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PROFITABILITY OF PHOTOVOLTAICS IN POLAND: CASE STUDY OF A HOUSEHOLD

Martyna Łączkowska, Michał Borychowski✉

Poznań University of Economics and Business, Poland

ABSTRACT

Photovoltaics is increasingly used to convert solar energy into electricity in households, including in Poland. The development of this type of renewable energy results, on the one hand, from legal regulations related to climate and energy policies, and on the other hand, from the numerous benefits connected with the use of photovoltaics. These include both economic and environmental advantages. The aim of the work was to assess the profitability of installing photovoltaics in a Polish household in 2019–2021. Therefore, the costs of the investment are presented, as well as the benefits, mainly in economic terms. Different calculations and estimates concerning return on the invested capital are also shown. During the 31 months covered by the study, the cumulative positive balance of electricity that was generated above the energy consumed in the household exceeded 2,900 kWh, which resulted in an economic surplus of over PLN 1,600 (about EUR 360). What is more, the investment contributed to the protection of the natural environment which is the added value of the photovoltaics.

Key words: photovoltaics (PV), electricity, renewable sources, profitability, household, Poland

JEL codes: Q41, Q42, Q50, D14

INTRODUCTION

In the European Union, the following targets are currently in force in the area of climate and energy policy, planned to be achieved by 2030 [European Commission]: (1) reducing greenhouse gas emissions by at least 40%, from 1990 levels; (2) increasing the share of energy from renewable sources to at least 32%; (3) improving energy efficiency by at least 32.5%. This is, of course, a step forward compared to the 3 × 20% package, according to which by 2020 the share of energy from renewable sources in total energy consumption was to be at least 20%, calculated for the entire European Union. The current regulations therefore emphasize the importance of renewable energy sources (RES) as an important element of the wider energy system. In Poland, the key targets in the field of energy until 2030 include [Ministerstwo Gospodarki 2009, Ministerstwo Energii 2019]:

- striving to maintain zero-energy economic growth;
- reducing the share of coal in the production of electricity to the level of 56–60%;
- reducing the energy intensity of the Polish economy to the EU-15 level;
- increasing the effectiveness of electricity production through the construction of highly-efficient generating stations;
- promoting high-effective cogeneration technology;
- reducing greenhouse gas emissions by 7% in sectors not covered by the ETS system, compared to 2005 levels;
- achieving a 21–23% share of renewable energy sources in gross final energy consumption.

Michał Borychowski https://orcid.org/0000-0001-6256-2680
✉michal.borychowski@ue.poznan.pl

Due to its climate and natural conditions, solar energy in Poland may not have optimal conditions for obtaining energy (e.g. in comparison with Southern Europe); however, the climate does allow for a much wider use of the sun than is currently being implemented. Solar radiation energy in Northern and Central Europe could provide around 25 to 40% (e.g. in Poland) of the demand for thermal energy during the year. To this end, it is important to install photovoltaic panels that convert solar energy into electricity, as well as solar collectors that accumulate solar energy and transform it into heat or electricity [Jastrzębska 2017].

Among the numerous advantages of using renewable energy, including that produced by photovoltaic panels, it is worth noting that it comes from inexhaustible resources (such as wind and sun) and is associated with much lower greenhouse gas emissions (no emissions when using energy, although emissions occur in the production of panels). Using renewable energy increases energy security, reduces the risk and possibly the scale of energy poverty[1], and offers independence from conventional energy. In addition, renewable energy is dispersed, so it reduces the costs associated with the construction of transmission lines. It can also serve as a stimulus for economic development at the local level and the creation of workplaces in the renewable energy sector, as well as related fields [World Bioenergy Association 2009, Góral 2014, Riffkin 2011, Borychowski and Czyżewski 2017, Guaita-Pradas and Blasco-Ruiz 2020, Olczak et al. 2020, IRENA and ILO 2021].

Photovoltaic panels can belong to large energy companies (the largest power plants in Poland are: Jaworzno, Czernikowo, Bierutów, Cieszanów or Ostrzeszów). They can also be part of the so-called 'prosumer' energy industry, where for example, a household owns photovoltaic panels and thus becomes both a producer and consumer of electricity [Popczyk 2014, Sobczyk 2020]. Prosumer energy is partly a response to growing energy prices, as it helps makes consumers less dependent on conventional energy supplies by independent generating their own energy, thus reducing household expenditure on electricity [Mirowski and Sornek 2015, Szpulak et al. 2017, Sobczyk 2020].

Government energy policies support prosumer initiatives through various subsidies and including dedicated programs. This is beneficial both for the subsidised households and for the country as a whole, because the prosumer energy sector helps fulfil the nation's required share of renewable energy as a percentage of total energy consumption. This support for investments in renewable energy from public funds is one of the key factors in the context of investment implementation [Chmieliński 2015, Szpulak et al. 2017, Guaita-Pradas and Blasco-Ruiz 2020, Brodziński et al. 2021]. Another important factor is the stability of laws and regulations, as so-called 'legislative risk' discourages businesses from undertaking investments, including RES micro-installations [Mirowski and Sornek 2015, Guaita-Pradas and Blasco-Ruiz 2020]. On the other hand, separate from the prosumer perspective, Hirschburger and Weidlich [2020] feel that due to a better match of energy supply and demand, photovoltaic panels are a more advantageous solution for municipal buildings than for residential ones.

The importance of renewable energy sources, including through use of photovoltaic panels, provided motivation for conducting this research. The aim of the study was to assess the profitability of investing in photovoltaic panels, using a household in Poland in 2019–2021 as an example. The costs of the investment are presented, as well as the benefits, focusing mainly on economic benefits. Different calculations and estimations concerning return on invested capital are also presented. It is assumed that photovoltaic panels are advantageous from both an economic and an environmental standpoint. The research differentiates between environmental economics and ecological economics. The first theory assigns priority to economic over environmental issues, adopting a so-called 'economization of the environmental'. In turn, ecological economics reverses this order and treats the natural environment as more important than the economic aspects. In this situation, it is rather a paradigm of greening the economy and economic activity [Costanza et al. 1997, Rogall 2010, Czaja 2012, Borys 2013, Prandecki et al. 2014]. In the context of a photovoltaic micro-installa-

[1] More about energy poverty – see [Wysokiński et al. 2017, Piwowar 2020, 2021].

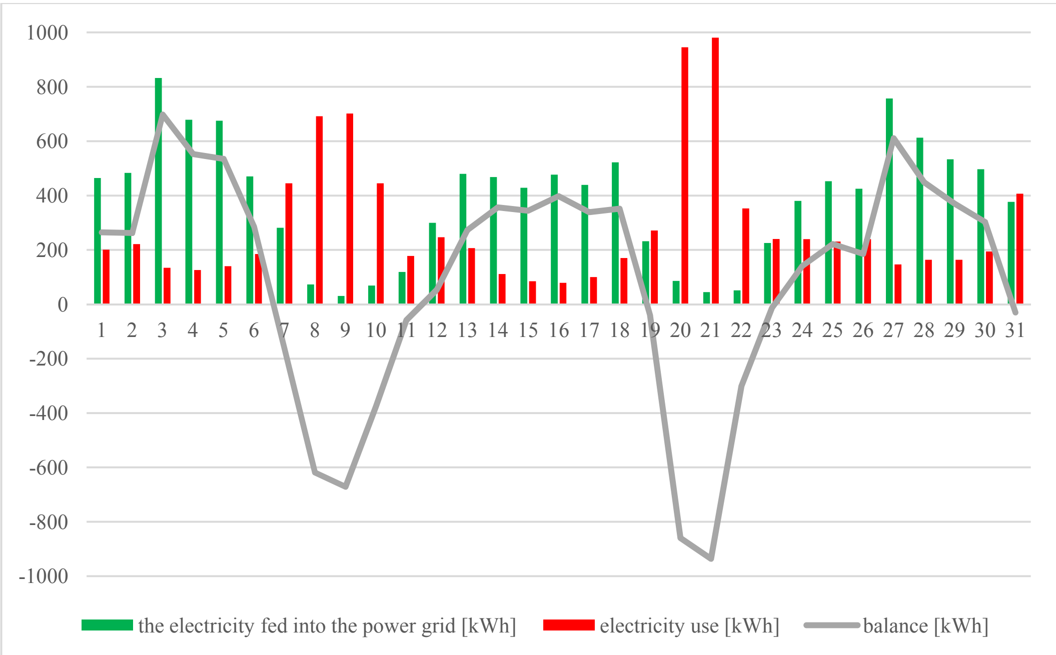
tion in a household, it is possible to achieve goals from both areas at the same time (economic benefits associated with environmental protection).

MATERIAL AND METHODS

The analysed installation consists of 24 photovoltaic panels mounted on the south side of a sloping roof of a single-family house, which is the most advantageous positioning in terms of effective use of solar radiation. This micro-installation is located in the Turek district, in the Wielkopolska voivodeship of Poland. The total cost of installation with assembly was PLN 18,000 (EUR 4,000), of which PLN 8,000 (EUR 1,780) (i.e. 44,4% of the total amount) was paid with support from public funds allocated for the installation of photovoltaic panels. Microeconomic data was collected individually for the period from April 2019 to the end of October 2021, i.e. the most recent available. The data was compiled on a monthly basis, so the series covers 31 periods. In each period, the amount of electricity fed into the power grid, household energy consumption, and energy prices are given. This allowed a calculation of the energy balance in the household, as well as the potential benefits, in the case of a surplus of energy fed into the grid compared to the energy used. The work uses elements of financial analysis, including profitability analysis.

RESULTS AND DISCUSSION

The Fig. 1 shows the amount of electricity fed into the power grid and consumed by the surveyed household, together with the monthly balance between these values, from April 2019 to October 2021, in kilowatt-hours (kWh). For obvious reasons, the highest energy production (and the amount fed into the grid) is achieved in the summer months when there is the most sunshine, with relatively low production in the winter months. In the most favourable months, the amount of energy fed into the grid was 675–832 kWh, while in the winters it was only about 30 kWh. Throughout the entire



*period t1 = April 2019.

Fig. 1. Electricity fed into the power grid, electricity used in the analysed household, and balance between these values in the following months in the period April 2019–October 2021 in kWh

Source: Elaboration based on data collected by the authors.

period of study, the photovoltaic installation produced and fed into the power grid nearly 12 thousand kWh (almost 12 MWh). Electricity consumption in the household was also unevenly distributed in individual seasons – it was definitely the highest in the winter and relatively low in the summer, and was characterised by high fluctuations – the variance is nearly 15% higher than the amount of energy fed into the grid. In December 2019 and December 2020, the amount of energy consumed by the household was over 22 times greater than the amount produced by the photovoltaic panels. In turn, during the period June–August, in the three consecutive years, the household usually used only 16–30% of the energy generated by the panels.

In turn, Fig. 2 shows the distribution of the balance between the amount of electricity fed into the power grid and the amount of energy consumed in the household on a monthly basis from April 2019 to October 2021 in kWh. From the standpoint of economic profitability for the entire micro-installation, including changes in energy consumption, the most favourable balances were achieved in the summer months of 2019, and the weakest in 2020. During nine months of 2019 (from the start of data collection in April, through December) the balance was 1,143 kWh (data from 2019 did not include several winter months with very low values of electricity production from photovoltaic panels[2]). In 2020, the weather conditions were much less favourable, with less sunshine (peak sun hours). Throughout 2020, the balance between generated and consumed energy was negative, at a level of 155 kWh. In turn, in 2021 (until the end of October), there was a clear positive balance, exceeding 1,930 kWh. Generally speaking, over an entire year, less solar energy is generated in November and December. Therefore, a negative balance occurs in the months of November–January, the balance fluctuates around zero in February, March and October, and in the remaining months it is possible to generate a surplus. This means that using a photovoltaic micro-installation to generate solar energy can be seen not only as beneficial for environmental reasons, but also in economic terms.

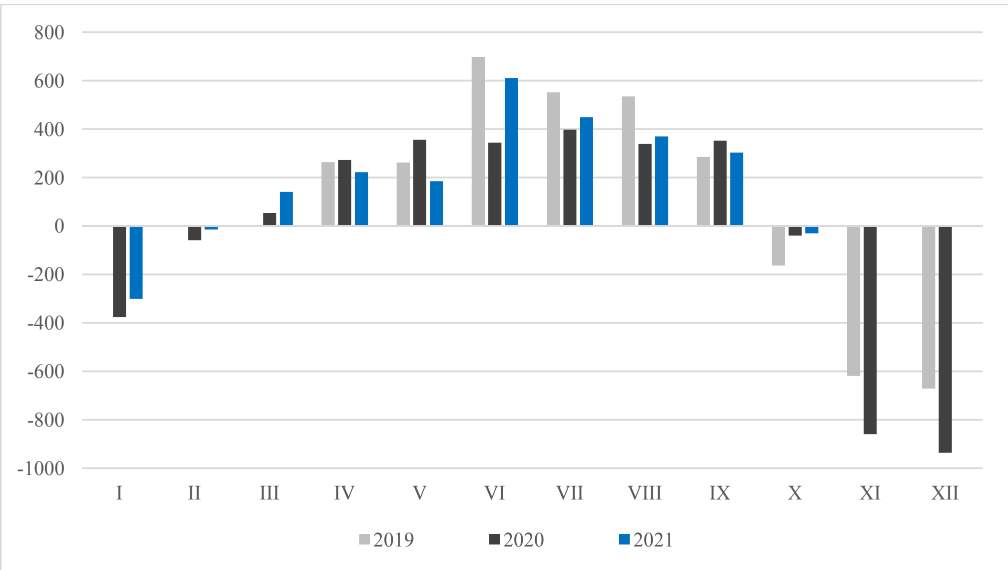


Fig. 2. Balance between electricity fed into the power grid and electricity used in a surveyed household in the following months, in 2019–2021, in kWh

Source: Elaboration based on data collected by the authors.

[2] The number of annual sunshine hours in Poland is estimated at 1,600, of which nearly 80% occur between April to September. Taking into account climate change, the annual number of sunny hours may even increase to 2,000 [Kruzel and Helbrych 2018].

Table 1 presents data on the amount of energy fed into the power grid, use and balance, as well as electricity prices for each year, along with the difference expressed in monetary units (PLN) and balance expressed in PLN and EUR. Such a summary allows us to see the current profitability of the analysed prosumer micro-installation. Taking into account the 31 months covered by the study (a relatively short period), the cumulative positive balance exceeds 2,900 kWh, which results in a surplus of over PLN 1,600 (EUR 360). The current cumulative return of investment (ROI) would be 16% (PLN 1,600/10,000), with the average value

Table 1. Electricity fed into the power grid, electricity use and balance in a household [in kWh], as well as electricity prices [in PLN] and balance [in PLN and EUR] in the following months of period April 2019–October 2021

Specification	Electricity fed into the power grid [kWh]	Electricity use [kWh]	Balance [kWh]	Price for 1 kWh [PLN]	Balance [PLN]	Balance [EUR]
04.2019	464.639	200.573	264.066	0.4862	128.389	29.95
05.2019	483.225	221.154	262.071		127.419	29.66
06.2019	832.516	134.422	698.094		339.413	79.56
07.2019	678.516	126.193	552.323		268.539	63.04
08.2019	675.078	139.995	535.083		260.157	59.89
09.2019	470.3	184.897	285.403		138.763	31.87
10.2019	281.525	445.19	–163.665		–79.574	–18.49
11.2019	72.812	691.653	–618.841		–300.880	–70.23
12.2019	30.594	701.916	–671.322		–326.397	–76.40
total 04–12.2019	**3,989.205**	**2,845.993**	**1,143.212**		**555.83**	128.84
01.2020	68.661	444.782	–376.121	0.5374	–202.127	–47.55
02.2020	118.859	177.558	–58.699		–31.545	–7.37
03.2020	299.864	246.443	53.421		28.708	6.47
04.2020	479.644	206.877	272.767		146.585	32.25
05.2020	467.752	111.517	356.235		191.441	42.27
06.2020	428.663	84.579	344.084		184.911	41.60
07.2020	476.605	78.725	397.88		213.821	48.02
08.2020	439.313	100.27	339.043		182.202	41.39
09.2020	522.393	170.363	352.03		189.181	42.28
10.2020	231.826	271.403	–39.577		–21.269	–4.68
11.2020	85.84	945.564	–859.724		–462.016	–102.62
12.2020	44.483	980.933	–936.45		–503.248	–112.42
total in 2020	**3,663.903**	**3,819.014**	**–155.111**		**–83.36**	–20.36
01.2021	51.348	352.463	–301.115	0.5940	–178.862	–39.37
02.2021	225.356	239.96	–14.604		–8.675	–1.93
03.2021	380.466	239.836	140.63		83.534	18.16
04.2021	452.696	230.823	221.873		131.793	28.87
05.2021	424.911	239.708	185.203		110.011	24.28
06.2021	757.324	146.413	610.911		362.881	80.61
07.2021	613.058	163.875	449.183		266.815	58.47
08.2021	533.642	163.613	370.029		219.797	48.10
09.2021	496.828	194.147	302.681		179.793	39.37
10.2021	376.822	406.898	–30.076		–17.865	–3.89
total 01–10.2021	**4,312.451**	**2,377.736**	**1,934.715**		**1,149.22**	252.68
Total in the entire period	**11,965.559**	**9,042.743**	**2,922.816**	–	**1,621.69**	361.16

*the values in EUR were calculated using monthly exchange rates published by the central bank of the Republic of Poland [NBP 2022].

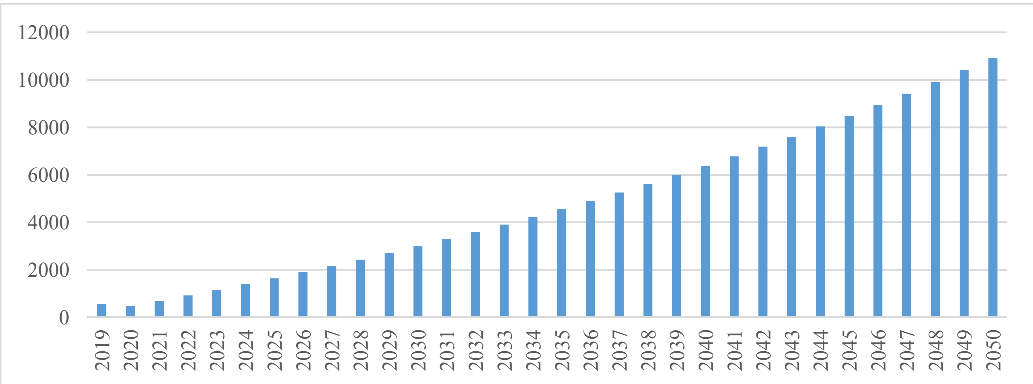
Source: Authors' own elaboration based on data from a household and [Urząd Regulacji Energetyki] (prices).

of 6.2% when annualised. However, it is important to note that data was collected for only 31 months, and excluded five less-sunny autumn and winter months from the 36 month period of years 2019–2021.

The profitability of the investment depends on several factors, including those already presented: the effectiveness of the installation, i.e. the amount of energy it will generate, which in turn depends on the level of solar radiation and the number of sunshine hours, as well as energy consumption and electricity prices. This data is presented in Fig. 3. According to manufacturing information as well as available data, photovoltaic panels should be efficient for about 25 years, with an annual degradation rate of 0.5–0.8% [National Renewable Energy Laboratory 2022]. Therefore, after this period their efficiency may decline to the level of 80–88%. However, the appropriate utilization and maintenance of panels could extend their functionality to 35 years.

As the analysed period does not cover three full years and is missing several particularly unfavourable winter months, it should be assumed that on average each year (starting from 2021) the installation will generate a production surplus of approx. 370 kWh, based on the available data. When calculating profitability in the long term, it has been assumed that electricity prices will increase at a rate of 3% annually. The data currently available shows that the installation generated an economic surplus of PLN 555.8 (EUR 128.8) in 2019, a loss of PLN 83.4 (EUR 20.4) in 2020, and it is estimated that the surplus will amount to approximately PLN 220 (about EUR 50) in 2021. In the context of the presented assumptions, the surplus will grow by approx. 3% annually in the coming years. In this situation, by 2050, the installation will pay back in full (the cumulative value of the surplus will amount to PLN 10,930), as shown in Fig. 3. However, at a higher annual rate of energy price growth, at which it would be possible to sell excess solar-generated energy to the power grid, e.g. 3.5 or 4%, then the cumulative value of the surplus will exceed PLN 10 thousand – 3 or 4 years earlier, respectively. This means that, looking at economic conditions only (including the annual degradation rate), a photovoltaic micro-installation is profitable in the long term, taking into account the co-financing for the installation of these panels through government subsidies, as mentioned earlier.

Kruzel and Helbrych [2018] showed that investments in photovoltaic panels in Poland are economically justified and that, from a financial point of view, they can pay off even in as few as twelve years. However, it should be noted that these authors, when calculating future values, assumed macroeconomic variables (PLN/EUR exchange rate, inflation rate or



*the current (February 2022) exchange rate is: 1 EUR = 4.5 PLN [NBP 2022].

Fig. 3. The cumulative economic surplus from the prosumer photovoltaic panels in the surveyed household in 2019–2050 in PLN

Source: Elaboration based on data collected by the authors.

electricity price growth rate) at levels that significantly differed from the actual rates at the end of 2021 (assumptions were made in the 2017–2018 year, but at the end of 2021 some of them were far from actual values). For this reason, these calculations should be slightly modified. Brodziński et al. [2021], analysing the economic efficiency of 22 photovoltaic farms of various sizes located in the north-eastern part of Poland, concluded that all of them were economically justified and profitable. At the same time, they indicated that the government support system was important in the context of actually getting investments to be implemented. Guaita-Pradas and Blasco-Ruiz [2020], in their analysis of the profitability of solar panels in Spain, emphasized the great importance of the initial investment costs as a factor that must be taken into account in long-term financial calculations. Sobczyk [2020] indicated that a prosumer micro-installation consisting of solar collectors in a household in Poland has a chance to pay for itself after a longer period, i.e. after a minimum of 20 years, assuming that it is an alternative to heating water with coal. In the case of heating water with other sources (e.g. electricity, heating oil), the investment could pay back much faster. Some authors even pointed out that photovoltaic installations can be economically viable even without a subsidy system, assuming the use of this solution in households with above-average electricity consumption [Chmieliński 2015] or favourable macroeconomic conditions [Kruzel and Helbrych 2018].

The authors of the present article are aware that a full financial analysis should take into account the cost of capital (loans, home equity or external capital), although it is now relatively low due to low interest rates. On the other hand – while facing high inflation rates, which the global economy is currently struggling with, including developed economies, like Poland [Eurostat], the decision to install such a prosumer installation is reasonable and it can be treated as an investment that protects against inflation and its consequences. In addition, aside from financial aspects of the installation, there are also economic issues that are difficult to calculate, and which are important in a holistic approach. From the household perspective, namely it is about independence and greater energy security as well as a lower risk of energy poverty. And finally, in the context of such an investment, it is worth pointing to the undeniable benefits for the natural environment resulting from the use of photovoltaic panels: significant reduction of carbon dioxide and other harmful substances that accompany the combustion of fossil fuels, renewable and inexhaustible nature of solar energy, no environmental degradation related to the extraction of mineral resources. If environmental benefits were to be valued under market conditions, the profitability of this micro-installation would certainly be higher.

CONCLUSIONS

The aim of the work was to present the profitability of investing in a photovoltaic micro-installation in a household in Poland during the period 2019–2021 (for 31 out of 36 months, over three calendar years). Therefore, the costs of the investment were presented, as well as the benefits, mainly in economic terms. Moreover, different calculations and estimations concerning return on the invested capital were made. Taking into account the entire period covered by the study, the cumulative amount of electricity generated by the panels reached almost 12 thousand kWh. This resulted in a positive balance above household energy consumption at a level of 2,900 kWh, i.e. an economic surplus of over PLN 1,600 (EUR 360). With careful and rational assumptions, the installation can bring savings of several hundred PLN a year, which means that it can fully pay for itself over 30 years. It should be noted that the purely financial profitability of an investment in the long term is influenced by several factors, including the technical efficiency of the installation, energy consumption and prices, as well as various external factors. However, it is worth viewing the use of photovoltaic panels also in non-financial terms. After all, their use provides undoubted benefits for the natural environment, as well as various economic arguments related to greater energy security and partial energy independence. Taking all these elements into account would make the overall calculation much more favourable.

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OPŁACALNOŚĆ INWESTYCJI W PANELE FOTOWOLTAICZNE W POLSCE NA PRZYKŁADZIE GOSPODARSTWA DOMOWEGO

STRESZCZENIE

Panele fotowoltaiczne są coraz częściej wykorzystywane do przetwarzania energii słonecznej na energię elektryczną w gospodarstwach domowych, także w Polsce. Rozwój tego rodzaju energii odnawialnej wynika z jednej strony z obowiązujących regulacji prawnych w obszarze polityki klimatyczno-energetycznej, z drugiej strony natomiast z licznych korzyści, które są związane ze stosowaniem tych paneli. Wśród nich należy wymienić zarówno argumenty ekonomiczne, jak i środowiskowe. Celem pracy była ocena opłacalności inwestycji w mikroinstalację fotowoltaiczną w gospodarstwie domowym w Polsce w latach 2019–2021. Omówiono więc koszty inwestycji, a także korzyści wynikające z jej podjęcia. Ponadto, dokonano różnych obliczeń i szacunków dotyczących zwrotu z zainwestowanego kapitału. Przez 31 miesięcy objętych badaniem skumulowany dodatni bilans energii elektrycznej wytworzonej ponad energią zużytą w gospodarstwie domowym przekroczył 2900 kWh, co skutkowało nadwyżką ekonomiczną w kwocie ponad 1600 PLN (ok. 360 EUR). Co więcej inwestycja przyczyniła się do ochrony środowiska naturalnego, co jest wartością dodaną fotowoltaiki.

Słowa kluczowe: panele fotowoltaiczne, energia elektryczna, odnawialne źródła, opłacalność, gospodarstwo domowe, Polska