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Economic Analysis of Profitability of Using Energy Storage with Photovoltaic Installation in Conditions of Northeast Poland

Maciej Neugebauer [1,*], Jakub d'Obyrn [2] and Piotr Sołowiej [1]

[1] Faculty of Technical Science, University of Warmia and Mazury in Olsztyn, Oczapowskiego Str. 2, 10-719 Olsztyn, Poland
[2] Faculty of Economic Sciences, University of Warmia and Mazury in Olsztyn, Oczapowskiego Str. 2, 10-719 Olsztyn, Poland
* Correspondence: mak@uwm.edu.pl; Tel.: +48-895-233-639

Abstract: This work presents an economic analysis of the use of electricity storage in PV installations, based on previously adopted assumptions, i.e., the type and location of the tested facility and comparative variants, divided into the share of the storage in the installation, and the billing system. The work takes into account the share of the energy shield and assumes a consumption limit of 2000 kWh. The cost of building the installation is based on July 2023 prices. The work assumes potential directions of changes in electricity prices, based on which the degree of investment profitability for a given price situation is determined. Depending on the adopted change in the direction of electricity prices, with a low price increase rate, for installations in the new billing system (net-billing), the optimal choice is an installation without energy storage with a power exceeding the actual energy demand. Assuming a high increase in electricity prices, the optimal choice is an installation with energy storage with an installation capacity exceeding the actual demand. For installations billed using the net-metering system, the optimal choice is an installation without storage with an appropriately selected installation power. This article shows how much you can gain after installing a PV installation and not only what costs must be incurred to complete the investment. Profit analysis will enable a more complete assessment of the profitability of investing in PV panels (with or without energy storage). It describes the verification of the profitability of a PV installation for a standard user depending on various types of settlements with the electricity supplier and the lack or installation of an energy-storage facility.

Keywords: PV installation; energy storage; profitability; operating costs

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1. Introduction

Rising energy prices and the climate crisis cause more and more people to install PV installations in private homes. Due to the nature of the operation of a PV installation—most of the energy is produced when the owners are not at home—the profitability of such an installation is often not as high as initial calculations would suggest. Even smart home solutions (maximizing necessary consumption during "sunny" hours) and minimizing consumption by energy saving throughout the day do not significantly improve profitability. To improve it, the legislator introduces various solutions (net-metering, net-billing, etc.), but they often do not work properly in Poland due to the condition of energy networks. This results, for example, in the top-down disconnection of the PV installation from the grid, and consequently, the generated electricity is not received by the grid, and the owners of the plants suffer economic losses.

The introduction of changes to the prosumer billing system is aimed at implementing the provisions of Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market in electricity and the amending Directive 2012/27/EU, to which EU Member States are obliged. It aims, among other things, to ensure that end consumers can participate directly in the energy market and that they can sell their surplus electricity produced. The new solution is based on billing prosumer installations on a system of value billing of produced surplus energy not consumed at the place of generation (so-called net-billing), according to exchange prices, first at the average price of the previous month and, from mid-2024, at an hourly price in line with the applicable dynamic tariff. EU Member States are obliged to ensure that active electricity consumers, including prosumers, can sell surplus electricity themselves.

One of the methods to improve this situation is the use of electricity storage in private homes. Many prosumers wonder about the profitability of such a solution. In this work, the energy and economic profitability of such a solution compared to classic solutions—e.g., net-billing—was calculated and simulated over 30 years. The calculations were made for an installation located in the north-eastern part of the country.

A photovoltaic installation consists of structural elements, i.e., the assembly structure of the installation, and power generating, and power converting elements, as well as protection elements, i.e., photovoltaic panels, an inverter, and overcurrent protection, surge limiters, and fire protection switches [1–3].

Photovoltaic panels can be divided into several main groups, including monocrystalline, polycrystalline, amorphous, and the increasingly used mono-half-cut cells. Panels with mono-half-cut and monocrystalline cells are characterized by the highest achieved efficiency, which translates into greater production using the same area compared to other technologies. Mono-half-cut technology involves cutting a monocrystalline cell in half to later connect them in parallel to form sub-modules. The consequence of such a procedure is an output current and voltage similar to the value of the entire module [4–6]. Additionally, the temperature coefficient of the module is lower, which also improves energy efficiency and operation in partially shaded conditions [7–9]. Apart from the DC switchgear, power optimizers may also appear between PV panels and the inverter [10,11].

Additionally, in addition to the above-mentioned elements, a PV installation may also include energy storage [12]. Energy storage can be divided according to, among others, methods of energy storage, as [13] mechanical, chemical, in an electric field, etc. Furthermore, in addition to the above elements, a PV installation can also include energy storage 12. Energy storage can be categorized according to the methods used to store energy, including [13] mechanical, chemical, in an electric field, etc.

In this work, we will focus only on battery storage in lithium-ion technology (e.g., $LiFePO_4$) as the most commercially available technologies [12,14,15] on the market prepared for cooperation with PV installation inverters. A lithium-ion battery works on a similar principle to a lead-acid battery, with the difference that during discharge, instead of precipitating lead sulfate, compounds of lithium and the refrigerant used in the battery are precipitated [14,16,17].

Another aspect that is taken into account in this work is the settlement system with the electricity supplier, described by Kwaśniewski [18]. In Poland, there are now two different systems: net-metering (sometimes called the prosumer system) and net-billing. The method of settlement on a net-metering basis is the possibility of storing unused electricity in the national power grid for a period of 12 or 18 months (depending on the contract signed with the energy company), taking into account the return of 20% in the case of installations with a capacity of up to 10 kW and 30% above 10 kW. The owner of the installation has the right to settle on a prosumer basis for 15 years from the date of the official start of electricity production [19–21].

Settlement in the net-billing system is based on dynamic sales and purchases from the energy supplier with whom the contract was signed. Electricity is purchased when the production from the photovoltaic installation is insufficient to meet the demand. Electricity is purchased at a retail price. The sale takes place when the production from the photovoltaic installation is higher than the electricity demand. Electricity is sold at the wholesale price, while the upper limit of the power for which funds can be withdrawn is 20% of the stored power from the network in a given month. This is to prevent intentionally oversized installations [22,23]. For energy efficiency reasons, micro-storage combined with a photovoltaic system is always recommended

From the energy point of view, a micro energy-storage unit cooperating with a PV installation is always desirable [24,25]. The Bhoi and Nayak work [26] shows the advantages of such a solution in the case of energy storage for hours. The resulting stabilization of the operation of the PV installation and the lack of disconnection from the National Power System and the resulting stabilization of the operation of PV installations in cooperation with the National Electricity System are shown in the articles [27,28]. In turn, the works [29–31] analyzed the impact of energy storage over a longer time—from days to months—on the stability of the power supply and the possibility of using surplus energy produced on sunny days later depending on the installation power and daily consumption. The work [19] shows that the longest profitable storage time in the case of PV installations up to 5 kW (in private homes, production for own needs) is several months in Central Europe.

However, an economic analysis of the use of energy storage is not so obvious. The investigations [32,33] show the profitability of such a solution, but in turn, the work [34–36] shows that the use of energy storage in private homes with on-grid installations does not make economic sense. The payback period of the investment exceeds the life of the energy storage—compare [20,37]. The differences in the analysis results can, among other things, be explained by the difference related to the geographical location of the analyzed installation and energy storage. This affects the value of the average daily production, and the length of the energy-storage period in the warehouse. Therefore, in each case, profitability analysis should be performed individually for a given installation. The economic profitability of such a solution depends on several basic factors—the geographical location of the installation (number of sunny days, energy-storage period, etc.), the size of the installation and storage, the costs of the investment itself, and the legal and system conditions defining the principles of cooperation of PV micro-installations with the energy grid, described by Borek and Romaniu [38].

An analysis from the cost side for similar installations is available in various studies. In [39], the authors analyze the cost of PV installation in Poland, but for large investments—in photovoltaic farms with a capacity of about 1 MW. In turn, in [40], an analysis of the profitability of investment in PV panels is shown, but only for the program "My Current", which is a specific way of billing in the prosumer system. In the paper [41], the authors show the impact of the self-consumption of electricity on the profitability of investments—but in turn without taking into account the different methods of accounting for the electricity grid operator for the electricity consumed and injected. In turn, in [42], the authors analyzed hybrid solutions—i.e., combining PV systems with wind turbines. The works [43–45] analyzed similar solutions and assumptions as in this article, but for larger buildings, e.g., offices or public buildings. Such analyses were also performed for various climatic and sunny conditions—e.g., in [46] for Iraq and in [47] for countries in sub-Saharan Africa.

This work analyzed the economic profitability of 5 and 9 kWp PV installations with and without energy storage (and various systems of cooperation with the National Power System) over a period of 30 years of operation of PV installations in private houses in northeastern Poland. However, the novelty of this article is the analysis of the profits of the installation user, and the profit is defined as the cost not incurred and additional financial income due to the installation and the method of settlement with energy network operators. Such analyses showing how much you can gain (and not only how much you have to spend to gain) is not available, and they should be available—because on their basis, potential owners of single-family houses should make decisions about investing in a PV installation.

In particular, it should be emphasized that the novelty of this article is that the calculations presented in it are not based on optimal conditions—i.e., we do not calculate how much, for example, the auto-consumption of electricity should be for the installation to be as profitable as possible. This article calculates the profitability of such an investment from the point of view of an ordinary user who cannot increase, for example, the above-mentioned self-consumption, because he goes to work during the day. The calculations and models show how settlements with the electricity supplier and the impact of the energy storage after the entire period of use of the electrical installation will translate into the final profit for the user. They also show which system is more attractive to small prosumers—so that legislators/creators of energy law know what mechanisms should be used to promote and support the development of small, distributed energy sources (in this case, PV installations). However, similar conclusions can also be drawn for different various other renewable energy sources, e.g., for small-home wind turbines.

2. Materials and Methods

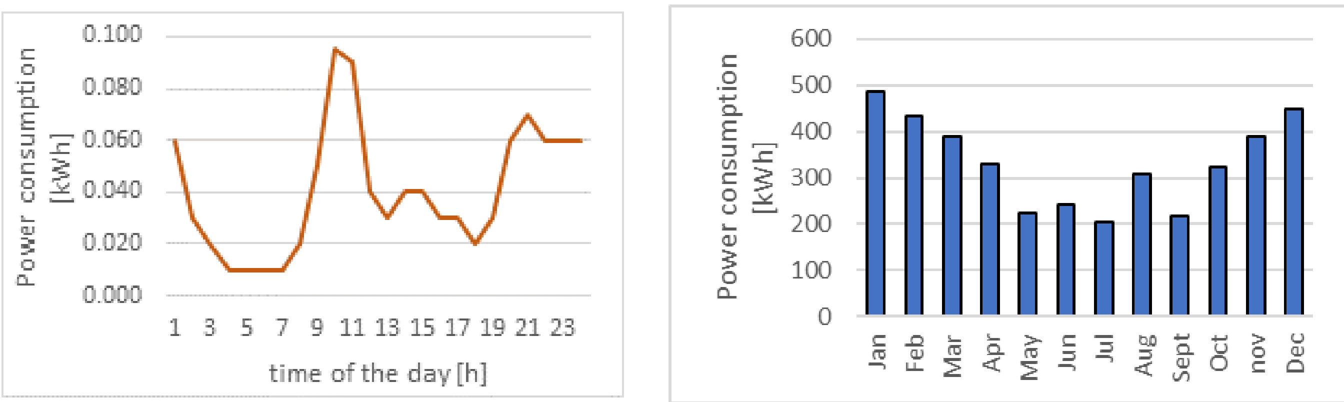
2.1. Aim and Scope of the Work

The work aims to conduct an economic analysis of the use of electricity-storage facilities cooperating with PV micro-installations to determine the profitability of the investment in terms of energy and economics in the conditions of northeastern Poland.

For the above analyses, appropriate comparative variants were adopted for nine variants of photovoltaic installations of different power levels with and without energy storage to compare them with the tested installation with electricity storage and to determine the profitability of the investment in terms of energy and economics. The variants were defined in such a way as to be able to independently determine the energy and economic differences between having an energy storage and a photovoltaic installation, having only a photovoltaic installation without energy storage, and the complete lack of the above-mentioned installation with a building connected to the power grid.

2.2. Description of the Facility and Variants

The object on which the analyses were carried out is a single-family house with a gable roof with a roof inclination angle of 30 degrees and an electricity demand of 4000 kWh per year. The analyzed case is billed under a single-tariff system. This level of consumption is based on a value close to the typical consumption in a single-family home. The house is located in the northeastern part of Poland, oriented 165 degrees to the azimuth. The solar insolation value in the area is 1032 kWh/m^2 per year (PV Sol premium 2023, Meteonorm 8.1). Electricity demand growth was assumed at 0.4% per year (GUS, 2021). The daily averaged electricity demand profile and monthly profile are shown in Figure 1. A presentation of the variants adopted for analysis is shown in Table 1.



(**a**) (**b**)

Figure 1. (**a**) The averaged daily consumption profile of the case study. (**b**) Monthly consumption profile of the case study.

Table 1. Description of the variants.

Variant	Description
I	Home installation without photovoltaic installation; all electricity drawn from the power plant's connection
II	Home installation with a photovoltaic installation with a capacity of 5.06 kWp in a net-metering system
III	Home installation with a photovoltaic installation with a capacity of 5.06 kWp, and electric energy storage with a capacity of 10 kWh in a net-metering system
IV	Home installation with a photovoltaic installation with a capacity of 9.66 kWp in a net-metering system
V	Home installation with a photovoltaic installation with a capacity of 9.66 kWp, and an energy storage facility with a capacity of 10 kWh in a net-metering system
VI	Home installation with a photovoltaic installation with a capacity of 5.06 kWp in the net-billing system
VII	Home installation with a photovoltaic installation with a capacity of 5.06 kWp, and electric energy storage with a capacity of 10 kWh in the net-billing system
VIII	Home installation with a photovoltaic installation with a capacity of 9.66 kWp in the net-billing system
IX	Home installation with a photovoltaic installation with a capacity of 9.66 kWp, and an energy-storage facility with a capacity of 10 kWh in the net-billing system

2.3. Economic Analysis

In the analyzed variants, it was assumed that the photovoltaic installation consists of a series connections of modules (panels), without power optimization due to the simple roof structure and the lack of objects casting a shadow. The need to replace the electricity batteries in the 14th year of operation of the installation was also determined, based on the average frequency of storage discharge cycles and battery life [48,49]. Forecasts of an increase in electricity prices of 2%, 5%, and 10% year on year throughout the analyzed period were also taken into account. Such price increase variants were determined based on energy costs in the competitive market in previous years, as in Figure 2.

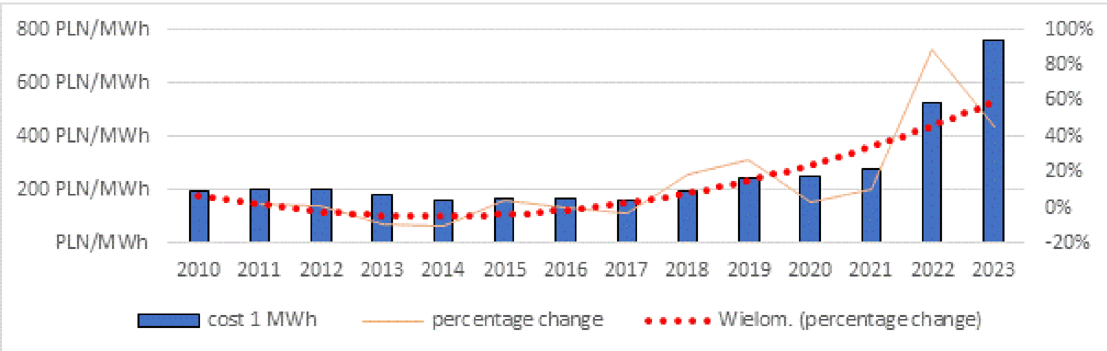
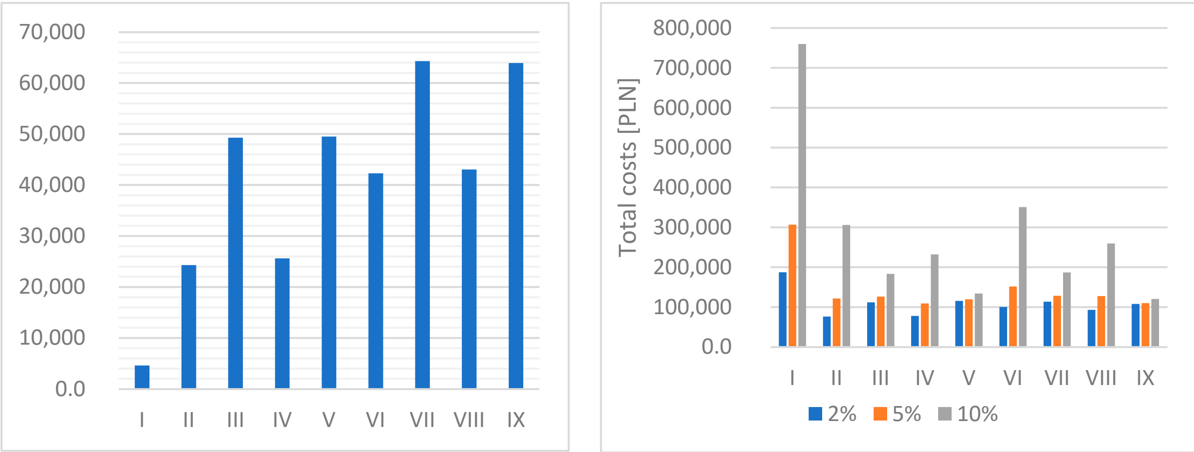


Figure 2. Change in and cost of electricity in the competitive market from 2010 to 2023. [Own chart based on data: https://www.ure.gov.pl/pl/energia-elektryczna/ceny-wskazniki/7852,Srednia-cena-sprzedazy-energii-elektrycznej-na-rynku-konkurencyjnym-roczna-i-kwa.html, accessed on 2 April 2024].

Each considered variant is characterized by different unit costs, such as the construction of the installation, and fixed costs, such as the purchase of electricity. In the case of a house without a photovoltaic installation, the only costs incurred are the cost of purchasing electricity and the related fixed and distribution costs. In the case of a building with a photovoltaic installation, the costs incurred include the cost of building a PV power plant and possible service costs, and in the case of an installation with energy storage, there is the cost of installing and replacing the battery after its end of life. A summary of the initial costs, i.e., costs incurred in the first year of the period under consideration, is shown in Figure 3a. and the summary costs in Figure 3b.



(**a**) (**b**)

Figure 3. (**a**) Summary of costs incurred in the first year of use of the installation of each variant. I–IX—individual variants described in Table 1. (**b**) Summary of total costs of all variants. I–IX—individual variants described in Table 1.

The expected annual production of electricity for the installation of PV 5.06 KWp—in the first year, it is 5094 kWh (and 9725 kWh for a 9.66 kWp installation), with a yield of 1006.75 kWh/kW/year (date from PV Sol Premium 2023). It is less in the following years, in line with the linear decline in power declared by the module manufacturer. The initial costs for investments have been estimated (based on market data) as follows:

- 24,000 PLN for an installation with a power of 5.06 kWp;
- 42,000 PLN for an installation with a power of 9.66 kWp;
- 25,000 PLN for an energy-storage facility;
- 9000 PLN for disposal of PV 5.06 kWp;
- 15,000 PLN for disposal of PV 9.66 kWp;
- 12,000 PLN for battery disposal one time (two times during the analysis).

The total cost calculations for each variant are presented below.

Variant I:

The total costs in this variant include only the costs of purchasing energy and the rest of the related costs. The energy-consumption limit resulting from the Solidarity Shield was set at 2000 kWh. After exceeding this value, active energy and distribution costs increase by 89%, and fixed costs increase by 17%. These data and calculations were made based on specific invoices for electricity consumed by a specific customer for the analyzed variants. Basic costs, such as the cost of active energy, the cost of distribution, and other costs have been compared before and after exceeding the energy shield value of 2000 kWh.

$$K_{wI} = \sum_{n=1}^{30}\left[\left(1 + P\right)^{n-1}\cdot\left(K_c + K_d + K_{st}\right)\right] \quad (1)$$

where

P—increase in energy price per year,
n—years,
K_c—costs of purchasing active energy,
K_d—distribution costs,
K_{st}—fixed costs.

Variants II to IX:

Variants II to V assume settlements with the energy company based on net-metering. Agreements with the energy company are signed for 15 years, it was assumed that for the next 15 years (resulting from the period in question), the user will settle accounts in the net-billing system. Variants VI through IX assume that the user will be billed on a net-billing basis for the entire 30-year period.

$$K_{wII} = K_{PV5.06} + \sum_{n=1}^{15}\left[(1+P)^{n-1}(K_e + K_d + K_{st})\right] + \sum_{n=1}^{15}\left[(1+P)^{n+14}\left(K_{e_{nb}} + K_d + K_{st}\right)\right] + K_{UPV} \tag{2}$$

where

$K_{PV5.06}$—the cost of building a photovoltaic power plant with a capacity of 5.06 kWp,
K_{UPV}—the cost of disposal of pv modules

The costs of purchasing active energy [3] and distribution costs [4] in the case of settlement based on net-metering result from the following relationship:

$$K_e = \begin{cases} k_e(Z_{ee} - A) \\ Z_{ee} = e_{ps} - e_{os} \\ e_{os} = E_w - A - E_o \end{cases} \tag{3}$$

$$for\ \ Z_{ee} < 0,\ k_e = 0$$

where

k_e—gross cost of one kilowatt hour,
Z_{ee}—demand for electricity,
A—autoconsumption,
e_{ps}—energy taken from the grid,
e_{os}—energy fed into the grid,
E_w—energy produced,
E_o—energy transferred to the grid for rebates.

$$E_o = (E_w - A)\cdot 0.2 \tag{4}$$

$$K_d = k_d \cdot n_e \tag{5}$$

where

k_d—distribution costs of one kilowatt hour,
n_e—the amount of energy taken from the network, equal to the amount of energy purchased, and with zero energy purchases, the value is 0.

Autoconsumption was assumed at the level of 21.8% for a 5.06 kWp installation and 12.7% for a 9.66% installation without storage—from data based on PV Sol Premium 2023. For installations with storage, it is 62% for a 5.06 kWp installation and 35% for a 9.66 kWp installation—based on simulation data based on SolarEdge Designer and empirical data. These are typical values for an average resident of a house with a PV installation in Poland.

The costs of purchasing active energy and distribution costs when settling on the basis of net billing are as follows:

$$K_{e_{nb}} = k_e \cdot e_{ps_{nb}} - e_s \cdot K_{RCEm} \tag{6}$$

where

K_{RCEm}—the average monthly market price of electricity provided by PSE.

The value of production and the value of energy taken from the network takes into account the degradation of the efficiency of photovoltaic modules (the net-billing system has been in place in this variant since the 16th year of operation of the installation). Due to the existence of the energy shield in Poland, at the time of writing the publication, which freezes electricity prices to a given level of consumption (depending on the household type), the formula presents a simplified form of the calculation of energy costs, omitting the separation of costs between the frozen and applicable prices, while these values were included in the final results.

The calculations of the total costs of variant II present the calculation methodology of all cases, i.e., costs when settling based on net-metering, and net-billing, and hence, a further presentation of calculations is omitted. The only difference in the next variants (VI through IX) is that the first component, calculating energy costs incurred with net metering, is not taken into account, and the component counting costs incurred with net-billing are for the full period of the analysis. A summary of the total costs for each variant, divided into each price increase forecast considered, is presented in Figure 1b. The time horizon assumed was 30 years of operation of the PV installation. The adoption of such a period results from two assumptions. Firstly, the operating time of PV panels given by manufacturers is 20–25 years. Based on previous research [50,51], it can be assumed that a period of 30 years without failure is highly probable. Secondly, the assumed operational period of the energy storage is 14 years. At that time, the level of DoD will fall to the level declared by the manufacturer (80%); thus, the usable capacity and the level of self-consumption will decrease. The model assumes the cost of replacing and disposing of used batteries and the cost of disposing of PV modules.

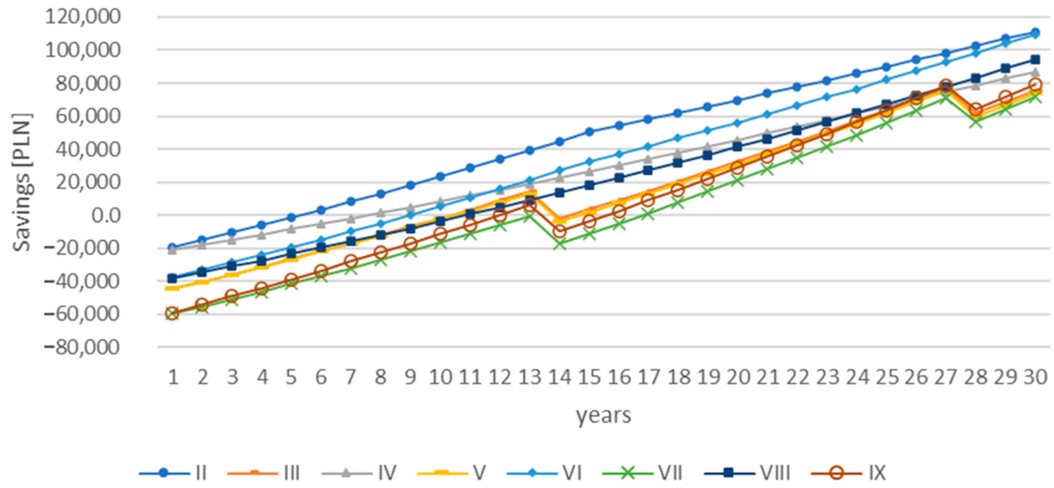
3. Results

Based on the calculations shown, the following conclusions can be drawn. Regardless of future price forecasts, in which prices may change at different rates, purchasing a photovoltaic installation was a profitable investment on a net-metering basis and is still on a net-billing basis. However, the profitability of an energy-storage installation is not so clear. In the case of slow price growth, presented in the analysis for 2% changes per year, installation without energy storage is a more advantageous option than with storage—looking at the total costs. For a 5% price increase, the situation is mixed—the energy storage is profitable only if the installation is settled on a net-billing basis. In the case of a 10% price increase, the situation is clear—in each case, electricity storage is a more advantageous option from the perspective of many years of operation of the installation. Charts showing savings for individual variants (I–IX) and the projected increase in electricity prices are shown in Figure 4a–c.

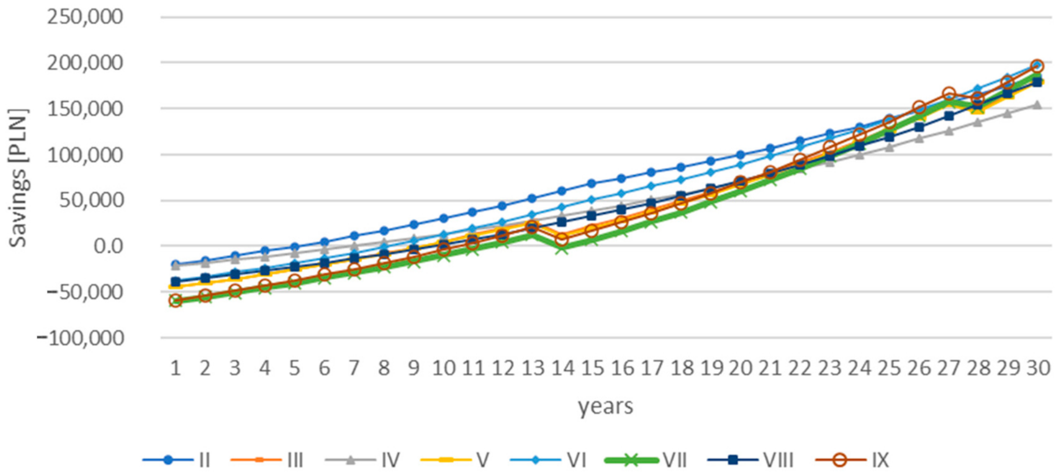
As can be seen in the charts (Figure 4), the installation described in variant II (i.e., with a capacity of 5 kWp, without storage, settled in the net-metering system) pays off the fastest, regardless of the forecast price increase. The remaining variants pay off between 9 and 14 years of use, depending on the forecast increase in electricity prices. The higher the assumed price increase, the faster individual installation variants pay off. At the same time, which is worth emphasizing, the highest savings with a 2%, and 5% increase in electricity prices also occur in variant I; only with larger increases in electricity prices are greater savings (in order) for variants IX, VII, and III. However, variant I is still very profitable.

Profitability of PV installations without energy storage: The results of the analysis showed that the profitability of photovoltaic installations without energy storage varied depending on the system of cooperation with the power plant. In the case of a net-metering system, where surplus energy can be fed into the grid, the profitability of these installations was usually better than in the case of a net-billing system. However, even in the case of the net-metering system, the profitability was not always satisfactory, which proves the need for additional solutions in the form of energy storage.

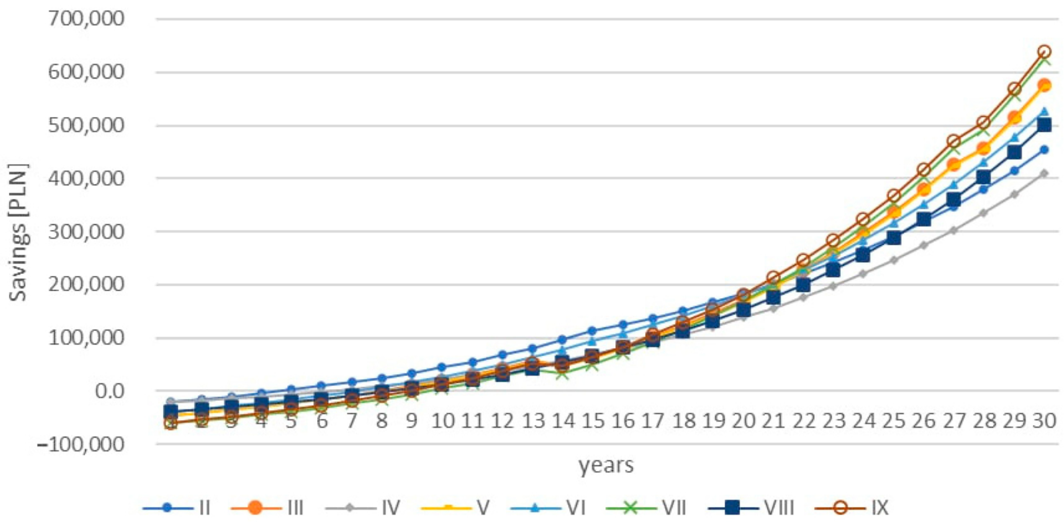
The role of energy storage: The introduction of electricity storage to PV installations had a significant impact on improving profitability. The analysis showed that homes equipped with energy storage were better able to use the generated solar energy, even when the owners were not present at home. This made it possible to limit the purchase of electricity from the network in the evening or at night, which translated into savings for users.



(**a**)



(**b**)



(**c**)

Figure 4. Summary of investment savings for a house in different scenarios of installation for individual variants with a 2%—(**a**), 5%—(**b**), and 10%—(**c**) increase in electricity prices.

Comparison of different variants: A comparison of different variants, such as different powers of PV installations, and different capacities of energy-storage facilities allowed for the selection of the optimal solution in terms of profitability. The results suggest that a greater power of PV installations and greater energy-storage capacity may contribute to even greater savings and better investment profitability.

Impact of legislation and billing systems: The analysis also took into account the impact of applicable legislation and billing systems with electricity suppliers on the profitability of PV installations with energy storage. It was found that differences in settlement systems may significantly affect the profitability of investments, and therefore, it is necessary to take these factors into account when making investment decisions.

To sum up, the results of the analysis showed that the use of electricity-storage facilities together with PV installations can be an effective way to improve the profitability of investments in renewable energy, especially in the conditions of north-eastern Poland. Additionally, an analysis of various variants and systems of cooperation with energy plants allows for the selection of the optimal solution, taking into account the specific needs and conditions of users.

4. Discussion

The construction of a photovoltaic installation, especially one with energy storage, involves significant unit costs that must be covered in the first year, as well as the cost of replacing the batteries if the installation has them. For the same reason, attention should be paid to the payback period of the investment—in the case of installations without storage, this occurs (depending on the case) between 5, and 11 years of use of the installation. For installations with storage, this range is 9–14 years. At the same time, the greatest savings, from the perspective of using the installation for years, will be brought by the variant with high installation capacity and energy storage—in the case of an installation settled on the net-billing basis and an installation without storage, settled on a net-metering basis, assuming a slow increase in electricity prices.

This means that if the state wants to encourage investors to install PV installations; the most encouraging solution will be to return to the net-metering system. On the other hand, in order to encourage users of PV installations in private homes to set up storage facilities, the attractiveness of installations with storage should be increased, e.g., by additional payments (or discounts in the form of tax refunds, etc.) for the installed electricity-storage facility.

Regardless of the economic profitability of a PV installation with energy storage, it has additional benefits. Electricity-storage facilities (often) have the option of-grid operation, which allows for maintaining power in the event of a power outage from the supplier but requires the installation of additional technical equipment (which translates into additional costs, most often in the amount of several thousand zlotys). However, it gives you an additional sense of security and independence. An additional advantage is the possibility (although in the case of only a few types of energy storage) of stabilizing the voltage in the network if it is too high, which would result in shutting down the installation.

At the same time, bearing in mind the upcoming change in the method of billing owners of PV installations, namely hourly billing, a properly programmed storage facility can store energy when it is cheap and send it to the grid at the most favorable times—at the same time, using energy from storage for your own needs when it is more expensive to purchase.

5. Conclusions

Profitability of PV installations on a prosumer and net-billing basis: Regardless of future forecasts regarding electricity prices, the purchase and installation of PV systems were and still are a profitable investment. Both in the case of prosumer billing and net-billing, PV installations can bring significant savings for homeowners.

Profitability of installations with energy storage: The situation is more complicated in the case of a PV installation with energy storage. The analysis showed that the profitability of such installations may depend on future increases in electricity prices. For slow price growth (2%), installations without energy storage are more advantageous. However, with higher price increases (5%, and 10%), electricity storage becomes a more profitable option, especially when net-billed.

PV installation variants: Charts presenting savings for individual PV installation variants (I–IX) indicate that the quickest payback is the installation described in variant II (with a capacity of 5 kWp, without storage, settled in the net-metering system). However, the remaining variants are also profitable, paying off between 9 and 14 years of use, depending on the forecast increase in electricity prices.

The analysis results suggest that the decision to purchase and install a PV system and electricity storage should be made considering forecast changes in electricity prices and user preferences. It is also worth considering various installation and billing system variants to choose the most cost-effective solution for specific conditions and needs.

In further research, the model should include variable electricity prices in individual years and not just a constant increase in prices year to year. At the same time, the model could be improved by adding the costs of the utilization of energy-storage facilities and the PV panels themselves or optimal scheduling of an isolated microgrid with a battery storage considering load and renewable generation uncertainty. The value of the article in this form is to show that even in the case of a simple model of electricity price increases, the profitability of investments in e-PV micro-installations and energy storage facilities is influenced most by the State—through, among others, promoting specific methods of settling accounts for consumed electricity with owners of houses with PV micro-installations.

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