

THE DEA MODEL IN THE MANAGEMENT OF ENERGY EFFICIENCY FROM PHOTOVOLTAICS IN SMES IN TERMS OF THE CONCEPT OF CORPORATE SOCIAL RESPONSIBILITY (CSR)

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Purpose: Renewable energy sources (RES) are currently one of the most important global issues. Renewable energy refers to energy derived from natural, recurring natural processes from renewable non-fossil energy sources. Renewable energy sources (RES) are an alternative to traditional primary non-renewable energy carriers (fossil fuels). In Poland, approximately 75% of electricity is produced from coal - the highest percentage in the entire European Union. Due to the problems of the domestic mining industry and underinvestment in the energy sector, as well as EU regulations, energy from coal regularly becomes more expensive. Therefore, energy transformation is a very important issue, especially for SMEs, which play an important role in the economies of countries all over the world. The SME sector in Poland accounts for 99% of the total number of enterprises in Poland (according to GUS 2020). SMEs are a stimulator of economic development, and their number and potential can be one of the measures for assessing economic growth. Thanks to the use of renewable energy sources by the SME sector, including mainly photovoltaic panels, we can achieve a major energy transformation by supporting the concept of sustainable development economics (ESD), whose message is to ensure sufficiently high environmental, economic and socio-cultural standards for all people living today and future generations within the limits of the Earth's natural endurance, applying the principle of intra- and intergenerational equity. Companies, in response to the increasing expectations of their environment, are increasingly taking environmental management into account from a social and ecological perspective by implementing the concept of social responsibility (CSR). The primary objective of the research was to identify stimulants and barriers to the development of investments in photovoltaic panels in the SME sector and to assess their energy efficiency.

Design/methodology/approach: In 2021, a survey was conducted, included in the quantitative research, and the obtained data were subjected to the analysis with statistical methods (CATI). The aim of the survey was to analyse the determinants of photovoltaic energy efficiency management in the sector of micro, small and medium-sized enterprises in Poland. Another part of the research carried out concerned the assessment of energy efficiency from photovoltaics in SME companies using the DEA model.

Findings: A study identifying the stimulants and barriers to the development of investments in photovoltaic panels as the main source of renewable energy for the SME sector (technical, economic considerations) should contribute to the construction of an optimal support system, for example by subsidizing investments by at least 80%. Money is both a major barrier and can

also be a major stimulant. Research has confirmed that SME companies that have already invested in photovoltaic energy are energy efficient, using the energy cost saving effect and actively pursuing a green CSR strategy achieving a competitive advantage.

Originality/value: The value of the article is the research on the use of renewable energy sources, in particular the construction of an energy efficiency management model from photovoltaics in SMEs with the concept of CSR. The results are mainly aimed at managers of MSME enterprises.

Keywords: PV energy efficiency management, renewable energy sources, EZR, CSR, DEA, SMEs.

Category of the paper: Research paper.

1. Introduction

The idea of social responsibility concerning voluntary action on environmental protection and social aspects in the activities of enterprises gained popularity in the 1990s (Kulczycka, Wirth, 2010, pp. 147-148). The concept of organizational social responsibility is a multifaceted notion, which is why many definitions of this concept can be found (Arouri, Pijourlet, 2017, pp. 263). Corporate social responsibility is an issue increasingly addressed by theoreticians and practitioners of socio-economic life (Tylec, 2017, p. 510). Currently, in the literature one can encounter opinions that nowadays, from the point of view of management, CSR is a business strategy, one of the most modern and promising (Sikorska, 2010, p. 143). The problem of CSR is considered, among others, in the fields of economics, law, sociology, philosophy or ethics. One of the oldest books related to the topic of CSR was written in 1953 by H. Bowen (*The Social Responsibilities of Businessman*). In this book, social responsibility was defined for the first time. According to Bowen's conception, CSR is the commitment of a businessman to make policies, decisions and follow such lines of action as will be desirable as the goals and values of our society (Bowen, 1963, p. 6). It is worth noting that the concept used to refer to the activities of the entrepreneur, whereas today CSR is mainly associated with the activities of organisations. Nowadays, corporate social responsibility can be understood as an economic organisation taking into account pro-social and pro-environmental aspects in its business activities. Responsible practices include adherence to ethical standards in relations with employees, competitors and contractors, increased investment in human resources, activities for the development of the local community or environmental protection, i.e. voluntary involvement (Białasiewicz, Marek, p. 99). R.W. Griffin and R.J. Ebert present a model of organisational responsibility based on activities directed at stakeholders. According to a European Union document, CSR is defined as the responsibility of companies for their society. A prerequisite for CSR is respect for legislation and collective agreements between social partners (Caroll, 2008, pp. 8-16). In order to effectively implement the CSR concept,

economic operators should have a mechanism to integrate social, environmental, ethical as well as consumer concerns into their operations and strategy, in close cooperation with their stakeholders (Hopkins, 2007, p. 15). It is worth mentioning that in an earlier definition of CSR, the European Commission presented the concept as a voluntary commitment, going beyond legal requirements.

Corporate management should be systemic, flexible and open to the changing environment, adapted to it and, where possible, shaped to achieve the organisation's objectives. An important management challenge with renewed relevance is corporate social responsibility (Kazmierczak, 2017, p. 49). Social impact and social responsibility need to be managed (Drucker, 1976, p. 327). This is a new direction of change in the strategic management of organisations (Lisiecka, 2015, p. 296). In the context of deliberations on socially responsible management, an important problem concerns the qualification of CSR issues to a theory, concept or method of management. The literature on the subject does not offer unambiguous solutions in this respect. Most often, CSR is considered a management concept. Socially responsible management requires that organisational culture should include social and environmental values in addition to economic values. In management in line with the CSR concept in the SME sector, the person of the owner plays an important role. It is the owner who decides whether his or her enterprise will follow the direction of social responsibility, including the use of ecological solutions such as the use of renewable energy.

2. Energy from photovoltaic panels as a renewable energy source in SMEs

Renewable energy sources (RES) are currently one of the most important global issues. RES is one of the fastest growing economic sectors influencing growth in the associated sectors: transport, construction, energy storage and is the source of many eco-innovations influencing technological progress. Renewable energy refers to energy derived from natural, recurring natural processes from renewable non-fossil energy sources. Renewable energy sources (RES) are an alternative to traditional primary non-renewable energy carriers (fossil fuels). Their resources are replenished by natural processes, which practically allows them to be considered inexhaustible. Furthermore, obtaining energy from these sources is, compared to traditional (fossil) sources, more environmentally friendly. The use of RES significantly reduces the harmful impact of energy on the environment, mainly by reducing emissions of harmful substances, especially greenhouse gases. In domestic conditions, energy from renewable sources includes energy from solar radiation, water, wind, geothermal resources, energy generated from solid biofuels, biogas and liquid biofuels, as well as ambient energy from heat pumps. The acquisition of energy from RES has shown a slight upward trend in recent years. The share of renewable energy in total primary energy generation increased from

13.25% to 15.96% between 2015 and 2019. The structure of renewable energy generation for Poland is primarily due to the geographical conditions and developable resources characteristic of our country. Energy obtained from renewable sources in Poland in 2019 comes predominantly from solid biofuels (65.56%), wind energy (13.72%) and liquid biofuels (10.36%). The total energy value of acquired primary energy from renewable sources in Poland in 2019 was 396 498 TJ. The national total energy consumption from renewable sources between 2015 and 2019 increased by 8.80%, i.e. from 381 129 TJ in 2015 to 414 682 TJ in 2019. Over the same period, gross final energy consumption from renewable sources increased by 15.57%, i.e. from 325,387 TJ in 2015 to 376,063 TJ in 2019.

The renewable energy market by installation size can be divided into the following categories (Grudzinski, Sulich, 2018, pp. 174):

- large photovoltaic or wind installations designed to produce large amounts of electricity fed into the grid, called farms,
- medium-sized installations, invested in by small and medium-sized enterprises and individual consumers, which supply energy for their own needs and sell any surplus to the grid, thus becoming prosumers,
- specialized installations which are not connected to the power grid and which supply energy to facilities where there is no access to mains power or where its connection is uneconomic (off-grid), for example solar lighting of a mountain path,
- very low-power installations that power specialized applications, for example IoT (Internet of Things), which use free energy from the environment (Magdziak, 2016, p. 26).

The potential of renewable energy systems for cogeneration of electricity and heat installed in RES installations in Poland is high. It naturally depends on the geographical location of the installations concerned. For installations solar collectors and photovoltaic cells, latitude will play the most significant role in energy production, due to the location of the sun. For these installations installations, the energy source is solar radiation (Sowa, 2018, p. 188).

In Poland, wind energy has the largest share among renewable energies, reaching 6401.9 MW in 2020, followed by solar energy of 3960 MW, which has the highest growth rate of 259%. Considering the possibilities for the development of renewable energy sources, photovoltaic energy in Poland has the greatest potential for development both among individual households and among the SME sector (taking into account costs, technical conditions, environmental impact). Therefore, it is important to identify barriers and stimulators for the use of this energy source among the SME sector in order to sustain or increase the development dynamics of this energy source in the coming years. The draft Polish Energy Policy until 2040 envisages the development of photovoltaics as a primary renewable source alongside offshore wind power. The IEO forecast "Photovoltaic Market in Poland 2019" shows that the largest group of PV installation customers are individual prosumers, i.e. households. Their share will decrease from more than 50% in 2019 to less than 45% in 2030 in favour of business

prosumers, whose share will increase to almost 30% in 2030. Due to the increase in energy prices for SME companies in particular, companies in the PV market have recognised the growing interest among business prosumers and see them as future customers.

3. Determinants of energy efficiency management from photovoltaics in the SME sector

A survey based on an interview questionnaire, categorized as quantitative research, was conducted in 2021 and the data obtained were analysed using statistical methods. The aim of the survey was to analyse the determinants of photovoltaic energy efficiency management in the sector of micro, small and medium-sized enterprises in Poland. Interviews were conducted with owners, co-owners and persons responsible for finance in the segment of SME companies from all over the country, from different industries. A total of 96 interviews were conducted of which 40% were micro-entrepreneurs employing up to 9 persons, 30% small entrepreneurs employing up to 49 persons and 30% medium-sized entrepreneurs employing up to 249 people. The structure of the survey was reweighted to the structure of companies in Poland according to the Regon database operator (GUS). The research sample thus prepared allows data to be analysed at the level of the entire SME population in Poland. The survey was conducted using the CATI (Computer Assisted Telephone Interview) telephone survey method in 2021. This is one of the methods of collecting information in quantitative research. The CATI survey was conducted using a special program that assisted the caller to the respondent throughout the call. The interview questionnaire consisted of a core part (pertinent questions) and a metric (classification questions). The core part of the questionnaire was designed to elicit information on the determinants of photovoltaic energy efficiency management. The metric included information on the companies surveyed: number of employees, revenue size, balance sheet total, legal form, type of business according to PKD, period of operation, official position of the person completing the questionnaire. The main research concerned the identification of determinants and their relevance in socially responsible management in the SME sector. The surveyed companies responded to each group of factors according to the following scale 1 - unimportant factor, 2 - unimportant factor, 3 - moderately important factor, 4 - rather important factor, 5 - very important factor. After receiving the results, the scores were added up and the contribution to the total number of points possible was quantified (number of interviews received x 5). One of the factors examined was the awareness of CSR in terms of environmental solutions. The companies surveyed showed a high level of environmental awareness among SME entrepreneurs, with more than 96% of the surveyed entities being aware of renewable energy sources, including 94% who had heard of photovoltaics as a potential source of renewable energy. Surveyed SMEs rate their knowledge

of RES quite highly, with nearly 78% of managers of surveyed entities declaring that their knowledge of photovoltaics is extensive. Unfortunately, when asked about the practical use of RES, the vast majority of surveyed Polish SMEs 93% do not use renewable energy. An optimistic factor behind the development of photovoltaic energy is that if these companies already use RES, they choose energy from photovoltaic panels 6%. 18% of micro and small companies are planning to install photovoltaic panels in the future (up to three years), while among medium-sized companies, more than 37% are planning to invest in solar eclectic energy installations. If investments in photovoltaic panels were subsidised to a minimum of 80%, more than 96% of the companies surveyed would be willing to install such an energy source. Therefore, the size of the possible subsidy is very strongly correlated with the number of potential installations. Only 8% of those surveyed who already have a photovoltaic installation financed it with their own funds, 74% used credit and 16% leasing. The development of green energy sources in the SME segment is most influenced by the investment costs. When deciding to install RES in a company, costs were indicated as the biggest barrier by 93% of the surveyed entities. Currently, Poland is at a favourable moment in terms of the economics of RES use in a company. On the one hand, the costs of the installations themselves are falling due to the increasing scale of production, growing competition on the market, on the other hand, subsidies and support from local authorities and the government are increasing. In addition, the support of EU funds in future years for the use of RES will be very significant. Also, the current situation on the energy market - its continuous increases - is prompting more and more entities to consider investing in photovoltaic panels. It is worth adding that the larger the company and thus the greater the demand. Another barrier indicated in the survey is the long payback period (78%), as well as low or no subsidies (76%). Micro-companies, as one of the categories of SME companies surveyed, are far more likely than other respondents to indicate that energy expenses are too small a part of costs to invest in photovoltaic panels. On the other hand, as the size of the company increased, entrepreneurs more often indicated complicated procedures and legal regulations as well as a lack of knowledge and space to install renewable energy installations.

Subsidies of at least 80% of the investment costs are the biggest driver for the development of PV investments, followed by cheaper and increasingly efficient technology (74% of the surveyed entities), tax breaks (62%) less bureaucracy related to the installation and notification of investments (36%) and other factors (18%). Funds, on the one hand, are holding back the transition of SMEs to 'green energy', on the other hand, they can help accelerate the process. In the last two years, a number of new measures have been adopted, called the 'clean energy' package for all Europeans. These documents clearly show the direction in which the European Union will develop over the next decade (in line with the so-called 'green deal'). Climate neutrality is set for 2050. Which means that the energy industry should get rid of emission power plants apparently by 2040, i.e. within the next 20 years. The entire new energy system of the future will be based on renewable energy sources. To a large extent this will be solar and

wind, all other regulations are aimed at phasing out coal-fired and, in the future, gas-fired power plants and building flexibility into the energy system. An appropriately structured system of incentives and support, making use of the new EU funds, should further boost the development of energy from photovoltaic panels installed in the SME sector, which wants to operate in line with the CSR concept, wants to invest in RES, which is firstly cost-effective and secondly means complying with legal requirements. Under Polish market conditions, PV installations are already a solution that is price-competitive compared to grid energy. It is therefore associated with measurable savings, which will become increasingly significant in the future as energy prices rise. In Poland, approximately 75 per cent of electricity is produced from coal - the highest proportion in the entire EU. From the problems of the country's mining industry and underinvested power industry, as well as EU regulations, energy from coal regularly becomes more expensive. At the same time, RES technologies are constantly being developed. As a result, their efficiency is increasing and the investment costs, which are so important for SMEs, are decreasing - a trend that will continue in the future. Given these circumstances, the largest companies, looking for opportunities to purchase cheap energy, are signing long-term PPAs (Power Purchase Agreements) for the supply of energy from wind farms. Unfortunately, given the scale of wind projects and their technical conditions, they are too large for the SME sector. The conditions for a moderate initial outlay are met by investments in photovoltaic installations. An appropriately sized solar installation makes it possible to reduce energy expenses in each SME, indirectly improving their profitability. As a result of the research, an optimal organisational model for energy efficiency management with PV in the SME sector was formulated.

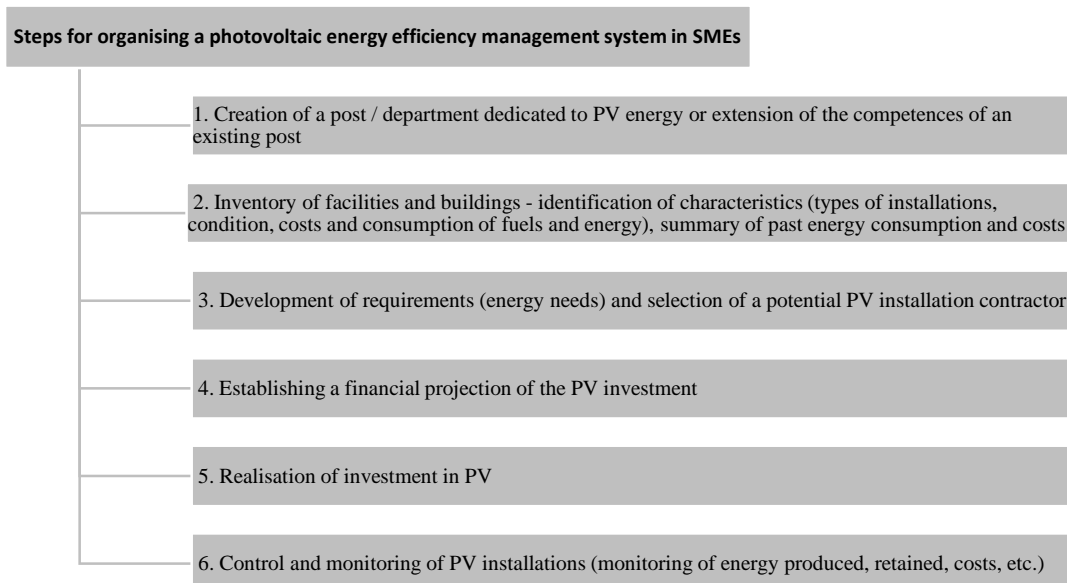


Figure 1. Photovoltaic energy efficiency management model for SMEs.

Source: Own study based on the conducted research.

By applying the above model, the benefits of investing in photovoltaic panels can be optimised. With these investments, companies can also emphasise the realisation of CSR concepts in addition to financial benefits.

4. Evaluation of PV energy efficiency in SME companies using the DEA model

The next part of the research conducted concerned the assessment of photovoltaic efficiency in SME companies using a DEA model. Efficiency analysis using the non-parametric DEA method is based on a two-factor concept - technical efficiency (TE) (Lang, Welzel, 1996, p. 1004), meaning a firm's ability to produce maximum output (effects) for a given level of inputs, and allocative efficiency (AE) (Rogowski, 2008, p. 130), meaning in turn that a firm can use inputs in the optimal proportion to particular prices (input costs). It is often used to study efficiency (Tavares, 2002, p. 6). An important element in the study of firm efficiency is the assessment of economies of scale. Failure to exploit existing economies of scale results in efficiency losses for the enterprise (Wielgórka, 2008, p. 71). The DEA method makes it possible to determine the presence or absence of scale effects. Proponents of non-parametric methods, including the authors of the DEA method, rely on the concept of productivity, defining a measure of productivity as the quotient of a single output and a single input. By having one input (x) and one output (y), we obtain an efficiency curve. This curve contains the set of objects with inputs (x) and outputs (y) that have achieved the maximum technologically possible results, given a given level of inputs. All combinations of inputs and technologically possible outcomes lie between the OX axis and the efficiency curve (production frontier), i.e. the input-output relationship curve. The first point in assessing efficiency using DEA is to define the relevant technology, which is the reference point for the measurements to be made. For this purpose, a set of n decision-making units (DMUs) that produce s outputs using m inputs is considered. For each DMU, the vector of inputs and effects are labelled respectively as $X_j = (x_{1j}, \dots, x_{ij}, \dots, x_{mj})$ and $Y_j = (y_{1j}, \dots, y_{rj}, \dots, y_{sj})$. With $x > 0$ and $y > 0$, that is, each decision-making unit is assumed to have at least one input and one output. A production technology defined in this way (Banker 1992, pp. 75):

$$T = \{(X, Y) : X \geq \sum_{j=1}^n \lambda_j X_j, Y \leq \sum_{j=1}^n \lambda_j Y_j, \lambda_j \geq 0\}$$

Implementation of the DEA method requires defining inputs and outputs, and then subjecting these factors to an effectiveness analysis. After analyzing all possible inputs and effects, it was assumed that the following factors have the main impact on the individual PV energy efficiency of enterprises: savings in energy costs thanks to the installation of photovoltaic panels and the use of a CSR strategy through the use of "green energy" included

in the effects and expenditure on fixed assets (investment in PV) and the power of installed panels included in the expenditure. Energy cost savings achieved by using PV were estimated over a ten-year period. The basic sources of data were CATI surveys; in the case of enterprises that confirmed an investment in PV, an extended interview was conducted, including questions about the costs of investing in PV, installed capacity, energy costs before PV installation, estimated annual cost savings, and CSR effects.

Table 1.

Statistics of CRS TE effectiveness measures in the surveyed SMEs

Statystics CRS TE	Value
Average	0,64
Standard deviation	0,21
Minimum value	0,24
% energy-efficient PV SMEs	96%
% energy-inefficient PV SMEs	4%

Own study based on the conducted research.

The measures obtained from the estimation of input-oriented models will determine the ratio of the actual production of an enterprise from the SME sector to that which it should have if it used the same amount of inputs effectively. In the analyzed period, the share of energy-efficient PV enterprises is at a high level, reaching 96% (Table 1). By estimating the CCR model, it is possible to calculate technical efficiency (TE), which determines the possible amounts of inputs that can be used in given technological conditions to produce at least the same number of effects. During the period under review, only 4% of enterprises showed inefficiency in the use of energy from photovoltaic panels. After the research, it should be concluded that enterprises from the SME sector that have invested in energy from photovoltaic panels are energy efficient thanks to the effect of saving energy costs and actively implement the CSR strategy in the field of ecology, achieving a competitive advantage.

5. Summary

Resources of conventional energy raw materials are being depleted at a rapid pace, while the global demand for electricity is increasing. If we want to rationally use the energy potential that nature gives us, the renewable energy sector should be developed. Otherwise, we will contribute to environmental pollution and the rapid depletion of our planet's natural resources. To avoid this, we should create conditions conducive to the development of renewable energy, mainly for the sector that dominates the economy, i.e. SMEs. The conducted research identifying stimulants and barriers to the development of investments in photovoltaic panels as the main source of renewable energy for the SME sector (technical and economic reasons) should contribute to the construction of an optimal support system, for example by

co-financing the investment in the amount of at least 80%. Money is both the main barrier and can also be the main stimulator. The conducted research confirmed that enterprises from the SME sector that have already invested in energy from photovoltaic panels are energy efficient thanks to the effect of saving energy costs and actively implement the CSR strategy in the field of ecology, achieving a competitive advantage. It is possible to create a business model of an economically effective and CSR-implementing enterprise that uses energy from photovoltaic panels, uses energy-saving technologies, uses electric cars in its logistics processes, etc. We should currently use all possible instruments to make this vision of the "future" as soon as possible. present". European Union funds can be used for this purpose, which will have a positive impact on the global environment. Energy supplied from renewable sources is able to reduce the consumption of primary raw materials and limit the emission of harmful substances that enter the atmosphere in the process of producing electricity and heat, negatively impacting the natural environment. The development trend in the sector of renewable energy systems, including PV panels, should be maintained and strengthened, providing support and solutions ensuring the implementation of new technologies and the profitability of "clean energy" production.

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