Table 8.

Summing up variant third, the investor, after paying income tax of 19% on profit, obtains net PLN 156 824,02. Reducing this amount by the amount of investment outlays, we obtain net profit of PLN 137 724,02

**Tab.8. Net profit from PV micro-installations and the fund after 30 years in third analysis**  
**Tab.8. Zysk netto z mikroinstalacji PV oraz funduszu po 30 latach w trzeciej analizie**

Lp	Year	investment costs	net profit from PV installation	financial result in year
		[PLN]	[PLN]	[PLN]
1	2021	19100	205,54	219,93
2	2022	0	1875,20	2110,52
6	2026	1000	1951,48	9295,72
11	2031	1276,28	2490,63	24288,47
16	2036	13628,89	3178,75	32573,10
21	2041	2078,93	4056,98	64011,72
26	2046	2653,30	5177,85	113169,23
30	2050	3166,04	6293,71	170062,76

The third option turned out to be the most reasonable solution in terms of savings achieved over a 30-year period.

## Conclusions

On the example of a specific case, assuming a discount rate of 5% for the price of 1 kWh of electricity and an increase in energy demand of 1% year to year, a net profit of PLN 57 481,75 was achieved over the entire life cycle of the PV installation. This allows us to claim that the installation of a PV installation is justified. However, only a few necessary items were adopted for the analysis of operating costs – mandatory 5-yearly inspections of the electrical installation and replacement of the inverter once in a life cycle and the cost of disposal. It is possible that operating costs will be increased by additional operating expenses throughout the life cycle, which will reduce the net profit.

There are many possible directions for future work. It would be reasonable to consider installing an energy storage system compatible with the PV installation. Then there would be no need to sell the produced electricity to the grid at a reduced rate per 1 kWh of energy. Further investigation will also enclose replacing the current heat source with a heat pump and increasing the number of photovoltaic panels.

In the example of the analyzed PV installation in a single-family house, the profit obtained is not significant. The analyzed installation reduces electricity costs by 34% on average per year. Based on the available long-term investment products, greater profit could be achieved over a 30-year period, for example by the ETF S&P500 investment fund with the average annual return rate over 7% for many years. This variant allows for average annual savings of 61%. However, the best solution is to invest in a PV installation and, at the same time, reinvest the money saved in a long-term investment fund. Based on the analyzed case, the amount of savings obtained in this variant is more than twice the amount of savings obtained thanks to the installation of the PV system and over 35 thousand PLN more than the investment in the fund itself. This gives savings of as much as 83% over a 30-year period.

However, the final profits depend on many factors that cannot be predicted over

the entire life cycle of the PV installation, as well as the current market situation in the country and around the world.

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