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MANAGEMENT OF HOUSEHOLD FINANCES USING RENEWABLE ENERGY SOURCES

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Purpose: Study of the profitability of investment in photovoltaic cells and building home energy storage facilities.
Design/methodology/approach: Own research.
Findings: A way that can increase household income is to invest surpluses in photovoltaic cells. Energy storage does not increase the profitability of photovoltaic investments at current purchase prices, but in the long run they may be a necessary solution in the development of renewable electricity sources.
Originality/value: The article presents original research related to the profitability of the development of photovoltaic installations for prosumers, which results in an increase in self-consumption of the produced electricity.

Keywords: photovoltaic cells, household, energy storage.

Category of the paper: Research paper, Case study.

1. Introduction

As a result of the energy transformation, a new entity appeared on the market, whose name comes from the combination of two words: producer and consumer. Example of prosumers are the households with photovoltaic micro-installations. On the one hand, it sells the surplus energy produced to the country's energy system, and on the other hand, in case of shortages of its own production, it buys it from this system. Carrying out this type of activity does not require any formal activities, such as registration in the records, but only the possession and connection of a properly prepared photovoltaic installation to the network. This article attempts to assess the benefits of operating such an entity on the market and its financial effectiveness. Due to the saturation of the energy system with photovoltaic micro-installations, the need for prosumers to have energy storage facilities becomes inevitable. Whether such additional, considerable investment outlays make sense for a household is also analyzed in this article.

2. The household as an economic entity

Not only in Poland, but also around the world, scientists try to emphasize the importance of household finances (Campbell, 2006, pp. 1553-1604). The household sector is heterogeneous, which then leads to different divisions and classifications of households and to problems in comparative analysis (Hoffmeyer-Zlotnik, Warner, 2009, pp. 1-26).

Household finance covers the largest group of market stakeholders. It is difficult to establish the boundaries between a household and a business unit, as many individual entrepreneurs respond more to the specifics of a household than an entrepreneur. Household finance as a scientific subdiscipline includes the study of theoretical phenomena and relationships. However, it should be mentioned that it has a wide practical application in economic reality. The subject of interest in household finances is extremely broad, as it concerns: savings, investing, lending, spending (consumption), insurance, taxes, income, pensions, wealth, etc. (Świecka, Musiał, 2016, p. 823).

The household is an active market participant. In economics, the market is understood as an institution enabling transactions between producers and consumers. The market can be divided, taking into account the household, into, among others, the labor market, goods and services market and the financial market (Podolec, Ulman, Wałęga, 2008, pp. 15-16).

The labor market is a special type of market because work has an immaterial dimension. The subject of exchange in the labor market are the specialized skills offered by employed people. The labor market should fulfill the function of allocating and relocating labor factors and ensuring a long-term balance between the supply and demand for labor. Entrepreneurs expect the labor market to provide them with the opportunity to recruit employees with appropriate qualifications. However, from the employees' point of view, it should enable them to find a job that brings them satisfactory income and enable their development. In the labor market, employees offering labor resources and employers meet, which leads to the determination of the price for work, i.e. remuneration.

The next market is the market for goods and services. It is worth noting the change in the function performed by the household. The household plays the role of a consumer and reports demand for a given product or service. Household consumption is a type of collective consumption, consisting in the use of the item of consumption by at least two members of the household. Goods and services are obtained by households through exchange. This exchange takes place between the seller and the buyer and is called a purchase-sale transaction (Świecka, 2008, pp. 26-27).

Some households possess excess cash and often decide to invest it, hoping for a higher profit. Such transactions are made on the financial market and concluded between capital providers and capital recipients. In the literature, the financial market is defined in a broad and narrow sense. In a broader sense, the structure of the financial market includes not only

activities related to money and its flow, but also economic activities based on monetary turnover. In a narrower sense, the financial market includes decisions related to money, the purpose of which is to protect the value of money held or to increase it in future periods. Financial markets enable the creation of the structure of investment and consumption in economic entities over time and increase the efficiency of the use of resources in the economy. Financial markets enable investors to diversify their portfolio of assets, thereby limiting investment risk, and also provide financial information about economic entities in the form of financial statements, especially in the case of listed companies. (Szrama, 2010, pp. 8-9).

Financial markets bring together entities with financial surpluses and entities experiencing financial shortages. The idea of processes taking place in financial markets is based on making temporarily available cash available to those who do not intend to use it at that time to those who need funds for consumption or business development. The reason for both parties to make money available and use it is to gain benefits. The household acts on financial markets as either a seeker or an offerer of money. There is also a third group of entities in financial markets: financial intermediaries who facilitate the transfer of savings from surplus entities to deficit entities. Theoretically, one can imagine a financial market where there are no financial intermediaries and surplus entities communicate with deficit entities themselves, but the modern, developed financial market is based on a widely developed structure of financial institutions (financial intermediaries). Financial intermediaries provide many different types of financial services, but the most important function is to distribute free cash from entities with savings to entities with a deficit (Czekaj, 2008, p. 4).

Modern financial markets are very complex, consisting of many different entities issuing and purchasing financial instruments as well as trading intermediaries and modern technical means enabling transactions. Financial markets can be classified according to various criteria, three classifications are basic. The financial goods market can be divided into: money and capital. The first one covers only one year; the subject of this market are securities and deposits. In turn, the capital market is based on long-term transactions such as the purchase of shares or bonds. Households can participate in both markets, primarily as entities investing financial surpluses. The amount of wealth accumulated in the form of financial instruments by a household is influenced by factors such as financial tradition and culture, the degree of financial market development, and at least an average propensity to save (Świecka, 2008, p. 28).

The amount of savings depends on the household's income and expenses. Namely, this relationship involves the division of income obtained into current consumption and savings purposes. An increase in money resources for consumption causes a decrease in savings and vice versa. In income management, it is necessary to find the so-called "golden mean" that allows for shaping the proportion between the household's expenditure and savings sphere. Savings may be voluntary or compulsory. Voluntary saving involves voluntarily giving up

spending your income on consumption purposes. However, forced saving involves allocating part of one's income to repay, for example, a bank loan (Bywalec, 2009, p. 163).

There are six types of savings strategies. The first strategy is a low-risk strategy. This type of strategy is used by households with savings in the form of bonds. This strategy is used by households with the following socio-economic and demographic characteristics (Anioła, Gołaś, 2013, pp. 1-11).

- households of pensioners,
- households whose place of residence is a city,
- the education of household members is secondary or higher,
- households with health problems or disabilities,
- households with average or higher income.

Another savings strategy is the so-called conservative strategy. This strategy is used by over half of households in Poland, investing all their savings in the form of PLN deposits. Households using this type of strategy lack a cash form of saving. A conservative type of strategy, characterized by a low savings rate. This strategy is used by households in which:

- members are middle-aged and older,
- farms located both in cities and in the countryside,
- households earning an average level of income.

The third type of strategy is an extremely passive strategy. Approximately 25% of households in Poland use this type of strategy. Households have 100% of their savings in cash. A passive savings strategy is characterized by a very low savings rate. Households using a passive saving strategy use credits and loans, but the value of their debt does not exceed their monthly income. Farms of this type show that they have difficulty making ends meet. This strategy is used by households consisting of middle-aged people living in rural areas and very often run by widowers.

The fourth type is an extremely conservative strategy. It is used by households who invest their savings in bank deposits and in cash. This strategy has an average savings rate. According to NBP (National Bank of Poland) data, the value of household deposits in July 2023 was PLN 786,794 million. Households using this type of strategy are characterized by income stability and therefore have no problems making ends meet. Only every fourth household using this strategy has to use credits and loans. An extremely conservative strategy is used by households in which household members are older and middle-aged, the location of households is both urban and rural, and income is obtained from hired work (Anioła, Gołaś, 2012, pp. 1-11).

The next strategy is the diversification strategy. The smallest number of households use this type of strategy - only 0.4%. This type of saving is characterized by a variety of saving forms and the lowest savings rate. Households using a diversification strategy very rarely use credits and loans. Nevertheless, if they do incur debt, the value of this debt is high, most often

exceeding their annual income. This strategy is used by households with the following socio-economic and demographic characteristics (Anioła, Gołaś, 2012, pp. 1-11):

- low age of household members,
- households where the head of the family is a man,
- households located in large cities,
- households with minor health problems,
- household members have secondary or higher education,
- income is obtained from hired work or from running your own business.

The last sixth saving strategy is the aggressive strategy. This type of strategy is used by approximately 1.6% of farms that are not afraid to take risks. Farms using this strategy have the highest levels of debt in excess of their annual income. This strategy is used by households in which (Anioła, Gołaś, 2012, pp. 1-11):

- low age of household members,
- high level of education of household members,
- households whose members are unmarried,
- the income obtained is higher than average,
- there is a low level of disability on farms.

Household financial decisions are complex, interdependent, and heterogeneous, and central to the functioning of the financial system (Gomes, Haliassos, Ramadorai, 2021, pp. 919-1000). In households, the most important is a conservative and very passive strategy based on saving in the form of bank deposits and/or cash. In Poland, households most often use banking services, placing their money in the form of deposits secured by the Bank Guarantee Fund. However, in English countries, a significant part of household funds is allocated to pension funds (Czapiński, Panek, 2014, pp. 87-92).

A relatively new form of functioning of a household is its presence on the market as a prosumer. The name prosumer comes from a combination of the two words producer and consumer. In the light of the Act of February 20, 2015 on renewable energy sources, a renewable energy prosumer is an end user who produces electricity exclusively from renewable energy sources for his own needs in a micro-installation, provided that in the case of an end user who is not a household consumer of electricity, it is not the subject of the main economic activity and the installation power does not exceed 50kWp. In practice, installations up to 10 kWp are most common. On April 1, 2022, new rules for settling prosumers in the net-billing system entered into force. It is obligatory for owners of photovoltaic installations that were launched after March 31, 2022. The change in settlement is that prosumers sell surplus energy to the power grid at market prices published by Polish Energy Networks. The funds obtained in this way go to the prosumer deposit and are used to purchase energy from the grid in periods of shortages of own production. It is difficult to place a prosumer in the strategies of a household's approach to investing and saving, but the features necessary to undertake a prosumer activity are:

- relatively low age of household members due to the long period of operation of the micro-installation and the rather impossibility of cashing it in earlier,
- owning a house and therefore most often living in the countryside or on the outskirts of cities,
- the household consists of at least two members,
- most often have secondary or higher education,
- a household with an income of at least average or higher.

With this in mind, the prosumer has features typical of various household strategies, but the closest one seems to be an extremely conservative and diversified strategy. Analysis, moreover, shows that P2P energy trading based on human decision-making may lead to financial benefits for prosumers and traditional consumers, and reduced stress for the grid (Pena-Bello et al., 2022, pp. 74-82). The number of prosumers currently constitutes a very large group of households and is approaching 10 percent of all households, according to the Central Statistical Office data, amounting to over 15 million. The reason for the increase in the number of households is mainly a decrease in their size. The digital revolution adds new layers to the material cultures of financial inclusion, offering the state new ways of expanding the inclusion of the legible, and global finance new forms of profiling poor households into generators of financial assets (Gabor, Brooks, 2019).

3. Development of photovoltaic installations in Poland

The photovoltaic sector in the country is developing very dynamically, installation capacity in May 2023. increased to 13,926 MW, which means an increase of several dozen times in recent years. Photovoltaics has the largest installed capacity of all renewable energy sources. Prosumer micro-installations still have the largest share in the installed potential of photovoltaic power plants in Poland. Total installed capacity of photovoltaic micro-installations at the end of May this year. amounted to 9,630.31 MW. This means that they had almost a 70% share in the total photovoltaic capacity in Poland. According to the Energy Market Agency, there were a total of 1,269,792 prosumer photovoltaic micro-installations at the end of May 2023, and their number increased by 186.2 thousand within 12 months.

Photovoltaic panels work on the principle of the photoelectric effect, which requires light, which is why photovoltaics generate electricity even on cloudy days. However, the highest efficiency is achieved in sunny weather, which we have relatively a lot in Poland, which translates into an average energy yield in the range of 900-1100 kilowatt hours per year from one kilowatt of solar cell power. A small solar power plant consists of photovoltaic panels, an inverter, cabling and a mounting system. The cost of devices is the largest component of installation expenditure. The devices included in the solar power plant have a long warranty.

This is at least 10 years for panels and 5 years for inverters. The service life of the devices is also very long, for high-quality solar modules it can reach up to 40 years. The expense associated with launching a solar micro-installation begins to pay off immediately, resulting in a significant reduction in electricity bills. A photovoltaic installation on a roof or ground is virtually maintenance-free. Photovoltaic inverters inform about faults themselves, so there is no need to constantly personally monitor the condition of the installation. Inverters connected to the Internet can send information about a failure directly to the service, so that in the event of a failure, it can quickly react and resume the production of free energy.

The legislator obliged energy companies to connect micro-installations with a capacity of up to 40 kW. It also ordered the operator to cover related costs, such as replacing the meter with a two-way one. The requirements for devices and installers are strictly defined in the Act and after meeting them and submitting complete documentation, the energy operator has 30 days to connect the micro-installation. Introducing energy to the grid by prosumers is also beneficial for operators for several reasons. They can sell energy from a photovoltaic installation to the nearest customer, saving on transmission from a distant power plant. Poland must also fulfill international obligations regarding the share of renewable energy in overall electricity production. It is also worth paying attention to the fact that the greatest demand for electricity, which occurs in the summer, occurs during the period of greatest productivity of photovoltaic installations, which will relieve the load on conventional power plants that are overloaded during this period and reduce the possible need to import electricity.

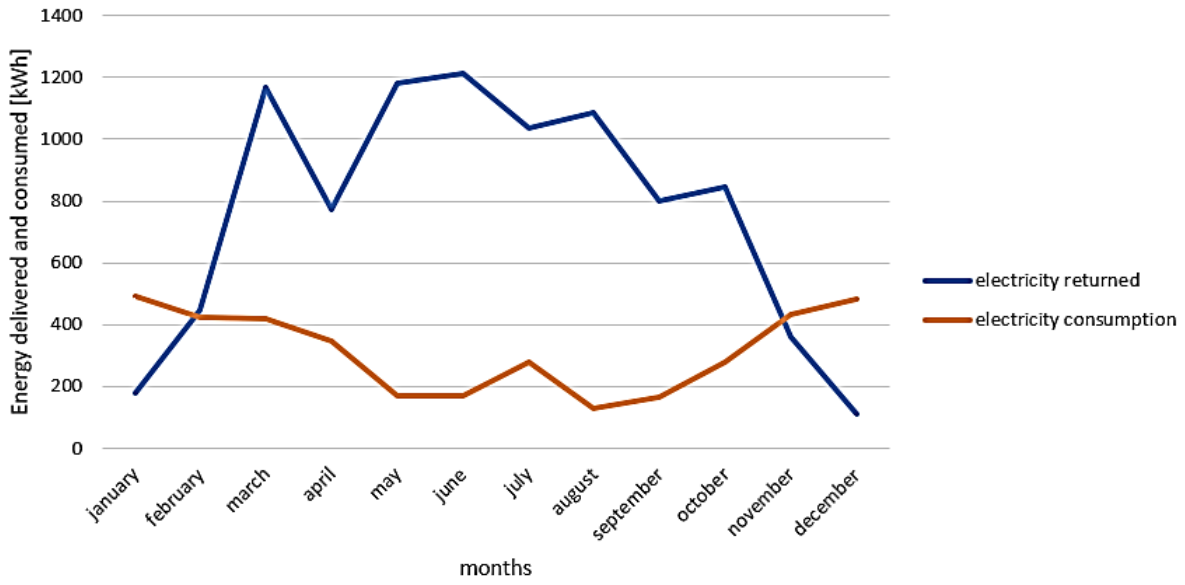

Figure 1. Energy returned and consumed by a household from a 9.92 kWp installation in 2022 [in kWh]. Source: own research.

According to the rules in force before April 2022. it is possible to store surplus energy in the network in the summer and collect it in the winter months in order to compensate for the slightly worse results of electricity production in winter. Thanks to this, we can balance our

energy demand with the production from the photovoltaic power plant throughout the year and reduce electricity bills to subscription and fixed fees.

However, the instability of energy production from photovoltaic installations necessitates its storage. Storage can be organized by specialized companies, energy transmission companies and even their producers, including prosumers. Then, instead of returning the surplus energy from your own solar micro-power plant to the grid, where it is stored virtually, you store it at home, in a battery bank in which electrical energy is converted into chemical energy, and when electricity is consumed, back into electrical energy.

Having an energy storage facility allows you to optimize the energy consumption rate at home, while extending the operating time of electrical devices on electricity generated from a renewable energy source. This applies especially to the summer months, when the amount of energy produced from photovoltaic installations is at the highest level. The electricity produced by photovoltaic panels is stored in a warehouse and used on an ongoing basis. The repetition of this cycle means that self-consumption reaches its highest level.

Analyzing Chart 1, however, it should be stated that increasing autoconsumption does not mean that home photovoltaic installations will be self-sufficient, because the capacity of energy storage would have to be huge. Basically, the energy stored on summer and early autumn days could be used in winter, especially during two months, in December and January. In addition to the increase in self-consumption, arguments for the construction of an energy storage facility may include frequent network failures and, therefore, the need to maintain access to electricity. Another argument is the stabilization and maintenance of voltage in the network. Such an argument may also be the construction of real estate far from the power grid, but in principle it will only apply to real estate used from March to October, where the periods with low energy production by the installations will be relatively short.

Approximate gross prices of Plug & Play energy storage kits (ready to be connected to a photovoltaic installation without the need for additional configuration) at the beginning of 2023 were as follows:

- energy storage 3 kW, 2.4 kWh - from PLN 15,000,
- energy storage 3 kW, 4.8 kWh - from PLN 21,000,
- energy storage 4.2 kW, 5.1 kWh - from PLN 33,000,
- energy storage 5 kW, 10 kWh - from PLN 43,000 to PLN 57,000,
- energy storage 10 kW, 10 kWh - from PLN 49,000 to PLN 60,000.

You can obtain funding for the purchase of an energy storage facility in 2023 under the My Electricity program. The subsidy for a photovoltaic installation with energy storage is currently PLN 16,000. A much larger part of the energy from a home photovoltaic installation is transferred to the power grid. Prosumers whose installations were launched before April 1, 2022, can then collect it within 12 months from the moment it was introduced to the network. However, it should be taken into account that for each kilowatt-hour fed into the network,

only 0.8 kWh is entitled to be collected in the case of installations with a power of up to 10 kWp and 0.7 kWh in the case of installations with a higher power (10-40 kWp).

Households that settle accounts with their energy supplier in the system in force from April 1, 2022, i.e. so-called net-billing, can sell surplus energy from photovoltaic installations. They are purchased from them for the price of energy from the Day Ahead Market of the Polish Power Exchange. The energy value calculated in this way, the so-called prosumer deposit, is recorded on the account kept by the seller. The value of the deposit is then reduced by the value of energy drawn from the grid by the owner of the photovoltaic installation. It is calculated based on the rates specified in the contract with the seller. Since the prosumer deposit is valid for 12 months from the date of posting, energy surpluses generated in summer can cover its shortage in winter. However, to what extent is unknown, because energy prices on the stock exchange constantly fluctuate. Therefore, there may be a situation where prices in winter will be much higher than in summer, which means a loss for the prosumer.

Regardless of the photovoltaic billing system, in order not to lose money on selling surplus energy, you can use an energy storage facility. It is of great importance that the power supply being turned off by the energy company does not mean that the user is also cut off from his own photovoltaic installation.

4. Profitability of a photovoltaic installation using energy storage

Figure 1 shows the supply and consumption of energy from an installation with a capacity of 9.92 kWp, which is subject to the rules in force before April 2022. The installation has a significant surplus of production over consumption due to the owner's planned introduction of one of two solutions:

- purchase of an electric car,
- heat pump installation.

Using either solution means that the entire surplus will be consumed by the household.

The cost of investing in a photovoltaic system is related to the total power of photovoltaic cells and the place where the installation will be built. Small photovoltaic installations, up to 10 kW, are located on the roofs of buildings. Systems with power above 10 kW are usually mounted on the ground with the help of supporting structures. In the analyzed photovoltaic investment, implemented in the Częstochowa district, 36 photovoltaic panels were installed. In total, the installation has a power of 9.96 kWp. The total value of investment outlays is PLN 49,000.

It was assumed in the investment profitability analysis that the investor would benefit from the thermal modernization relief, the maximum amount of which was PLN 53,000. PLN and that he pays income tax of 32% on part of his income (second tax threshold).

The calculations included a loss of efficiency of the installation of 0.5% per year. The final value of the project was omitted in the analyzes due to its negligible value. Investment flows also include the expense of PLN 10,000 for repairing the installation in the middle of the investment period.

According to the manufacturers, the lifespan of photovoltaic cells is estimated at 40 years, and this is the project lifespan assumed in the analysis. It is worth adding that many products available on the market have a warranty of up to 25 years, covering at least 80% of the output power obtained from photovoltaic cells. Auto consumption was also assumed to be 12%. This value was obtained by analyzing the production and delivery of electricity to the power plant.

Table 1.
Study of the profitability of a photovoltaic installation

Year	**2022**	**2023**	**2024**	**2025**	**2026**	**2059**	**2060**	**2061**	**2062**
Energy price [PLN/kWh]	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75
Energy production by a photovoltaic installation [kWh]	10 416	10 364	10 312	10 261	10 209	8 653	8 610	8 566	8 524
Own energy consumption [kWh]	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250	1 250
Savings due to the operation of the PV installation	6 437	6 406	6 375	6 344	6 313	5 379	5 353	5 327	5 302
Capital expenditure including:									
Photovoltaic installation	-49 000								
Energy storage									
Subsidy for energy storage									
Tax benefits from the thermal modernization relief		15 680							
Flows	-42 563	22 086	6 375	6 344	6 313	5 379	5 353	5 327	5 302
Discount factor for discount rate = 2%	1,000	0,980	0,961	0,942	0,924	0,481	0,471	0,462	0,453
Discounted flows	-42 563	21 653	6 127	5 978	5 832	2 585	2 522	2 461	2 401
NPV [PLN]	125,254.56								
IRR	21,0%								
NPVR	225%								
Return period	4 years		3 months						
Discounted payback period	4 years		6 months						

Note. NPV – Net Present Value; IRR – Internal Rate of Return; NPVR – Net Profit Value Ratio.

Source: own research.

Table 1 presents the results of research on the profitability of a photovoltaic investment without energy storage. The discount rate was assumed to be the interest rate on deposits. The net present value (NPV) of the investment is positive, which means that it is more advantageous to make such an investment than, for example, investing cash in a bank deposit

with an interest rate of 2%. The internal rate of return (IRR) indicates a project profitability of 21 percent, but one should remember the limitations of this method, as it assumes reinvestment of surpluses according to the obtained rate of return, which in this case will be rather impossible.

The payback periods of the tested investment are 4 years and 3 months and 4 years and 6 months for the discounted version of this method.

Table 2.
Study of the profitability of a subsidized photovoltaic installation, including energy storage

Year	**2022**	**2023**	**2024**	**2025**	**2026**	**2059**	**2060**	**2061**	**2062**
Energy price [PLN/kWh]	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75
Energy production by a photovoltaic installation [kWh]	10 416	10 364	10 312	10 261	10 209	8 653	8 610	8 566	8 524
Own energy consumption [kWh]	6 250	6 250	6 250	6 250	6 250	6 250	6 250	6 250	6 250
Savings due to the operation of the PV installation	7 187	7 156	7 125	7 094	7 063	6 129	6 103	6 077	6 052
Capital expenditure including:									
Photovoltaic installation	-49 000								
Energy storage	-50 000								
Subsidy for energy storage	16 000								
Tax benefits from the thermal modernization relief		16 960							
Flows	-75 813	24 116	7 125	7 094	7 063	6 129	6 103	6 077	6 052
Discount factor for discount rate = 2%	1,000	0,980	0,961	0,942	0,924	0,481	0,471	0,462	0,453
Discounted flows	-75 813	23 643	6 848	6 685	6 525	2 946	2 876	807	2 741
NPV [PLN]	113,999.8								
IRR	11,00%								
NPVR	108%								
Return period	8 years		4 months						
Discounted payback period	9 years		4 months						

Note. NPV – Net Present Value; IRR – Internal Rate of Return; NPVR – Net Profit Value Ratio.

Source: own research.

Table 2 shows the situation in which the investment also includes energy storage. The expenditure needed to install the warehouse was assumed to be PLN 50,000 and a subsidy for its purchase was assumed in the amount of PLN 16,000. Thanks to the energy storage, auto consumption should increase to 60% energy generated.

From those carried out in 2019 surveys among households showed, among other things, that the most frequently expected payback period in the case of building a home photovoltaic power plant is 4-5 years. The analysis of the two situations presented in tables 1 and 2 indicates that such a payback period is achievable in the case of an installation without energy storage. However, both cases are profitable taking into account both the NPV and IRR methods. However, it seems that a quick payback period is more important for households than a holistic view of the investment, as is the case with the NPV and IRR discount methods. The first factor that will popularize energy storage among them must be greater public funding. The second factor that will increase interest in energy storage will be the decline in their prices. Unfortunately, this decline has not occurred recently, which has also stopped the growth of interest in electric cars. Technological progress is expected in this area, which in the case of households may be easier than in the case of cars, as the size and weight of warehouses is of little importance for them.

In the current reality, for an investment with a warehouse to have the same payback period as one without it, the price of the warehouse would have to be only PLN 21,500 (table 3). The net cost of such a warehouse for a household would be PLN 5,500. The analysis based on such a low price of the warehouse showed that the profitability of the investment using the NPV method is the highest of all the considered variants.

Table 3.
Assessment of the profitability of a photovoltaic investment for a household, taking into account the reduced price of the warehouse

Year	**2022**	**2023**	**2024**	**2025**	**2026**	**2059**	**2060**	**2061**	**2062**
Energy price [PLN/kWh]	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75
Energy production by a photovoltaic installation [kWh]	10 416	10 364	10 312	10 261	10 209	8 653	8 610	8 566	8 524
Own energy consumption [kWh]	6 250	6 250	6 250	6 250	6 250	6 250	6 250	6 250	6 250
Savings due to the operation of the PV installation	7 187	7 156	7 125	7 094	7 063	6 129	6 103	6 077	6 052
Capital expenditure including:									
Photovoltaic installation	-49 000								
Energy storage	-21 500								
Subsidy for energy storage	16 000								
Tax benefits from the thermal modernization relief		16 960							
Flows	-47 313	24 116	7 125	7 094	7 063	6 129	6 103	6 077	6 052
Discount factor for discount rate = 2%	1,000	0,980	0,961	0,942	0,924	0,481	0,471	0,462	0,453
Discounted flows	-47 313	23 643	6 848	6 685	6 525	2 946	2 876	2 807	2 741

Cont. table 3.

NPV [PLN]	141,940.99								
IRR	21%								
NPVR	184%								
Return period	4 years		3 months						
Discounted payback period	4 years		7 months						

Note. NPV – Net Present Value; IRR – Internal Rate of Return; NPVR – Net Profit Value Ratio.

Source: own research.

The last option considered in this publication is the nowadays sensitive topic of electricity prices and their impact on the profitability of investments. It is obvious that the price increase improves the efficiency of photovoltaic investments both with and without storage. The reference point in the analysis was again the payback period expected by the household, ranging from 4-5 years. Data for calculations, assumptions and results are presented in table 4.

Table 4.

Assessment of the profitability of a photovoltaic investment for a household, taking into account the increase in electricity prices

Year	**2022**	**2023**	**2024**	**2025**	**2026**	**2059**	**2060**	**2061**	**2062**
Energy price [PLN/kWh]	1,32	1,32	1,32	1,32	1,32	1,32	1,32	1,32	1,32
Energy production by a photovoltaic installation [kWh]	10 416	10 364	10 312	10 261	10 209	8 653	8 610	8 566	8 524
Own energy consumption [kWh]	6 250	6 250	6 250	6 250	6 250	6 250	6 250	6 250	6 250
Savings due to the operation of the PV installation	12 649	12 594	12 539	12 485	12 431	10 787	10 742	10 696	10 651
Capital expenditure including:									
Photovoltaic installation	-49 000								
Energy storage	-50 000								
Subsidy for energy storage	16 000								
Tax benefits from the thermal modernization relief		16 960							
Flows	-70 351	29 554	12 539	12 485	12 431	10 787	10 742	10 696	10 651
Discount factor for discount rate = 2%	1,000	0,980	0,961	0,942	0,924	0,481	0,471	0,462	0,453
Discounted flows	-70 351	28 975	12 053	11 765	11 484	5 184	5 061	4 941	4 824
NPV [PLN]	255,108.02								
IRR	22%								
NPVR	241%								
Return period	4 years		3 months						
Discounted payback period	4 years		6 months						

Note. NPV – Net Present Value; IRR – Internal Rate of Return; NPVR – Net Profit Value Ratio.

Source: own research.

Using the method of subsequent substitutions in the Excel sheet, the value of the hypothetical electricity price was obtained, which should be PLN 1.32. This price, although much higher than the current price for households, occurs on the market, for example in settlements between energy companies and business entities.

To sum up the study of the profitability of four investment variants, it should be stated that photovoltaic investments, including energy storage, can be implemented on a large scale if two conditions are met. The first is even greater support for this type of investment with government programs, and the second is a decline in the purchase prices of energy storage facilities. The likely increase in electricity prices will also stimulate an increase in households' interest in energy storage. These warehouses can be implemented at the stage of construction of a new installation, as well as added to existing ones. The life expectancy of photovoltaic installations and the improvement in their efficiency make them even more profitable than in the research conducted by the author in other publications.

5. Summary

There are systemic problems in the supply of electricity resulting from the low stability of solar energy producers. The increase in energy prices is the result of the need to maintain increased power, caused, among other things, by the dynamic increase in the number of new photovoltaic installations. It is impossible to avoid the costs of this increase for households, because as a result of the increase in energy prices, the products purchased by consumers will become more expensive. Currently, the only solution supporting the development of photovoltaic installations in the context of energy system capacity limitations are energy storage facilities. As was the case with the development of photovoltaic installations, their widespread use may result in a decrease in prices while increasing the quality and durability of such storage facilities. In the future, the need to use energy storage seems to be a necessity. The lifespan of photovoltaic installations is becoming comparable to the lifespan of houses, which indicates that such installations should be taken into account when constructing new buildings. Such a long service life is mainly important for young people, because they can take full advantage of the savings in electricity consumption. It is worth considering whether to build a nuclear power plant, the cost of which exceeds USD 10 billion, or to develop technologies for building modern energy storage facilities. Today, the solution is to diversify production and solutions that maintain the power of the energy system. Energy storage alone will not be a sufficient solution to maintain the stability of the energy system, it is necessary to diversify solutions. However, for further intensive development of solar energy, solutions supporting the construction of solar energy storage facilities seem necessary. An optimal warehouse is one that provides complete energy independence for a household; such a solution, although

technically possible, is completely uneconomic in today's economic conditions. Research has shown that when auto-energy consumption increases from 12% to 60%, expenditures are required that cannot be balanced by the benefits resulting from energy storage. It is worth noting, however, that the total profitability of the investment measured by the NPV method, also taking into account energy storage, is positive.

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