Profitability of a hybrid heating system for a single-family house in Poland based on a heat pump and photovoltaics

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Abstract. The article presents an analysis of the profitability of an investment consisting of a heat pump and a photovoltaic installation located in Poland for an exemplary single-family house. The factors that have a significant impact on the profitability and payback time of such installations operating in a dual configuration are described. A simulation of profitability taking into account the legal regulations and support systems was presented. The considered case of profitability concerns a specific technical solution in which an 8 kW air / water pump was used. The pomp cooperates with a photovoltaic installation with a power of up to 10kW, operating in a discount system with an energy consumption factor of 0.8. For the purposes of this article, the DCF (discounted cash flow) method was used. Using this method, it is possible to calculate the market value of the investment with the assumed boundary criteria. A comparison of the economic efficiency of an investment can be presented using the IRR (internal rate of return) method.

1. Introduction

New technologies, which are supported by growing social awareness and consistently implemented policies of individual countries in the field of zero-emission economy, will change the way of energy generation and using. The availability and reduction of costs of the renewable energy sources (RES) production affects the countries' goals in this field of economy.

The sustainable development policy pursued in most countries is based on numerous support mechanisms for the production of renewable energy. This causes an increase in investments in renewable energy technologies, including installations consisting of heat pumps and PV installations, and contributes to reducing the emission of harmful gases into the atmosphere.

The agreement at the Paris Climate Conference (COP21) [1] in December 2015 is the first-ever universal, legally binding agreement on climate. It is the bridge between today's politics and climate neutrality, which is the goal at the end of this century. The adopted assumptions assume that in the coming years, global warming should be limited to a level below 2 °C, and ultimately to 1.5 °C, above the average temperature before the industrial revolution. In practice, this means that by the year 2030 people must reduce CO₂ emissions by approx. 45 percent (compared to 2010).

The latest Statistical Review of World Energy 2020 [2] reported that the increase in energy consumption was mainly driven by renewables and natural gas, which together contributed to 75% of the expansion. The report also indicates that renewables continued to grow at a record rate and provided the largest share (41%) of primary energy growth, with renewable energy production surpassing nuclear energy for the first time. These trends are also confirmed in the World Energy Outlook 2019 report [3].
Poland wants to join the low-emission countries and meet the provisions of the climate conference in Paris - COP21. Poland prepared and introduced in 2019 an amendment to the law, which creates the possibility of great interest in renewable energy by prosumers [3-10]. This stimulates development in the fields of modern technologies and intensifies trade in goods and services on the international arena [6, 7].

Technological advances in energy production, which are based on renewable sources and resources, mean that the global ability to generate energy is growing relatively quickly. This is particularly evident in the dynamics of increasing power in sectors based on renewable energy sources. Figure 1 shows the production of TWh renewable energy sources in the world and in Poland [11].

The increase in solar energy production in the world in 2019 is 24.3% compared to 2018, while in the period 2008-2018 this increase is 46.7%. The increase in solar energy production in Poland is 137.7% in 2019 compared to 2018 and is only 0.1% of global production.

Figure 1. Increase in the production of renewable and solar energy: a) in the world b) in Poland.

2. Methods of analysis

2.1. Economic and technical aspects and adapted assumptions

The calculation of profitability depends on many factors, which include dedicated support and co-financing programs for particular installations for various target groups of users [11]. For example, Clean Air is a government-wide nationwide financial support program in Poland for investments consisting in thermo-modernization and replacement of a heat source in existing buildings. The program aims to improve air quality and reduce greenhouse gas emissions into the atmosphere. It offers co-financing for replacing old and inefficient heat sources which use solid fuel, with modern heat sources that meet the highest standards, as well as carrying out thermo-modernization works accompanying the entire process. A subsidy in the form of non-returnable co-financing may constitute up to 20% of the value of the installation in a house heating system and hot water (central usable water) based on an air-to-water heat pump. The changes introduced in the Act concern a new alternative to the production and settlement of prosumers for electricity as part of the prosumer definition. In the article the authors present the results of simulation of the profitability of investments in PV micro installations up to 10kW.

The analysis of the operation of the hybrid system installation for an exemplary single-family house with an area of 185m² Located in Poland, was carried out based on the NIBE SPLIT AMS 10-8 heat pump with air/water exchange cooperating with a photovoltaic installation with a capacity of up to 10kW operating in the outlet system with an energy consumption factor of 0.8.

The use of photovoltaics is more and more common not only in solar farms or small PV instalations, but also as elements of small architecture [12]. For the production of such elements, a laser cutting process [13] modelled using various methods [14-17] can be used. In the presented article only a typical photovoltaic installation is analysed.

Due to the carried out calculations, the most efficient solution from the NIBE heat pump range has been selected that meets the selection criteria for such installation specified in the introduction and the required SCOP coefficients. The NIBE SPLIT heat pump is a modular unit in which the external exchange element connects to the compact HK 200S/HK 200S-6 central unit and with an integrated
domestic hot water tank and SMO controller. The hybrid installations are also of the interests of other group researchers [18].

The main conditions and assumptions for the development of the model are presented in Figure 2.

**KEY ASSUMPTIONS:**
- The photovoltaic installation power of 7.9 kWp was assumed
- Higher energy production is in the summer months with the possibility of receiving it in other months with a discount of 0.8
- The investment will be located on the investor’s own ground
- Electricity costs for the individual customer tariff:
  - Average price for active energy: 1.6 Euro/kWh gross
  - Variable component of the network rate: 0.95 Euro/kWh
gross
  - Quality rate: 0.06 Euro/kWh gross
- Initial and total costs of entering the installation taking into account the prices including VAT which the prosumer
- Energy yield from the installation expected in a given region (given in kWh/year including the decrease of cells efficiency).
- No operating costs such as service and maintenance costs, including estimated damage repair costs, etc. over a 10-year working period;
- The forecast revenues from the increase of price energy are taken into account, The increase are indexed by inflation rate on the basis of historical data;
- Discounted cash flow and IRR internal rate of return will be related to the alternative investment of financial resources in 10-year treasury bonds for the EDO0530 series, which give alternative interest in subsequent annual interest periods: margin 1.0% + inflation, with annual capitalization of interest
- Estimated total losses (cables, converter, etc.) of ~ 15% were assumed for the power plant.

**Figure 2.** The main conditions and assumptions for the development of the model.

### 2.2 Economic calculation

The analysis of the profitability of the hybrid system based on a source using a heat pump and photovoltaic installation with a capacity of up to 10 kW was carried out based on the method of assessing the economic efficiency of the investment using the DCF method at the assumed discount rate.

A simplified version of the DCF equation in a time distant by n time units (discounting periods) is presented below.

\[
DPV = \sum_{t=0}^{n} \left( \frac{PV}{(1+d)^t} \right)
\]  
(1)
where:
- DPV - discounted present value
- FV - future value – nominal value of future cash flow
- d - the interest rate or discount rate
- t - the time in years before the future cash flow occurs.
- n - number of flows [8]

The investment appraisal should include an analysis of the project based on dependencies, which include: discounted payback period (DPP), net present value (NPV), internal rate of return (IRR), break-even point (BEP).

The basic design research methods also include the Modified Internal Rate of Return (MIRR). The MIRR is the discount rate for which the (discounted) residual value of the investment equals the updated value of the capital expenditure for the project. The residual value is the future value of the net financial surplus generated by the PV system, deposited using a rate equal to the cost of capital. Compared to the IRR, the modification consists the fact that positive cash flows are not discounted immediately, but their future value is calculated according to cost of capital, which value (as a sum) is still being discounted up to the present moment [19-22].

The estimated costs and parameters of the heat pump installation can be described by:
- Initial and total investment costs for the installation of the heat pump (device cost + cost of floor heating installation): 11911 EUR (with TAX).
- Annual maintenance costs: 112 EUR
- Average efficiency of the heating system: 3.6
- Estimated annual energy costs before installation: 2375 EUR
- Estimated annual savings (electricity): 1613 EUR
- Estimated cost of heating installation based on electric heating mats: 7288 EUR.

The estimated costs and parameters of a PV installation can be described by:
- Initial and total costs of PV installation excluding operating costs: 7013 EUR (with TAX)
- Total losses in the system: 15%
- Average annual initial energy production: 8.2 kWh
- Forecast average annual decrease of energy production: 1%
- Average annual price index of consumer goods and services (inflation): 2%
- Average price for active energy 1 kWh of energy (including VAT): 0.081 EUR
- Variable component of the 1 kWh energy rate (including VAT): 0.047 EUR
- Quality rate of 1 kWh of energy (including VAT): 0.003 EUR
- Interest rate on 10-year EDO0530 bonds: 1.0% + inflation
- Discount rate: 0.8

Figure 3 presents a comparison of the return on capital invested in the heat pump installation in relation to the installation based on underfloor heating using floor heating mats. This figure shows the difference resulting from the costs of saved energy in an investment of a NIBE AMS 10-8 heat pump with a capacity of up to 8kW compared to a classic underfloor heating system consisting of heating mats and radiators. Additionally, the capitalization of savings with the use of an alternative form of investing funds in treasury bonds was assumed in given annual intervals. Values are given when converting EURO to PLN in the ratio of 4.45. Thus, the simulations assumed (for the simplicity) that the costs of making the floor installation itself are similar for the given types of installations. The cost of laying the pipes for the heat pump and their insulation is similar to the cost of laying the heating mats and insulation. Therefore, the analysis assumed, on the basis of the offers presented by the installer, the cost of the installation is EUR 7286. The cost of a heat pump unit for the proposed building is: 5242 Euro.
3. Results

Investment factors for a NIBE heat pump installation for a given house example:
- Discounted payback period: 3 years and 6 months
- Total discounted net cash flows (NPV 10 years): 8 763 Euro
- Internal Rate of Return (IRR 10 years): 28%

Figure 3 shows a comparison of the return on capital invested in the heat pump installation with an alternative form of investing funds in treasury bonds in subsequent annual periods.

The obtained investment indicators for PV installations are presented below.
- Discounted payback period: 8 years and 2 months
- Total discounted net cash flows (NPV 10 years): 1 362 Euro
- Internal Rate of Return (IRR 10 years): 6%

Figure 4 shows a comparison of the return on capital invested in a PV installation with an alternative form of investing funds in treasury bonds in the given annual time intervals. Such an installation can pay for itself after around 8 years.
Figure 5 shows a comparison of the return on capital invested in a hybrid heat pump installation cooperating with a PV system with an alternative form of investing funds without such an investment, assuming that the saved capital is reinvested in treasury bonds in given annual intervals.

Such installations have a very favourable rate of return. The period over which the total return on the cost of owning a hybrid installation compared to the alternative investment takes place is approximately 4 to 5 years.

In the analysis, the price of energy produced in individual periods was calculated from the product of the production forecasted in a given year (falling due to the decrease in cell efficiency) and the price of 1 kWh of energy updated by the value of inflation. In addition, it was adopted for investments in renewable energy, for each period the generated return on capital / profit 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 investment.

The analysis does not include the estimation of the project risk margin, which is not insignificant from the investor's point of view.

The investment indicators obtained for the dual installation (heat pump + PV) are presented below:

- Discounted payback period: 5 years
- Total discounted net cash flows (NPV 10 years): 11 249 Euro
- Internal Rate of Return (IRR 10 years): 19%

4. Summary

The results of the analysis shows that the return on investment in a hybrid photovoltaic solution with a heat pump is 5 years, which is attractive for an investor compared to an investment in long-term safe government bonds. Taking into account the long maturity of treasure bonds and their low interest rates on the scale of global economies, it is reasonable to make efforts in the area of installing a heat pump supported by photovoltaic panels. Obtaining energy from renewable sources is in line with the climate policy of individual EU countries, and is also advisable due to the high costs of electricity. By using the privileges that apply to the prosumer, it is possible to take advantage of very favourable billing options for electricity, and thus reimbursement of the costs incurred for the installations in a short time. The IRR for a PV plant is 6%, however its hybrid combination with a heat pump increases the rate of return up to 19%. Such a high rate of return justifies the investment risk. The analysis described in the article is a comparative analysis in relation to investments in government bonds. It should be emphasized that the adopted data are illustrative data which, depending on the technology used, may differ from the actual cost conditions. However, this data is the starting point for the simulation.
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