

М.А. Гендельманның 110 жылдығына арналған «Сейфуллин оқулары – 19» халықаралық ғылыми - практикалық конференциясының материалдары = Материалы международной научно-практической конференции «Сейфуллин оқулары – 19», посвященной 110-летию М.А. Гендельмана». - 2023.- Т. I, Ч. IV. – Р. 165-168.

UDC: 336.63

FINANCIAL ANALYSIS OF A PHOTOVOLTAIC INSTALLATION IN A SINGLE-FAMILY HOUSE AND ITS ENVIRONMENTAL CO-BENEFITS

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Abstract: Generating energy from renewable sources has a number of advantages, including: obtaining free renewable in time and ecological energy or independence from energy supplies from the grid. The last few years have been a time of dynamic development of distributed renewable energy in the world, in particular photovoltaic. This development is mainly caused by the decrease in the production costs of photovoltaic panels, increasing economies of scale and the introduction of support mechanisms for renewable energy in many countries around the world. The article analyzes the energy and economic gains resulting from the construction and operation of photovoltaic systems designed for a single-family building in Poland. The analyzes examined the impact of selected factors that decisively affect the level of economic profitability of this type of generation systems. The first stage was to determine the total costs of construction and operation of the photovoltaic system. Then, the annual financial profits of installation were calculated. Having all previously determined values, the time of return on investment was calculated. The analysis used both estimated and actual data from a functioning photovoltaic installation, showing on their basis significant differences in energy estimates affecting the assessment of economic efficiency in Poland.

Introduction

As expected, conventional (coal-fired) and nuclear power plants have the lowest generation costs so far. At the same time, both photovoltaics and wind energy are gradually catching up with the cost level. For several decades around the world, we have been dealing with an extremely dynamic development of technology that uses solar energy. Conventional fuels can be replaced by solar energy, which is free and environmentally friendly [1]. The amount of solar energy reaching Earth annually surpasses world demand many-fold [2]. Also in Poland, the market of photovoltaic systems has recently shown an upward trend. Nowadays, there is a continuous increase in electricity prices. However, "green energy sources", such as solar radiation, are becoming more and more popular and, above all, profitable. The use of renewable energy sources leads to the improvement of energy efficiency and reduces the emission of greenhouse gases, e.g. CO₂ and NO_x into the atmosphere. Within solar energy, there are

new, more modern and efficient elements of the system that participate in the process of converting solar radiation into electricity without emitting pollutants into the atmosphere.

Among the photovoltaic elements, traditional PV panels can be distinguished, whose task is to generate electricity from solar energy. The fast pace of development of the photovoltaic market causes decreases in the prices of devices, an increase in the popularization of solar systems and leads to the emergence of innovative solutions, which include the BIPV (Buildings Integrated Photovoltaics) technology, i.e. photovoltaics integrated with the building [3]. In addition, if the downward trend in the cost of photovoltaic installations continues in the near future, it can be expected that they will soon be able to operate without additional payments or subsidies. Depending on the material from which the semiconductor in the panels is made, they can convert solar energy into pure electricity with varying intensity. The operation of the panels takes place at the cell level: photons collide with electrons and transfer their energy to them. As a result, electrons are knocked out of atomic orbits. The effect of this phenomenon creates a potential difference - the electron has a negative charge and the ionized atom (without an electron) has a positive charge. The sun's rays, thanks to the operation of photovoltaic cells, are converted into direct current. This energy is transferred to the inverter, which converts it into alternating current.

1. Description of the case study of single-family house:

- House area: 175 square meters
- Number of batteries: 21 (10 on the east side, 11 on the west side)
- Roof pitch: 30 degrees
- Polycrystalline photovoltaic batteries manufactured by the German company Sunmodule (type SW 250)
- Danfoss TLX series inverter designed for installations with an active power of 10kW
- the inverter meets the needs of the house and allows you to heat it with the so-called farelkami

Financial analysis

The main tool used to assess the calculated heat load of a building and the impact of individual components of the energy balance on the value of the final heat load is the energy analysis. As part of this analysis, the heat demand of a typical single-family house located in Poland. Capital expenditures are the costs of purchase and assembly of installations producing electricity from renewable energy sources. Both estimated and actual data from a functioning photovoltaic installation were used for the analysis. In order to calculate the economic indicators, the costs associated with the purchase of the power plant, the subsidy for the renewable energy generation system and the price of electricity must first be determined. The assumptions for the economic analysis were presented, i.e. the cost of individual elements of the system, the price per kilowatt-hour of electricity taken from the grid and the co-financing of RES installations. The investment costs of the

PV plant were estimated according to [7] on the basis of the unit cost of similar PV installations.

The total cost was PLN 42,000 (no co-financing):

- Solar panels (21 x PLN 1,300) price is PLN 27,300
- Inverter price is PLN 5,800
- Construction made of aluminum profiles (adapted to the roof with metal roof tiles or ceramic tiles) price is PLN 4,500
- Protection and wires price is PLN 400
- Installation service with configuration price is PLN 4,200

Assumptions for consuming the photovoltaic panels:

- energy consumption is 400 kWh per month without batteries, the price is PLN 260 per month
- monthly energy consumption with batteries installed 400kWh, price = PLN 5.8/month
- installation price PLN 42,000

Based on the calculations, the total cost of building a photovoltaic installation can be estimated. The payback rate of the installation is approximately 13 years. Savings are then generated over the next year. It should be noted that at the moment, if it had received a subsidy for the installation of solar panels and the law allowing for further sale of energy to the grid had not changed, the payback period would have been shorter. The actual payback time of course depends on the actual price change for electricity consumption. Co-financing support programs for the purchase of energy sources using renewable energy have a positive impact on the growth of citizens' decisions to invest in them, taking into account not only economic, but also ecological aspects [4].

Environmental benefits

The use of renewable energy sources, including the installation of photovoltaic panels to generate electricity for individual homes, is of great importance due to the growing role of electrical and electronic devices in everyday life. The idea of photovoltaic panels is definitely environmentally friendly. They are a source of clean renewable energy, thus allowing buildings to be self-sufficient. Thanks to them, the amount of greenhouse gases that are generated by burning fossil fuels in the process of generating electricity is reduced. As a renewable energy source, solar energy plays an important role in reducing greenhouse gas emissions and mitigating climate change, which is critical to protecting people, wildlife and ecosystems. Solar energy can also improve air quality and reduce water consumption in energy production. The benefits of renewable energy sources, such as solar energy are well known. It can be assumed that the reduction of carbon dioxide (CO₂) emission as well as other greenhouse gases, energy security and energy affordability are their main advantages [5].

Due to the current state of the natural environment, the key indicator that allows you to state the excellence of a given technology is ecological analysis. It can be concluded that the use of renewable energy sources is consistent with the assumptions of sustainable development, because they contribute to the reduction of greenhouse gas emissions and allow saving non-renewable energy sources. Among all types of renewable energy, it is photovoltaics that enjoys the greatest social support, especially in Poland. The poll of the Public Opinion Research Center "Poles about energy sources, energy policy and the state of the environment" showed that among all sources of renewable energy, Poles strongly prefer photovoltaic systems (73%) Other strong suits include low operating costs, low maintenance needs, and low failure rates of solar systems [6]. Therefore, investing in renewable energy is not just a fashion, but in the short term it may bring measurable benefits to the owners of power plants based on renewable energy sources, and for the inhabitants - especially in urban areas - it may bring better well-being thanks to the reduction of low emission and its negative effects.

Conclusion

The subject of this study was a private house with a usable area of 175 m², inhabited by an ordinary family of three, located in Poland. The main tool to assess the total demand for heat was the energy analysis. Studies show that the production of electricity using photovoltaic installations fixed on the roofs of private houses in Poland is very cost-effective. The analysis shows that currently there are good conditions for the development of PV. It should be noted that the rapid development of PV will continue. Rapid technological progress increases the efficiency and lowers the cost of photovoltaic systems. The economic analysis is especially important for the investor, in this case it is the homeowner. The results of the financial analysis made it possible to determine whether the installation of photovoltaics is profitable. Based on the calculations, the total cost of building the photovoltaic installation and the payback period of about 13 years were calculated; however, it should be remembered that the determined indicator is burdened with high inaccuracy. In order to thoroughly study the return on investment, it is necessary to conduct a complete economic analysis, including the time value of money. Energy production during the year was the basis for the economic analysis of the system. The investment and operating costs of the system were calculated. Annual energy and financial benefits for various variants of the considered photovoltaic systems were calculated. For all the systems analyzed in the article, the periods of return on investment and financial benefits from the operation of the system were determined. The impressive development of the photovoltaic industry in Poland is due to the appropriate timing and reduction of technology costs, but above all it is based on the cooperation of stakeholders and trust in the regulatory environment. This work confirmed that there is a great potential for improving the environment by implementing modern heating systems and household installations using renewable energy sources. This is important in a global context, because natural resources should be used rationally, bearing in mind future generations

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