**Agnieszka Joanna DRZYMAŁA [1], Ewa KORZENIEWSKA [2]**

Department of World Economy and European Integration, Institute of Economics, University of Lodz (1)
Institute of Electrical Engineering Systems, Lodz University of Technology, 90-537 Lodz (2)
ORCID: 1. 0000-0003-1834-5202; 2. 0000-0002-0766-1376

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# Analysis of the profitability of a photovoltaic investment by private investors depending on the level of self-consumption of the energy produced in the amended RES Act in Poland

***Abstract.*** *The article presents an analysis of the profitability of private photovoltaic investments depending on the percentage of self-consumption of the produced electricity. The point of reference is the new RES Act, amended in 2021. The DCF (discounted cash flow) method was used to estimate the profitability of the investment. In the analysis, the IRR (internal rate of return) and NPV methods were used to compare the economic efficiency of the investment in relation to the investment in treasury bonds.*

***Streszczenie:*** *Artykuł przedstawia analizę opłacalności inwestycji fotowoltaicznej inwertorów prywatnych w zależności od stopnia autokonsumpcji wyprodukowanej energii elektrycznej. Punktem odniesienia jest nowa, zmieniona w 2021r ustawa o OZE. W szacowaniu opłacalności inwestycji wykorzystano metodę DCF (discounted cash flow). W analizie zastosowano metodę IRR (internal rate of return) oraz metodę NPV aby dokonać porównania efektywności ekonomicznej inwestycji w stosunku do lokaty kapitału w obligacje skarbowe. .(**Analiza opłacalności inwestycji fotowoltaicznej inwestorów prywatnych w zależności od poziomu autokonsumpcji wyprodukowanej energii w świetle zmienionej ustawy OZE w Polsce**)*

**Keywords:** renewable energy, photovoltaic power, cost-effectiveness of investment
**Słowa kluczowe:** energia odnawialna, fotowoltaika, opłacalność inwestycji

## Introduction

The period of recent years, starting from 2019, is characterized by unprecedented dynamics of changes in the demand for energy resources and energy since the Second World War. At the beginning of this period, as a result of the Covid19 pandemic, this dynamic was characterized by a significant decrease in demand and a drop in prices, and then, due to the rebound of global economies, a sharp, even steep growth. The demand for raw materials, including energy, was additionally intensified in 2022 by the ongoing military operations and the war in Ukraine. This led to the disruption of the raw materials and energy markets and to the emergence of economic disturbances as well to uncertainty for doing business and to challenges in the functioning of countries [1–5].

Referring to the latest legislation on photovoltaic installations, it should be noted that on December 14, 2021, the Polish President signed the Act on renewable energy sources and certain other acts (Act dated on October 29, 2021) [6]. Then the Act from January 27, 2022 was updated [7]. The legislator changed the rules of operation of the settlement system. However, they only apply to new prosumers who have registered their solar farms after April 1, 2022. These prosumers do not have a rebate system, but a net settlement system. It consists in settling the value of energy generated by the owner of a photovoltaic micro-installation based on the value of energy determined as a target at the price from the Day-Ahead Market (DAM).

The new legislation in this area reflects EU law. All Member States are implementing the new solutions [8]. Pursuant to Directive (EU) 2019/944 of the European Parliament and of the Council of June 5, 2019 on common rules for the internal market in electricity, amending Directive 2012/27/EU (the so-called market directive), all energy market participants, including prosumers have to pay network fees. Directive of the European Parliament and of the Council (EU) of December 11, 2018 on the promotion of the use of energy from renewable sources (the so-called RED II Directive) [9] provides for the obligation to enable prosumers to receive remuneration reflecting the market value of energy. The net-billing system puts these solutions into practice.

The article presents an estimation of the profitability of investing in a photovoltaic installation for the needs of private investors in the new net settlement terms applicable after April 1, 2022. A simulation of the impact of self-consumption of electricity on the investment payback period and its profitability has been presented. The simulation takes into account the boundary parameters that significantly affect the payback time. The new billing system based on Net-metering principles assumes many variable input parameters. As a result, estimating profitability is subject to a high risk of uncertainty.

## Research methodology

The implementation of the new Net-billing billing system is carried out in several stages and Poles are currently in the second stage, valid from July 1, 2022 to June 30, 2024. The value of electricity is determined for each calendar month and is the product of: the sum of the amount of electricity put to distribution network by the prosumer and the monthly market price of electricity for a given calendar month. Therefore, the price of electricity introduced by the prosumer to the grid in this period is determined as the monthly market price (RCEm) in accordance with:

$$RCE = \frac{\sum_{s \subset S} CG_s \cdot EG_s}{\sum_{s \subset S} EG_s} \qquad (1)$$

where: $CG_s$ – price of electricity determined in the single-price auction system at the day-ahead trading session of the Polish Power Exchange (TGE) [PLN/MWh], $EG_s$ – the amount of electricity constituting the trading volume at the day-ahead trading session of the TGE market with price determination energy in the single-price auction system [MWh], S – a set of day-ahead market trading sessions with determination of the energy price in the single-price auction system, run by the TGE commodity exchange or as part of the single day-ahead market coupling run by designated electricity market operators.

The monthly market price of electricity is determined for each calendar month as weighted with the volume of electricity put to the power grid by prosumers according to:

$$RCEm = \frac{\sum t \in T(E_t \cdot RCE_t)}{\sum_{t \in T} E_t} \qquad (2)$$

where: $E_t$ – total volume of electricity put into the power grid in the imbalance settlement period t by renewable energy prosumers generating electricity in micro-installations, $RCE_t$ – market price of electricity in the imbalance settlement period t, where if $RCE_t$ has a negative value for a given period t , then for this period t, $RCE_t$ equals zero [PLN/MWh], T – set of imbalance settlement periods in a month

In the third stage, applicable from July 1, 2024, the settlement of electricity prices between the seller and the prosumer of renewable energy will be based on the total amount of balanced energy (from all phases of the three-phase system) in each hour and expressed in kWh.

Settlement in the Net-biling system is carried out using the so-called prosumer deposit, in which it is possible to reduce the amount due for energy taken from the network by the prosumer. Such settlement takes place at mid-term market rates depending on the settlement stage described above. The value of the prosumer deposit for a given calendar month is determined and assigned to the prosumer account in the next calendar month. The funds with the oldest date of assignment to the account will be used for settlement with the seller in the first place. The amount of funds constituting a prosumer deposit may be settled on a prosumer account for 12 months from the date of assigning this amount as a deposit.

The developed model must take into account the price of electricity on the Polish Power Exchange TGE in given time intervals, energy demand by the investor. At the very beginning of the investment, the investor has to anticipate the demand for electricity in future billing periods in hourly periods; index of changes in prices of goods and services (inflation) and the interest rates on alternative investments, e.g. in EDO treasury bonds.

Although the current average monthly prices of electricity per 1MWh quoted on the Polish Power Exchange are very high, along with the stabilization of prices of energy resources and the war in Ukraine, these prices may drop significantly. In addition, it can already be seen that hourly quotations (especially in summer periods in the afternoon hours) when the production from renewable energy sources based on photovoltaics is high, the energy prices quoted on the Polish Power Exchange fall significantly.

The analysis of the profitability of the photovoltaic power plant with a capacity of 9.7kWp and average annual electricity production of 10.3 MWh was carried out based on the method of assessing the economic efficiency of the investment using the DCF method (discounted cash flows) at the assumed discount rate.

The investment assessment should include an analysis of the project based on the following relationships: discounted payback period (DPP), net present value (NPV), internal rate of return (IRR), break-even point (BEP) [10-12]. For such calculation the neural network can be also used [13,14].

A simplified version of the DCF equation in n time units (discounting periods) is as follows:

$$DPV = \sum_{nt=0}^{N} \left( \frac{FV_t}{(1+d)^t} \right) \qquad (3)$$

where: DPV - discounted present value of the future cash flow, adjusted for opportunity costs for an alternative cash investment, FV (future value) - nominal value of the future cash flow, d - discount rate, t - time in years preceding the future cash flow, N - number of cash flows

The NPV method is classified as a dynamic method and is based on the analysis of discounted cash flows of capital sums resulting from the saved costs of electricity consumption in relation to the interest rate on EDO treasury bonds. In the analyzed case, the NPV represents the surplus of the updated net profit over the alternative profit on investments with an internal rate of return equal to the adopted EDO bond discount rate. It also means an increase in the investor's wealth resulting from the implementation of the investment, taking into account changes in the value of money over time.

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I_0 \qquad (4)$$

where: NPV - net present value, $CF_t$ - cash flows (net) in period t, r - discount rate, $I_0$ - initial outlays, t - subsequent periods (usually years) of investment operation

The internal rate of return (IRR) is one of the most commonly used discounting methods for the purposes of evaluating investment projects. IRR is a measure of the return on investment and it shows the real rate of profit from the project, taking into account the change in the value of money over time. IRR is the interest rate at which the value of cash outflows equals the present value of cash inflows. In other words, the IRR represents the interest rate at which updated or otherwise discounted expenses will equal actualized receipts. The greater the investment income, the greater its value. In other words, it is the maximum investment loan rate that will allow you to finance the project without loss for the owners. IRR takes into account the change in the value of money over time. Calculation of the internal rate of return on investment (interest rate on capital employed) is a complex process that requires the use of the method of successive iterations and approximations to the result where NPV = 0.

$$\sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I_0 = 0 \qquad (5)$$

where: $CF_t$ - cash flows in period t, r - interest rate, $I_0$ - initial outlays in period zero, t - successive periods (years) of investment operation

In the analysis, the price of energy produced in particular periods was calculated from the product of the production forecasted in a given year (declining due to the decrease in cell efficiency) and the price of 1 kWh of energy updated by inflation. In addition, for investments in RES, the return on capital/profit generated for each period will also be reinvested once a year in long-term Treasury bonds with the same rate of return as the adopted alternative form of safe investing.

Two variants of the simulation for investor A and investor B were carried out in the analysis:

A - the investor invests in the installation immediately after April 1, 2022 and assumes the energy purchase prices according to the G11 tariff in 2022 and in subsequent periods discounted with an average annual constant inflation of 4.5%. The authors are aware that inflation is volatile, however, both 10-year Treasury bonds and energy prices follow inflation.

B - support from the government of Poland and protection of households and entities classified as SMEs in 2023 and in subsequent years of the investment was assumed. In the real economy, where market rules apply, this assumption is unlikely to be maintained in the long term. For the purposes of the simulation, it is the starting point for the simulation.

The adopted assumptions and input conditions of the costs incurred for the simulations carried out for the investor A and B in the 9.7kWp installation are presented in Table 1.

Table 1. Estimated installation costs and parameters. Costs were converted at the exchange rate EUR/PLN of 4.65 on June 13, 2022.

| No | Description | Value |
|---|---|---|
| 1. | Initial and total costs of entry into the RES installation (with co-financing only for a photovoltaic installation with a power from 2 kW - 10 kW and 8% VAT rate) of the installed peak power | 8889.80 € (with 8% TAX and co-financing) |
| 2. | Peak power of the photovoltaic installation | 9,765 kWp |
| 3. | Average annual initial energy production | 10294,36 kWh |
| 4. | Total losses in the system | 19.6% |
| 5. | Forecasted average annual decrease in energy production | 1% |
| 6. | Long term average annual price index of consumer goods and services (inflation) | 4.54% |
| 7. | Interest rate on 10-year bonds EDO0632 | 1.25% + inflation |

Monthly market prices of electricity RCEm quoted on the Polish Power Exchange (TGE) for 1 MWh in the months from June to September 2022 are presented in Table 2. Prices have been converted at the fixed PLN/EURO exchange rate published by the National Bank of Poland on June 13 2022 Due to the short reporting period of monthly $RCE_m$ prices, the simulation assumed the average rate for the 2 months given in Table.

Table 2. Monthly market prices of electricity quoted on the Polish Power Exchange (TGE) (price are converted at the fixed PLN / EUR exchange rate for the period: June to September 2022).

| No. | Month | Value (EUR/1MWh without TAX) |
|---|---|---|
| 1. | June | 139.389 EUR |
| 2. | July | 171,241 EUR |
| 3. | August | 219,153 EUR |
| 4. | September | 153,101 EUR |
| **Average RCEm Price:** | | **170,721 EUR** |

### Investor A case study

The adopted assumptions and input conditions for the simulation and estimation are presented in Table 1, 2 and 3.

Table 3. PGE constant electricity prices in the G11 tariff in 2022.

| No | PGE electricity prices in the G11 tariff: (price list for the period: 1 March 2022) | Value (EUR + TAX) - case A | Value (EUR + TAX) - case B |
|---|---|---|---|
| 1. | Average price for active energy - 1 kWh | 0.10950 | 0,1833097 |
| 2. | Qualitative rate of 1 kWh of energy | 0.00251 | 0.00251 |
| 3. | Variable component of the grid rate of 1 kWh of energy | 0.05880 | 0.05880 |
| 4. | Fixed component of the network rate - 3-phase counter for 1 month | 1.41075 | 1.41075 |
| 5. | Subscription fee - monthly cycle (for 1 month) | 0.96774 | 0.96774 |

### Investor B case study

The analysis of this case concerns the future period, i.e. 2023. As of the date of writing the article, on October 20, 2022, the Sejm of the Republic of Poland adopted an act limiting the amount of changes in electricity prices in 2023. Pursuant to the Act, protection of households, public utility entities and micro, small and medium-sized enterprises against a drastic increase in electricity bills was introduced. The regulation consists in introducing a mechanism of a "maximum" price of electricity for settlements with authorized customers by energy sellers, not higher than:

PLN 693/MWh (€149) (Net) for households after exceeding 2MWh of energy consumption (without a large family card or other privileged groups);

PLN 785/MWh (€169) (Net) for other eligible customers in the period from February 24, 2022 to December 31, 2023.

Another change in the gross prices of 1kWh of energy is the possibility of increasing the VAT rate from 5% to 23% in 2023 and this rate is not known at the date of writing the article, as is the variable component of the network electricity price. For this reason, apart from active energy, it was assumed that other charges will remain at the current level in 2023.

### Results of the analysis for the case of investor A

The simulations carried out on the data for investor A's assumptions made it possible to assess the economic efficiency of the investment. It has been presented in the form of charts and a table for various levels of self-consumption, varying from 5% to 60%.

Figure 1 presents changes in the Net Present Value (NPV). Figure 2 shows the payback period as a function of the decline in the investor's own electricity consumption from 5% to 60%. The self-consumption of 60% or more gives the shortest payback period of up to 6 years. It should be noted that payback periods do not differ significantly between self-consumption of 5% (6.3 years) and 60% (5.8 years).

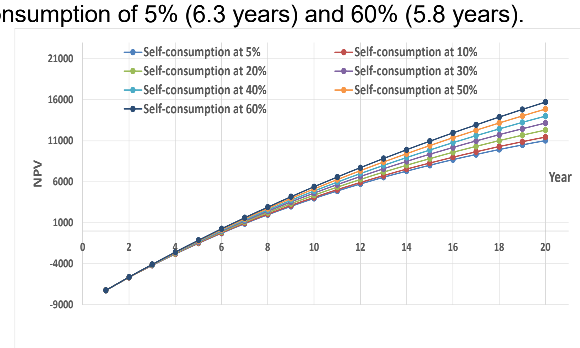


Fig. 1 Comparative characteristics of the value of changes in NPV for the case of investor A with self consumption in the range from 5% to 50%. The characteristics refer to the advantage of investing capital in an alternative form of investing funds in 10-year treasury bonds , self-consumption was assumed at: (a) 5%; (b) 10% (c) 20%; (d) 30%; (e) 40%; (f) 50%.

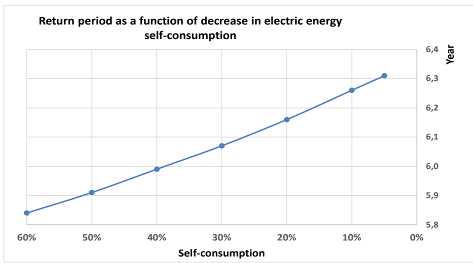


Fig. 2. Return period as a function of decrease in electric energy self-consumption for investor A. Self-consumption from 60% to 5%

However, the NPV characteristics presented in Figure 2 over a very long 20-year period indicate a significant advantage of the rates of return on capital for self-consumption 60% over the others. For example, an auto-consumption of electricity of 60% after 20 years of investment yields a return on capital of €15,7244 in absolute terms, while the same investment with an auto-consumption of 5% yields a return on capital of €11,037. Thus, the percentage difference in return rates in the 20th year of the investment is close to 43%.

Self-consumption at lower levels of 5% to 50% gives slightly longer payback periods. However, it is also a very interesting case of investing the capital. Therefore, it can be concluded that the auto-consumption of electricity is the main parameter influencing the payback period of the investment, with fixed prices of electricity sold to the investor and high resale prices. The obtained investment ratios are in Table 4.

**Results of the analysis for the case of investor B**

Comparative characteristics of the value of changes in NPV for the case of investor B with own consumption in the range of 5% to 50% are presented in Figure 3.

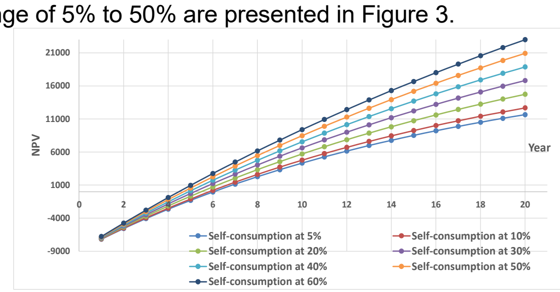


Fig. 3. Comparative characteristics of the value of changes in NPV for the investor B with self-consumption in the range from 5% to 50%. The characteristics refer to the advantage of investing capital in an alternative form of investing funds in 10-year treasury bonds, self-consumption was assumed at: (a) 5%; (b) 10% (c) 20%; (d) 30%; (e) 40%; (f) 50%.

Investor B who invests his capital in a photovoltaic installation according to the rules and support mechanisms provided for in 2023 will have even shorter payback periods and higher return on capital compared to investor A's rules. Figure 4 shows the payback period as a function of the decrease in own electricity consumption for this investor.

This period varies depending on the level of self-consumption and is 4.5 years for 60%, 6.2 years for 5 %.

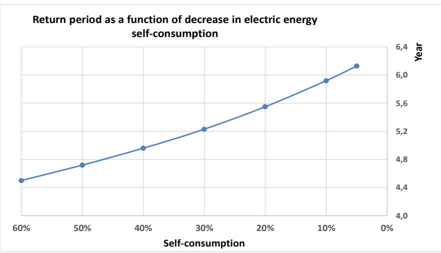


Fig. 4. Return period as a function of decrease in electric energy self-consumption for investor B.

Table 4 presents the main investment ratios - the ten-year payback period: NPV10 and the Internal Rate of Return (IRR).

Table 4. Investment indicators for case A and B

| Self-consumption: | NPV10 Year EUR | | IRR(10 years) | |
|---|---|---|---|---|
| | *Case A* | *Case B* | *Case A* | *Case B* |
| 5% | 3978.7 | 4309.9 | 14.1% | 14.8% |
| 10% | 4108.4 | 4770.9 | 14.3% | 15.6% |
| 20% | 4367.9 | 5692.8 | 14.8% | 17.3% |
| 30% | 4627.4 | 6614.7 | 15.2% | 18.8% |
| 40% | 4886.9 | 7536.6 | 15.6% | 20.4% |
| 50% | 5146.3 | 8458.6 | 16.0% | 21.8% |
| 60% | 5405.8 | 9380.5 | 16.4% | 23.3% |

For example, a 60% self-consumption of electricity for investor B after 20 years of investment gives an absolute return on capital of €22,987, while the same investment with a 5% auto-consumption level gives a return on capital of €11,642. Thus, the difference in percentage returns in year 20 of the investment is 102% in this case. This gives more than twice the capital advantage at this 60% level of self-consumption.

**Conclusions**

Simulations show that the rules applicable after April 1 for a new prosumer are not currently (i.e. in 2022 and 2023) worse for investments and rates of return than the old Net-metering rules applicable before April 1, 2022. However, the rules regarding fixed purchase prices as well as electricity resale prices may change (and depend on the Government's decision on the level of support). For the new prosumer, whose installation has been operating after April 1, 2022, it introduces a large degree of uncertainty as to the predictability of the rates of return.

Regardless of the level of self-consumption of electricity, the investment both in 2022 and on the terms in 2023 is beneficial in relation to the EDO bond alternative.

Self-consumption of 60% or more shortens both the investment time and, in the long run, gives higher rates of return, even exceeding 100% of the capital value (in case B).

Although the current average monthly electricity prices for 1MWh quoted on the Polish Power Exchange are very high, with the stabilization of energy commodity prices and the war in Ukraine, the prices may drop significantly. In addition, it can already be seen that hourly quotations (especially in summer periods in the afternoon hours), when the production from renewable energy sources based on photovoltaics is high, the energy prices quoted on the Polish Power Exchange fall significantly. Ultimately, it should noticed that the energy sold after July 1, 2024 by the prosumer will be at its market value and will be determined on the basis of hourly market electricity quotations. With high probability, it can be much cheaper than the one bought in other hours, e.g. in the evening or winter.

The profitability analysis shows that an investment in a photovoltaic installation is an interesting alternative to investing funds in long-term treasury bonds. The payback period is about 6 years and the IRR rate of return (depending on the level of self-consumption) ranges from 14% to 23% over 10 years of the installation operation, which more than compensates for the investment risk and the outlays incurred.

***Authors:*** *PhD Agnieszka Drzymała, Department of World Economy and European Integration, Institute of Economics, University of Lodz, 90-214 Lodz, Rewolucji 1905 Nr. 41, Poland; e-mail: agnieszka.drzymala@uni.lodz.pl; PhD, DSc Eng. Ewa Korzeniewska, Ass. Prof. Institute of Electrical Engineering Systems, Lodz University of Technology, 90-537 Lodz, Poland; Stefanowskiego, 90-537 Lodz,*
*e-mail: ewa.korzeniewska@p.lodz.pl*

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