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Method of Qualitative–Environmental Choice of Devices Converting Green Energy

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Abstract: In the plan of the European Green Deal, the European Union assumed that by 2050 Europe will become the first climate-neutral continent in the world. This will be supported by alternative (renewable) energy sources (RESs), also termed green energy (GE). Their use should have long-term environmental benefits. To do this, it is necessary to skillfully select RES products. Therefore, the purpose is to develop a method for selecting devices that convert to GE, including not only qualitative criteria, but also environmental criteria and their price. The method is based on customer requirements and expert knowledge. The general concept of the method allows for the assessment of selected qualitative and environmental criteria of products and determining the price of purchase of these products. In a hybrid way, the following techniques were used: SMARTER method, brainstorming (BM), MAP method (alternative-punctual Czechowski' method), ACJ method (price–qualitative analysis). Based on the results of qualitative criteria assessments or qualitative and environmental criteria assessments, the customer can select the best product. The customer can also select products, including the price of purchase, based on results from ACJ. A test of the method was carried out for solar collectors. The results testify to the possibility of controlling the selection control. The originality of this study is the creation of an uncomplicated sequence of techniques that provide the customer with the choice of RESs. The novelty of the method is the possibility of evaluating any products. In this study, the method is dedicated to devices converting GE, e.g., solar collectors.

Keywords: solar panels; decision making; RES; green energy; sustainable development; price–qualitative analysis; MAP method; mechanical engineering; production engineering

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1. Introduction

The idea of society's economic development assumes that development that satisfies the needs of modern societies will not simultaneously limit the possibility of development opportunities for future generations. It assumes a parallel development of the economy, society, and the environment. Therefore, in the European Green Deal plan, the European Union assumed that by 2050 Europe would become the first climate-neutral continent in the world. This is to be helped by alternative (renewable) energy sources (RESs), often referred to as green energy. Their use should have long-term environmental benefits. For this purpose, research studies are realized. These studies refer to not only aspects of physically minimizing the negative influence on the natural environment, but also other areas of the organization's activities, such as making decisions. This may apply, for example, to the selection of RES products. To choose skilfully, according to the idea of sustainable development, the aim is to prepare models and methods with current scientific potential. In this regard, as the development of devices producing green energy (GE) and devices of renewable energy sources (RESs) [1] are determined as the key to reducing negative climate challenges [2–4], the developed methods should be used to select them under specific environmental conditions. The 2030 climate and energy framework determines that it is needed to achieve improved energy efficiency at about a minimum of 32.5%, where the RES share is predicted as 32% RES share [5]. However, variable weather resources and the still relatively high cost of investment of RES installation are challenges for producers of these products [6]. Therefore, there is a search for different solutions to support RES improvement [7–9], also including customer requirements, e.g., by the authors of [10]. This is important because RESs not only are effective in the coverage demand for hot water, heating, and more [11], but also convert this energy as so-called green energy, so in a way that is friendly to the natural environment. The most popular RESs are photovoltaic panels and solar panels. The production of photovoltaic energy is on a global scale and is constantly growing [12]. It resulted from their possibility to cover around 70% of the demand for the use of hot water (even up to 100% in the summer months). For example, in the world, the total power from PV is equal to 505 GW [13]. Another advantage of PV is the decrease in the year-to-year cost of 1 kW, which increases the interest of customers during the choice of RESs [14]. Despite that, PVs are relatively trouble-free. Nevertheless, their adaptation to customer expectations remains an open problem, as presented in the literature review.

The main purpose of this study is to develop a method of selecting devices converting GE in which qualitative and environmental criteria and their price are included. In this aim, the following specific objectives were included:

- Incorporating environmental criteria into the developed method, in addition to the classically used criteria;
- Realization of the choice of products based on qualitative and environmental criteria integrated with the cost of purchase of the RES devices.

Depending on the customer's needs and experts' knowledge, it is possible to choose the best product for the customer, considering not only customer satisfaction but also the impact on the natural environment and price of purchase, in line with sustainable development. An additional aim of this article is to demonstrate, by means of verification, the practical applicability of this method. Therefore, the research hypothesis was formulated as follows:

Hypothesis 1. *It is possible to select devices that convert green energy based on a method that ensures customer satisfaction and simultaneously minimizes the negative impact on the natural environment.*

During the formation of the hypothesis, the following research questions appeared:

- What are the possibilities of introducing elements of sustainable development to the assessment of customer satisfaction?
- How can a product be selected considering quality and environmental criteria?
- How can one take into account the price, which is not a quality or environmental criterion and affects the choice and customer satisfaction, in the selection of a product?
- Will the methodology created be practical?

The originality of the method allows for its uncomplicated process, which allows for a choice of device that converts green energy for the individual customer. A novelty of the method is the possibility to verify any products, but this approach is dedicated to devices converting green energy (GE). The originality of this method is also the possibility to obtain a ranking of verified products, where this ranking will correspond to the idea of sustainable development, i.e., will be including customer expectations towards products described by qualitative criteria (affecting customer satisfaction in using the product), criteria of impact on the natural environment, and also the price of purchase of the product. An additional value of the study is filling the gap represented by the lack of a method by which a customer can select devices that convert green energy, where the choice will be realized based on qualitative criteria, environmental criteria, and the price of purchase.

2. Literature Review

The literature review was carried out in the context of popular RESs and the possibility of their adjustment to customers' expectations in view of qualitative criteria, environmental criteria, and price of purchase. For example, in [15], the level of satisfaction from promoting the use of solar panels was verified using the American Customer Satisfaction Index (ACSI), the unified theory of acceptance and use of technology (UTAUT) model, and a structural equation model (SEM). The authors of [16] developed a business model supporting the efficiency of solar panel installation in Brazil. Around 600 photovoltaics installed in this country were analyzed, and Business Model Canvas was also used to analyze these products in other countries to increase customer satisfaction. Another example is [17], in which the idea was to develop a model that would define the direction of improvement in a product, e.g., any RES. A test of the model for photovoltaic panels was carried out. In the model, selected techniques, e.g., weighted sum model (WSM) and naïve Bayesian classifier (NBC), were implemented and combined. In [18], the integrated approach of the analytic hierarchy process (AHP) method and quality function deployment (QHD) method was proposed. This approach consisted of photovoltaic choice, which included the technical criteria of these products and the customers' requirements. The AHP method was used to calculate the importance of the criteria for the customers, whereas the QFD method was used to process customer requirements into technical requirements. Another example is [19], in which the possibility of installing photovoltaic systems in public parking was verified for plug-in electric vehicles. The analysis consisted of determining the efficiency of the installed photovoltaic infrastructure. A similar analysis was carried out by the authors of [20], which studied the possibilities of using photovoltaic systems to charge a fleet of electric vehicles. The analyses were performed with a nonlinear optimization model. Research taking into account expectations was realized by the authors of [21]. Based on this research, the factors that influence satisfaction with PV systems were tested using the entropy weight method (EWM), factor analysis, and an ordinal regression model. The authors of [22] developed a model to predict the best photovoltaic system using customer requirements. This model was developed based on decision methods and other techniques, that is, the SMART(-ER) method, brainstorming (BM), a questionnaire with the comparison technique with the method in pairs and a Likert scale, the AHP method, the DEMATEL method, and a weighted product model (WPM). The authors of [23] identified innovative strategies for RESs in view of their efficiency. For this purpose, several decision support methods were also used, i.e., fuzzy DEMATEL method, Kano model, and fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS) method. The results obtained were verified with another decision method, i.e., fuzzy VIKOR. The research showed that during the choice of photovoltaic energy, it is important for customers to have the possibility of sustainable consumption and the price of purchase. Other price analyses that considered customer expectations were carried out by the authors of other articles, e.g., [24,25]. In the PV choice study [24], a model was developed that allows for the choice of PV to be the best for the customer in view of its quality and price of purchase, where quality is satisfaction of the customer with PV criteria (e.g., efficiency, size, color). It used the combined techniques zero-unitarization method (MUZ), weighted sum model (WSM), and qualitative cost analysis (AKJ). The authors of [25] developed a method of choosing the best RES in view of key criteria, e.g., customers' requirements towards the quality of RES, real RES effectiveness, and price of purchase. The method was developed using combined techniques, namely expert opinion, fuzzy AHP, TOPSIS method, and qualitative–price analysis (ACJ). Moreover, there were studies related to the environment and strategies to respond to climate change problems, i.e., [26,27]. For example, Ref. [26] presented an analysis of the benefits of ecosystem services in urban areas. The analysis was carried out on data from 25 urban areas in the USA, Canada, and China. The authors of [27] showed the results of the modified Delphi approach (MDA) realized among experts on the future of urban tourism, in the context of adaptation to climate change in Portugal, considering the perspective of the term conditions in outer areas.

After the literature review, it was concluded that different analyses of choosing devices for converting green energy were carried out, mainly for photovoltaics. These analyses were mainly concentrated on the efficiency of these products, as well as the need to meet customer expectations. Sometimes, the purchase price was included. Despite this, the impact of these products on the natural environment was not sufficiently analyzed. In addition, it was concluded that there was no analysis simultaneously including the quality of these devices (considering customers' expectations towards qualitative criteria of product) and considering the impact of these devices on the natural environment and the price of purchasing these devices. This was considered a research gap that was attempted to be filled by developing a qualitative and environmental method for selecting devices converting green energy.

3. Method

3.1. Concept of Method

The general concept of the method relies on the pro-quality and pro-environmental choice of the product to meet the expectations of customers. Meeting these expectations includes the quality of the product, its impact on the natural environment, and the price of the purchase of the product. Quality is determined by product criteria, e.g., technical (quantitative, measurable) and utility (often immeasurable, aesthetic). Impact on the natural environment includes environmental criteria, so product criteria impact the natural environment. The price of purchase of the product refers to the average price of the purchase, i.e., the price that the customer must bear when purchasing the product. The method of choosing the best product in view of quality and impact on the natural environment (that is, in the spirit of sustainable development) included the analysis of qualitative and environmental criteria, and also the price of purchase. In this aim, the use of the following techniques in a hybrid (sequential, combined) way was assumed: SMARTER method [28], brainstorming (BM) [29], MAP method (alternative-punctual method, Czechowski's method) [30,31], ACJ method (price–qualitative analysis) [24,30,32], and relative state scale [30,31,33]. The general concept of the method is shown in Figure 1.

The SMARTER method was used to determine the purpose of the investigation. The brainstorming method (BM) was used to determine a set of verification criteria. The MAP method (Czechowski's method) was used to analyze the weight of product criteria and to determine the quality level of the product and the qualitative–environmental level of the product (including customer satisfaction from product criteria and simultaneously the impact on the natural environment). The ACJ method (price–qualitative analysis) was used to verify products simultaneously in view of quality, price of purchase, and impact on the natural environment. The final decision on the product most beneficial to the customer is made according to the scale of relative states.

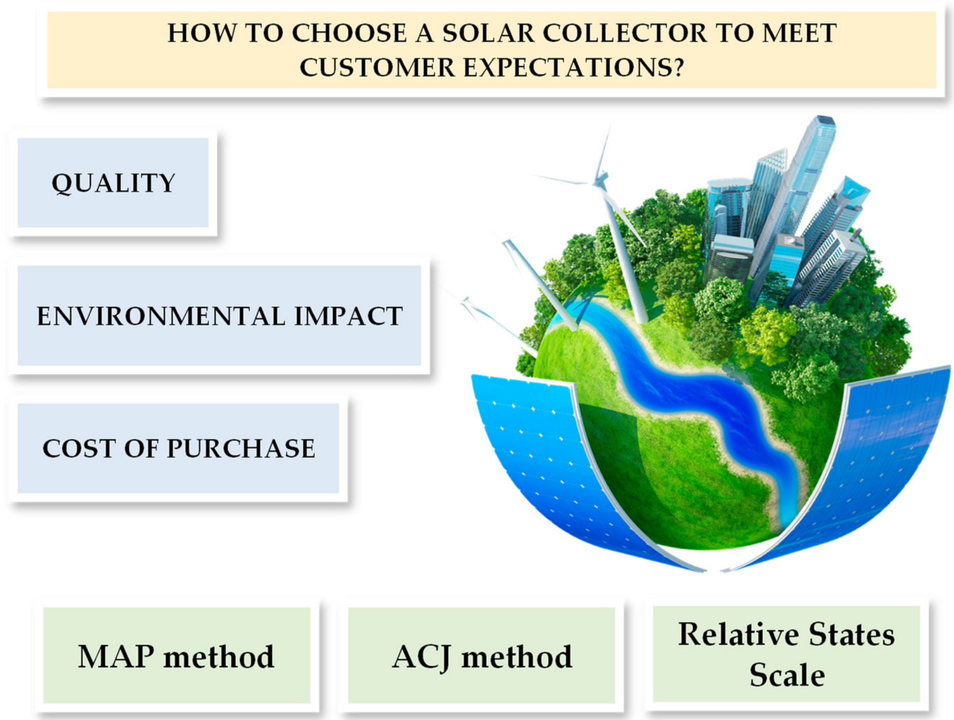

Figure 1. General concept of method.

This method is dedicated to the choice of products by the individual customer and any entity (expert, bidder, broker, i.e., producer offering product). The method can be used for any product. The proposed approach was tested for popular and dynamically developing devices converting green energy, i.e., solar collectors (solar panels).

3.2. Assumptions of Method

The assumptions of the method were made based on the literature review and selected techniques supporting this method. These assumptions were as follows:

- The product for research is unlimited [2,31];
- Product criteria should be qualitative and environmental criteria [32];
- Number of criteria should be equal from 14 to 25 [17,31];
- Evaluation of the product in view of qualitative–environmental level is realized by the entity (expert, bidder, offered) on a scale from 0 to 1, where 1 is the ideal quality (criterion quality standard), 0 is criterion with the lowest possible theoretical level, but assessment can be selected based on the relative state scale [34];
- Evaluation of the weights of the product criteria can be realized by customers on the scale of important criteria, medium importance criteria, and unimportant criteria [31];
- The quality level of the product and the qualitative–environmental level of the product are expressed in values 0 to 1, where their interpretation is possible according to the relative state scales [34,35];
- Qualitative–environmental level is combined with the price of competing products included in qualitative–price analysis, after which the best product for the customer is selected [36].

The assumptions adopted formed the basis for the development of the proposed method, the description of which is presented in the further part of the study.

3.3. Description of Method

The method was developed in eight main stages. Each stage was supported by adequate techniques, as shown in Figure 2.

The characteristics of the stages of the method are presented in the next part of the study.

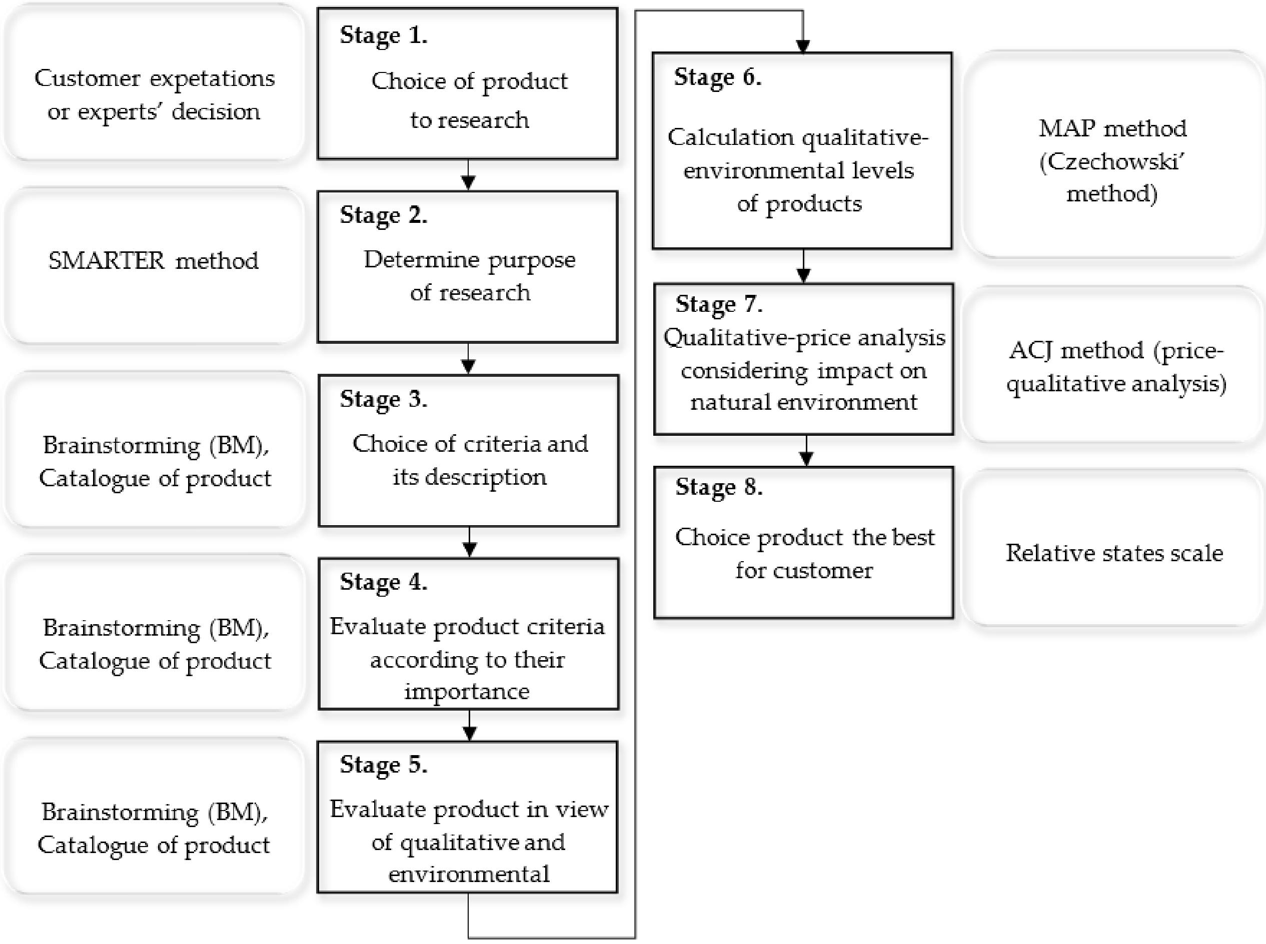

Figure 2. Algorithm of the method with techniques supporting its realization.

Stage 1. Choice of product to research

The product for research is unlimited and results from the customer requirements. The choice of product type is done by the entity (expert, broker, bidder) after the initial consultation with the customer. It is necessary to choose a few products of the same type (kind), so the same type of products but with other parameters. It is necessary to choose 7 ± 2 products for verification. It was the result of a literature review, in which, according to the authors of [37], the process of comparison is effective for not more than 9 criteria. Products are chosen by the entity. During brainstorming (BM), competing products which will be analyzed can be selected. The most favorable product for the customer will be selected from among these products.

Stage 2. Determine purpose of research

The purpose of the research should be determined according to the SMARTER method [28]. The purpose is determined by the entity (expert, bidder, broker). The purpose refers to the type of product selected for analysis. In the proposed approach, the purpose is to select a product from the products of the same types, in order to meet customer expectations. At the same time, the selection will consist of the assessment of products of one type according to the status of their criteria (e.g., determined by various parameters and values). These criteria will be expressed in terms of quality criteria, environmental impact, and the purchase price of the product.

Stage 3. Choice of criteria and their description

The product criteria are selected by an expert (entity, bidder, broker) or a team of experts during brainstorming (BM) [29]. Product criteria are features of the product, which are voiced by the following:

- Qualitative criteria, so technical (quantitative, measurable) criteria and utility criteria (often unmeasurable, aesthetic);
- Impact on the natural environment, i.e., as the product interacts with the environment;

The criteria can be selected based on the catalog (specification) of the product. According to the literature review [17,22,24,31], it was assumed that the number of all criteria can be between 14 and 25 criteria. All criteria should be characterized. This means attribution for each criterion value, range of values, parameter, or description. The purpose of the characteristics is to show differences in the states of product criteria selected for verification. The results from this stage can be presented in a table. At a later stage of the method, the purchase price of the product is also taken into account.

Stage 4. Evaluate product criteria according to their importance

It is necessary to assess all the criteria selected for verification in view of their importance to the customer. The weights of the criteria are determined for qualitative criteria and for criteria that determine the impact on the natural environment. The weightings of product criteria weights determine the degree of importance of criteria for customers during the use of the product and in view of its impact on the natural environment. The customer decides on the importance of the criteria by assigning them a weight in the group of criteria: important, medium, and not important. The entity (expert) can assist them in assessing the validity of the criteria.

Stage 5. Evaluate product in view of qualitative and environmental criteria

It is necessary to assess all the products selected for analysis. The assessment is realized by the expert (entity, broker, bidder) after consultation with the customer (after discussing which are customer requirements). The first stage is the evaluation of the product in view of qualitative criteria, so according to the criteria determining the quality of the product. The second stage is the evaluation of the product in view of its impact on the natural environment. The grades were assumed to be awarded on a scale from 0 to 1, where 1 is ideal quality (criterion quality standard) and 0 is the criterion with the lowest theoretical level [36]. Ratings can be selected based on a scale of relative states (Figure 3).

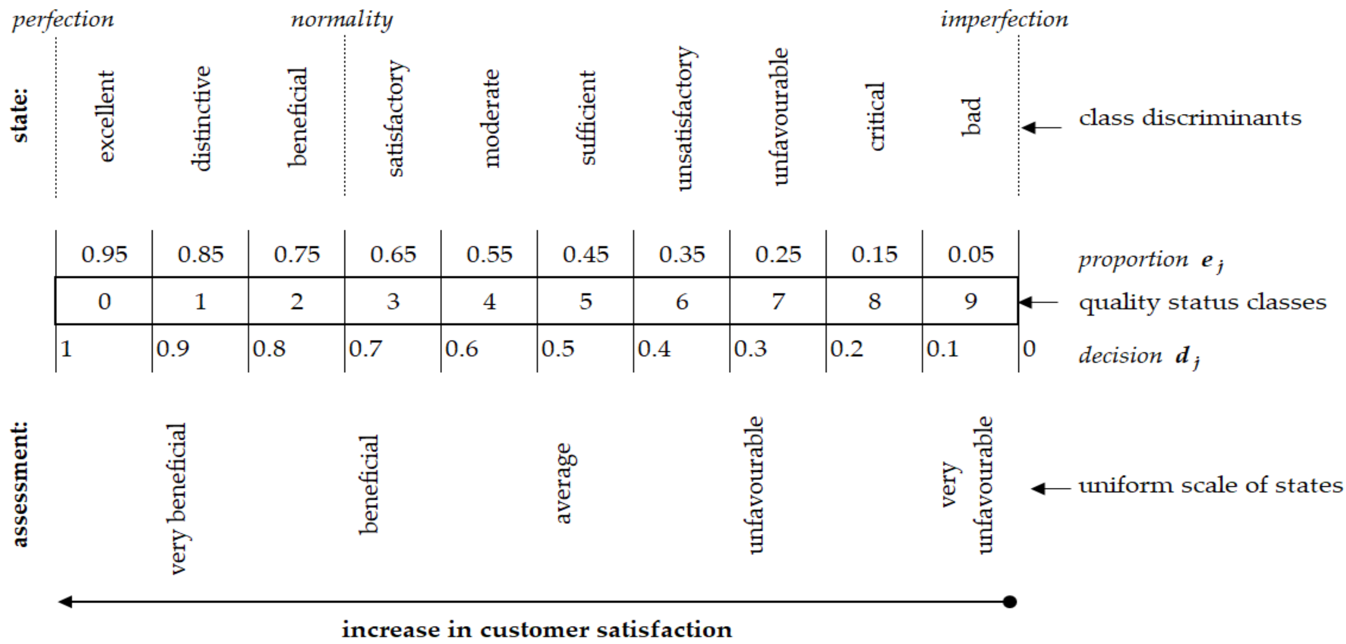

Figure 3. Relative state scale. Own study based on [17,22,30,31,36].

Stage 6. Calculation of qualitative–environmental levels of products

At this stage, the quality level is calculated, and then the qualitative–environmental level is calculated. The MAP method (Czechowski's method, alternative-punctual method) is used for that. The MAP method is a simplified method for calculating the quality of the product. The choice of this method resulted from its straightforward approach and the possibility to include weights (importance) of criteria in the quality assessment of any products. In addition, the method can be performed on the basis of expert assessment (or customer assessments).

Initially, the qualitative criteria are verified, i.e., weight (from stage 4), and qualitative and environmental criteria (from stage 5) are assessed. In the MAP method, product criteria are of additional importance, allowing one to distinguish the three groups of criteria. The weights of the criterion groups are constants and are equal: 50—important criteria; 10 moderately important criteria; 1—criteria of little importance. Continuing the MAP method, the product quality index should be calculated (1) [30,31]:

$$Q_0 = 50n_w + 10n_s + 1n_m \tag{1}$$

where n_w—number of important features; n_s—number of moderately important features; n_m—number of unimportant features.

Later, it is necessary to analyze qualitative criteria (omitting the assessment of environmental criteria and the purchase price).

Qualitative criteria assessments are used for the calculated quality of the product (2), in which the product criteria are identified. In the proposed approach, the evaluations of criteria below the value 0.65 [22,24,25] mean that these criteria are of low quality (not very satisfying), as shown in Figure 3. These criteria should be included not only in Formula (2), but also in the quality-comparison Formula (3), in which the index is calculated [31]:

$$Q_i = 50(n_w - m_w) + 10(n_s - m_s) + 1(n_m - m_m) \tag{2}$$

$$q_i = \frac{Q_i}{Q_0} = \frac{50(n_w - m_w) + 10(n_s - m_s) + 1(n_m - m_m)}{50n_w + 10n_s + 1n_m} \tag{3}$$

where n_w—number of important features; n_s—number of moderately important features; n_m—number of unimportant features; m_w—number of important features that do not meet customer expectations; m_s—number of moderately important features that do not meet customer expectations; m_m—number of unimportant features that do not meet customer expectations.

As a result, the quality level (q_i) is obtained for all analyzed products. The product quality level includes the weights of product criteria and refers only to qualitative criteria.

Then, it is possible to combine product quality levels with assessments of the impact of these products on the natural environment. For this purpose, the MAP method is used again. The purpose is to verify the importance of environmental criteria at the quality level. The methodology for determining the quality and environmental level is similar to the calculation of the quality level, but additionally, the environmental impact criteria should be taken into account, i.e., at the stage of determining the weighting of the criteria and when calculating the indicators from Formulas (1)–(3). As a result, a qualitative–environmental level $\left(q_i^{qe}\right)$ is achieved for all tested products. The quality and environmental level takes into account the weighting of product criteria and at the same time concerns quality and environmental criteria. Its interpretation is possible according to the scale of relative states.

Stage 7. Qualitative–price analysis considering impact on natural environment

The purpose of this stage is to verify how the price of purchase affects customer satisfaction with product quality and simultaneously its impact on the natural environment. Based on the results, it is possible to choose a product depending on individual customer preference considering its expectations towards the quality of product and also its impact on the natural environment and price of purchase. Price–qualitative analysis (ACJ) is used for this [24,32,36]. The choice of ACJ resulted from the possibility of combining the values of product quality with the real price of purchasing the product. Furthermore, ACJ was combined with other methods to calculate product quality, e.g., with FAHP method and FTOPSIS method, as in [25].

According to the ACJ method, it was assumed that the values of the price–quality ratio (e_j) in the coordinate system ($p - q$) are values of the decision function (4) [32]:

$$tg\delta = \frac{p}{q} \tag{4}$$

where angle δ is considered to be the accuracy angle.

According to this assumption, the price index for the quality level (c_p) (5) [32] is calculated as follows:

$$c_p = \frac{P}{Q^q} \tag{5}$$

where P—price of purchase (in the selected currency); Q^{q-} comparable quality indicator expressed in %.

This index determines the cost of 1% of the quality of product. The higher the value of this index, the more favorable it is for the product (better quality, for example, a lower negative environmental impact). Then the relative price is calculated as shown in Formula (6) [24]:

$$p = \frac{P_a - P}{P_a - P_i} \tag{6}$$

where P—price of product; P_a—maximum price in ACJ method; P_i—minimum price in ACJ method.

Later, a price–quality proportionality index is calculated which may also take into account environmental impact [36]:

$$e = \frac{p}{q^q} \tag{7}$$

where p—relative price; q^{q-} comparable quality indicator expressed a decimal fraction.

Then, the decision function index (d) is calculated (8) [31,36]:

$$\begin{array}{lll} for & e = 0 \div 1 & d = 0.5 \times e \\ for & e > 1 & d = 0.5 + 0.5 \times \left(1 - \frac{1}{e}\right) \end{array} \quad (8)$$

where e—price–quality proportionality index.

Subsequently, the relative price index (c) should be computed (9) [22,24]:

$$c = \frac{c_{pa} - c_p}{c_{pa} - c_{pi}} \quad (9)$$

where c_{pa}—maximum price index of quality; c_{pi}—minimum price index of quality; c_p- price index of quality.

After calculating the basic indicators, it is possible to calculate the settling index for technical preference (r_t) (10) [32]:

$$\begin{array}{ll} r_t = \frac{\alpha q^q + \beta d + \gamma c}{\alpha + \beta + \gamma} & where: \ \alpha : \beta : \gamma = 3 : 2 : 1 \\ r_t = 0.167(3q^q + 2d + c) & \end{array} \quad (10)$$

where q^q- qualitative level expressed as a decimal; d—decision function index; c—relative price index.

Later, the settling index for economic preference (r_e) is computed (11) [30,32]:

$$\begin{array}{ll} r_e = \frac{\alpha c + \beta d + \gamma q^q}{\alpha + \beta + \gamma} & where: \ \alpha : \beta : \gamma = 3 : 2 : 1 \\ r_e = 0.167(3c + 2d + q^q) & \end{array} \quad (11)$$

where q^q- qualitative level expressed as a decimal; d—decision function index; c—relative price index.

Ultimately, it is possible to calculate the average decision-making rate (r_d) (12) [25,30,32]:

$$r_d = \frac{r_t + r_e}{2} \quad (12)$$

where r_e—the settling index for economic preference; r_t—the settling index for technical preference.

According to the average decision-making rate, it is possible to make decisions about the best product for the customer. The higher the r_d index, the more advantageous the product is. Verbal interpretation of r_d index is realized based on the scale of the relative states (shown in Figure 3). The ACJ can only be used for qualitative criteria. However, in the proposed approach, it is used taking into account both qualitative and environmental criteria. The ACJ methodology is the same; only the grades given to the environmental criteria need to be additionally taken into account as shown in the method text.

Stage 8. Choice of best product for customer

The last stage of the method is to choose the best product for the customer with an idea of sustainable development. Therefore, this choice will take into account the satisfaction of customer, the impact of the product on the natural environment, and the price of purchasing the product. To this end, the values of the average decision-making rate (r_d) from stage 7 should be ordered in the ranking of preference. The first position in the ranking is product with the highest index (r_d), i.e., the most favorable product for the customer in view of qualitative criteria, environmental criteria, and price. The last position in the ranking is the product with the lowest index (r_d), i.e., the product that is the least satisfactory for the customer in view of qualitative criteria, environmental criteria, and price.

4. Test of Method

The test of the method was carried out for the most popular devices that convert green energy, i.e., solar collectors. These were solar collectors produced by one of the key EU producers. Solar collectors are the cheapest method of obtaining hot water in terms of operation. The method test was carried out according to the adopted procedure algorithm, that is, in eight main stages.

Stage 1. Choice of product to research

The method was carried out on solar collectors of one key producer from the EU as an example. According to the assumptions, the seven different solar collectors of a single producer were selected for analysis. The choice of solar collectors was performed by an entity (expert, broker, bidder) after initial consultation with the customer. There were solar collectors for domestic hot water heating and central heating support. The types of solar collectors analyzed are flat plate collectors and vacuum tube collectors. Flat plate collectors have a lower energy efficiency and heat faster. However, their price is lower. In contrast, tubular vacuum collectors use direct radiation and diffused radiation, i.e., radiation piercing a thin layer of clouds. Therefore, they are more effective and efficient even on cloudy days. However, their price is higher compared to flat collectors.

Stage 2. Determine purpose of research

The entity (expert) determined the purpose of the research according to the SMARTER method. The purpose was to select solar collectors to meet customer expectations by verifying the criteria in groups: qualitative criteria, environmental criteria, and price of purchase.

Stage 3. Choice of criteria and their description

The criteria of solar collectors were selected by an expert (entity, broker, bidder). As assumed, these criteria were qualitative and environmental criteria. Based on the product and literature review, 14 criteria were selected for analysis:

- Dimension (cm)—the dimension of the solar collector defined as width × length × height;
- Total surface (m^2)—the total external surface area of the installed solar collector; the surface of the collector does not affect its efficiency, but it is important because of the installation on the roof;
- Absorber area/aperture (m^2)—the absorber absorbs energy from the sun and is the basic element that generates heat and transfers it to the heating medium, and the efficiency of the solar collector depends on the absorber; while the aperture is the diameter of the opening of the optical device through which the light enters, it is the largest surface through which the sun's rays enter, where in flat collectors it is the internal area of the collector's frame, and in vacuum collectors, it is the sum of all sections of glass tubes;
- Optical efficiency (%)—it results from the amount of sunlight absorbed by the aperture of the collector surface, which is subsequently converted into heat;
- Absorption (%)—percentage of absorbed energy from the portion of solar radiation that entered the collector;
- Emission (%)—percentage of energy from the portion of solar radiation reflected from the absorber surface;
- Thickness of the glass or glass tube wall (mm)—thickness of the solar collector glass (in flat collectors) or the wall of the glass tube (in vacuum tube solar collectors);
- Maximum volume of heated water (L)—maximum volume of water that can be heated by the solar collector;
- Absorber or vacuum tube system—the system of pipes collecting the generated heat from the absorber; it can be in the form of parallel tubes, i.e., harp arrangement;
- Diameter of the vacuum connections or tubes (mm)—diameter of connections in a flat solar collector or diameter of pipes in a vacuum solar collector;
- Color of the housing—exterior color of the solar collector.

The characteristics of these criteria are shown in the subject literature, i.e., [17,22,24]. The environmental criteria were as follows:

- Method of packaging—type and quantity of packaging materials for solar collectors intended for transport to the customer, e.g., the use of paper packaging/cartons, stretch film, foam, other plastics, tapes, and fasteners; evaluation according to the degree of use of plastics negatively affecting the environment: high, medium, low. The choice of this criterion was determined by the sharp increase in waste, including used consumer packaging, which is currently a hot topic. More than 50% of consumers believe packaging waste is a very important environmental problem. According to research, nearly 40% of online shoppers are concerned about overpacking. To reduce the amount of packaging waste and therefore have a positive impact on the environment and climate change, organizations must introduce packaging products that are 100% recyclable or reusable (so-called ecological packaging) [38];
- Recycling—the degree of solar collectors, where the assessment concerns the degree of recovery of materials from the solar collector, that is, full, partial, and no recycling; the choice of this criterion results from surveys in which more than 15% of the respondents are concerned about the possibility of recycling products [38];
- Lifetime (degradation)—time of guaranteed, failure-free operation specified in catalogs of solar collectors, usually degradation after 25 years of 80% and less, after 25 years from 90 to 80%, or after 25 years above 90%; the flat collector is more durable compared to the vacuum collector, e.g., the flat collector is more resistant to hail or accidental impact, and when set at an angle, it is more easily cleaned by rain and sheds snow on its own; meanwhile, vacuum collectors are more temperature resistant.

The solar collectors selected for analysis were characterized according to their criteria. The characteristics were determined by the entity (expert) based on catalogs of these products. In addition, the price of purchasing a single solar collector was included. The price will be used in the next stages of the method. The list of conventional solar collectors for the purposes of the article marked with numbers 1 to 7 and the criteria characterizing them together with the purchase price is presented in Table 1.

Subsequently, the next step of the method was carried out.

Stage 4. Evaluate product criteria according to their importance

At this stage, the criteria for solar collectors were assessed according to their importance to the customer. Based on the opinion of the expert (entity), the customer assessed the weight of all criteria, i.e., important, medium importance, and low importance. Criteria weighting assessments determine the degree of importance of the criteria to the customer during the use of the product and with regard to the product's environmental impact. The result is presented in Table 2.

Table 1. Characteristics of solar collectors selected for analysis.

Type of Collector	Solar Collector 1 (Flat)	Solar Collector 2 (Flat)	Solar Collector 3 (Vacuum Tube)	Solar Collector 4 (Vacuum Tube)	Solar Collector 5 (Flat)	Solar Collector 6 (Flat)	Solar Collector 7 (Flat)
Qualitative criteria							
Dimension (cm)	106 × 190 × 6	106 × 190 × 9	199 × 192 × 18.2	2040 × 1590 × 182	127 × 224 × 9	127 × 224 × 6	112 × 224 × 9
Total surface (m^2)	2.0	2.0	3.61	2.98	2.8	2.8	2.5
Absorber area/aperture (m^2)	1.8	1.8	2.67	2.21	2.6	2.8	2.3
Optical efficiency (%)	80	80	93.7	0.94	80	80	80
Absorption (%)	>95	>95	>94	>94	>95	>95	>95
Emission (%)	<5	<5	<8	<6	<5	<5	<5
Thickness of the glass or glass tube wall (mm)	4	4	2	2	4	4	4
Maximum volume of heated water (L)	100	100	150	100	150	150	120
Absorber or vacuum tube system (pieces)	Single harp	Single harp	22	11	Double harp	Single harp	Double harp
Diameter of the vacuum connections or tubes (mm)	4 × 18	4 × 22	58	58	2 × 22	4 × 18	2 × 22
Color of the housing	Gray	Black	Silver/black	Silver/black	Silver	Gray	Silver
Criteria of impact on natural environment							
Method of packaging	low	low	high	high	average	low	average
Recycling	partial	partial	partial	partial	partial	partial	partial
Lifetime (degradation)	partial after 25 years from 90 to 80%	partial after 25 years from 90 to 80%	after 25 years over 90%	after 25 years over 90%	after 25 years 80% and less	partial after 25 years from 90 to 80%	after 25 years 80% and less
Price of purchase							
EUR	309.82	482.02	589.84	368.39	454.9	401.71	286.85

Table 2. Importance of criteria for customers.

No.	Type of Criterion	Symbol	Criterion	Weight
1	Qualitative criteria	C1	Dimension (cm)	low importance
2		C2	Total surface (m^2)	low importance
3		C3	Absorber area/aperture (m^2)	important
4		C4	Optical efficiency (%)	important
5		C5	Absorption (%)	important
6		C6	Emission (%)	important
7		C7	Thickness of the glass or glass tube wall (mm)	medium importance
8		C8	Maximum volume of heated water (L)	important
9		C9	Absorber or vacuum tube system (pieces)	medium importance
10		C10	Diameter of the vacuum connections or tubes (mm)	medium importance
11		C11	Color of the housing	medium importance
Variant I				
12	Environmental criteria	C12	Method of packaging	low importance
13		C13	Recycling	low importance
14		C14	Lifetime (degradation)	low importance
Variant II				
12	Environmental criteria	C12	Method of packaging	medium importance
13		C13	Recycling	medium importance
14		C14	Lifetime (degradation)	medium importance
Variant III				
12	Environmental criteria	C12	Method of packaging	important
13		C13	Recycling	important
14		C14	Lifetime (degradation)	important

The customer determined the importance of solar panel criteria in two types of criteria: qualitative criteria and environmental criteria (impact on the natural environment). Environmental criteria were separately assessed in three variants, i.e., low importance, medium importance, and important. Of course, it is possible to define other variants of weights for these criteria. These variants were assumed for the test and resulted from a lack of unequivocal customer expectations towards environmental criteria. The weights of the criteria were used to assess the products in terms of qualitative and environmental criteria, as is shown in the next part of the method.

Stage 5. Evaluate product in view of qualitative and environmental criteria

All solar collectors were assessed in view of meeting their customer criteria. Assessments were carried out by experts after consultation with the customer. The expert assessed qualitative and environmental criteria. The grades were awarded on a scale from 0 to 1, where 1 is the ideal quality (criterion quality standard) and 0 is the criterion with the lowest possible theoretical level, as defined in the scale of relative states. The evaluations are shown in Table 3.

Table 3. Assessments of solar collector criteria.

Criterion	**Weight of Criterion**	**Solar Collector 1 (Flat)**	**Solar Collector 2 (Flat)**	**Solar Collector 3 (Vacuum Tube)**	**Solar Collector 4 (Vacuum Tube)**	**Solar Collector 5 (Flat)**	**Solar Collector 6 (Flat)**	**Solar Collector 7 (Flat)**
Qualitative criteria								
C1	mw	0.4	0.5	0.8	0.8	0.7	0.7	0.6
C2	mw	0.8	0.8	0.65	0.7	0.75	0.75	0.8
C3	w	0.4	0.4	0.8	0.8	0.8	0.9	0.5
C4	w	0.7	0.7	0.9	0.65	0.7	0.7	0.7
C5	w	0.8	0.8	0.7	0.7	0.8	0.8	0.8
C6	sw	0.8	0.8	0.6	0.7	0.8	0.8	0.8
C7	sw	0.7	0.7	0.9	0.9	0.7	0.7	0.7
C8	w	0.6	0.6	0.9	0.6	0.9	0.9	0.7
C9	sw	0.7	0.7	0.7	0.65	0.9	0.7	0.9
C10	sw	0.6	0.8	0.65	0.65	0.65	0.6	0.65
C11	sw	0.6	0.1	0.1	0.1	0.6	0.7	0.6
Environmental criteria								
C12	mw/sw/w	0.8	0.6	0.8	0.8	0.5	0.4	0.65
C13	mw/sw/w	0.7	0.7	0.5	0.7	0.7	0.5	0.6
C14	mw/sw/w	0.5	0.75	0.65	0.65	0.4	0.75	0.7

C1—dimension (cm); C2—total surface (m^2); C3—absorber area/aperture (m^2); C4—optical efficiency (%); C5—absorption (%); C6—emission (%); C7—thickness of the glass or glass tube wall (mm); C8—maximum volume of heated water (l); C9—absorber or vacuum tube system (pieces); C10—diameter of the vacuum connections or tubes (mm); C11—color of the housing; C12—method of packaging; C13—recycling; C14—lifetime (degradation); mw—criterion of little importance; sw—medium-importance criterion; w—important criterion.

The assessments were used to calculate the quality level and qualitative–environmental level of solar collectors, as shown in the next part of the study.

Stage 6. Calculation of qualitative–environmental levels of products

At this stage, the quality levels (considering only quality criteria) of the solar collectors were calculated, and then the qualitative–environmental levels (considering quality and environmental criteria) of the solar collectors were calculated. The MAP method (Czechowski's method, alternative point method) was used for that.

Initially, only the qualitative criteria for which constant weights have been assigned are verified, i.e., 50—important criteria; 10—criteria of medium importance; 1—criteria of little importance. According to Formula (1), the product quality index was calculated (13):

$$\begin{gathered} Q_0^q = 50 \times 5 + 10 \times 4 + 1 \times 2 \\ Q_0^q = 292 \end{gathered} \tag{13}$$

where n_w—the number of important features (equal to 5); n_s—the number of moderately important features (equal to 4); n_m—the number of low-importance features (equal to 2).

According to assessments assigned to qualitative criteria for solar collectors, the quality of these devices (Q_i^q) and the index describing the quality were calculated (q_i^q). For that, Formulas (2) and (3) were used, including only criteria that do not meet customer expectations (assessments with values below 0.65). As a result, the quality level was calculated for each solar collector. The quality level includes weights of criteria and refers to only qualitative criteria (affecting customer satisfaction with the use of the product).

Later, the significance of the impact of the environmental criteria on the quality level of solar collectors was verified. The method of determining the qualitative–environmental level was similar to the case of quality level but also included criteria of impact on the natural environment (its weights and assessment). As previously established, constant weights for the quality and environmental criteria were used, i.e., 50—important criteria; 10—criteria of medium importance; 1—criteria of little importance. According to Formula (1), the qualitative–environmental index of the product qualitative–environmental index (Q_0^{qe}) was calculated. This index was calculated separately for three variants of the weights of environmental criteria (14):

$$\begin{gathered} \textit{when it is assumed that all environmental criteria taken into account are of little importance}: \\ Q_0^{qe} = 50 \times 5 + 10 \times 4 + 1 \times 10 = 300 \\ \textit{when it is assumed that all environmental criteria taken into account are of medium importance}: \\ Q_0^{qe} = 50 \times 5 + 10 \times 12 + 1 \times 2 = 372 \\ \textit{when it is assumed that all environmental criteria taken into account are importance}: \\ Q_0^{qe} = 50 \times 13 + 10 \times 4 + 1 \times 2 = 692 \end{gathered} \tag{14}$$

Then, from the qualitative and environmental criteria assessments, the qualitative–environmental level of these devices (Q_i^{qe}) and the index describing the qualitative–environmental level (q_i^{qe}) were calculated. For that, Formulas (2) and (3) were used, including only criteria that do not meet customer expectations (assessments with values below 0.65). As a result, the qualitative–environmental level $\left(q_i^{qe}\right)$ was estimated for each solar collector. This level took into account the weighting of the criteria and at the same time concerned the quality and environmental criteria, which were presented in three variants (environmental criteria of little importance, medium importance, and importance). The result of the MAP method is presented in Table 4.

It was concluded that including environmental criteria has an impact on the level of customer satisfaction with solar collectors. This phenomenon is observed when including important environmental criteria. The introduction of environmental criteria changes the ranking, especially when environmental criteria are accepted as important. For example, flat collectors with conventional numbers 5 and 6 had excellent quality levels (first position). However, after taking into account the environmental criteria with weighting "important", the quality level turned out to be outstanding (third position). In turn, solar collectors with conventional numbers 3 and 4 had the second position in the ranking in view of quality level. After additionally taking into account the environmental criteria with the weight "of little importance", no difference in the ranking was observed. However, after taking into account the environmental criteria with the weighting "medium importance" and "important", there were differences in their position in the ranking. Collector 3 was third and second in the ranking, respectively. On the other hand, collector 4 was the second and first in the ranking, respectively. Therefore, the discrepancies in the rankings determine the usefulness of further analyses, which in this case are price–quality analyses.

Table 4. Result of MAP method for quality level and qualitative–environmental level of solar collectors.

Type of Collector	Solar Collector 1 (Flat)	Solar Collector 2 (Flat)	Solar Collector 3 (Vacuum Tube)	Solar Collector 4 (Vacuum Tube)	Solar Collector 5 (Flat)	Solar Collector 6 (Flat)	Solar Collector 7 (Flat)
Quality level							
Q_i^q	171	191	242	242	282	282	231
q_i^q	0.59	0.65	0.83	0.83	0.97	0.97	0.79
Ranking	5	4	2	2	1	1	3
Interpretation	Moderate	Satisfactory	Distinctive	Distinctive	Excellent	Excellent	Beneficial
Quality level considering environmental criteria—variant for low-importance environmental criteria							
Q_i^{qe}	178	198	249	250	288	288	238
q_i^{qe}	0.59	0.66	0.83	0.83	0.96	0.96	0.79
Ranking	5	4	2	2	1	1	3
Interpretation	Moderate	Satisfactory	Distinctive	Distinctive	Excellent	Excellent	Beneficial
Quality level considering environmental criteria—variant for medium-importance environmental criteria							
Q_i^{qe}	241	261	312	322	342	342	301
q_i^{qe}	0.65	0.70	0.84	0.87	0.92	0.92	0.81
Ranking	6	5	3	2	1	1	4
Interpretation	Satisfactory	Satisfactory	Distinctive	Distinctive	Excellent	Excellent	Distinctive
Quality level considering environmental criteria—variant for important environmental criteria							
Q_i^{qe}	521	541	592	642	582	582	581
q_i^{qe}	0.75	0.78	0.86	0.93	0.84	0.84	0.84
Ranking	5	4	2	1	3	3	3
Interpretation	Beneficial	Beneficial	Distinctive	Excellent	Distinctive	Distinctive	Distinctive

Stage 7. Qualitative–price analysis considering impact on natural environment

The purpose of this stage was to verify how the price of purchase of solar collectors impacts customer satisfaction with the quality and simultaneously impacts the natural environment. For this purpose, the ACJ method was used, which was implemented only for the qualitative criteria, and then in three variants for the qualitative criteria and environmental criteria "of little importance" (I), for the "moderately important" qualitative criteria and environmental criteria (II), and for the "important" qualitative and environmental criteria (III).

Solar collector prices were obtained from the manufacturer's website. The prices were for the purchase of one solar collector piece and were expressed in EUR. According to Formula (4), the value of the decision function was determined. Then, according to Formula (5), the price index for the quality level (c_p) was calculated. Next, Formulas (6) and (7) were used to calculate the relative price (p) and the price–quality proportionality index (e). Later, Formula (8) was used to calculate the decision function index (d). Subsequently, Formula (9) was used to calculate the relative price index (c). After calculating basic indicators, it is possible to calculate the settlement index for technical preference (r_t), the settling index for economic preference (r_e), and the average decision-making rate (r_d). Formulas (10)–(12) were used for that. The ACJ result realized only for quality criteria is presented in Table 5.

Table 5. Results of the proposed method considering only qualitative criteria of solar collectors.

Type of Collector	Solar Collector 1 (Flat)	Solar Collector 2 (Flat)	Solar Collector 3 (Vacuum Tube)	Solar Collector 4 (Vacuum Tube)	Solar Collector 5 (Flat)	Solar Collector 6 (Flat)	Solar Collector 7 (Flat)
P (€)	309.82	482.02	589.84	368.39	454.9	401.71	286.85
Q_i^{qe}	65.44	71.10	85.84	85.84	97.17	96.88	82.72
q_i^{qe}	0.65	0.71	0.86	0.86	0.97	0.97	0.83
c_p^e	4.73	6.78	6.87	4.29	4.68	4.15	3.47
p	0.92	0.36	0.00	0.73	0.45	0.62	1.00
e	1.41	0.50	0.00	0.85	0.46	0.64	1.21
d	0.65	0.25	0.00	0.43	0.23	0.32	0.59
c	0.63	0.03	0.00	0.76	0.64	0.80	1.00
r_t	0.65	0.44	0.43	0.70	0.67	0.73	0.78
r_e	0.64	0.22	0.14	0.67	0.56	0.67	0.84
r_d	0.64	0.33	0.29	0.68	0.62	0.70	0.81
Ranking	4	6	7	3	5	2	1
Interpretation	satisfactory	unsatisfactory	unfavorable	satisfactory	satisfactory	beneficial	distinctive

In a similar way, the calculation was realized for other variants, i.e., for the qualitative and environmental criteria "of little importance" (I), for the qualitative and environmental criteria "of moderate importance" (II), and for the qualitative and environmental criteria "of importance" (III). Therefore, only the final values of r_d are shown in Table 6.

Table 6. Results of the method with considering qualitative and environmental criteria.

Type of Collector	Solar Collector 1 (Flat)	Solar Collector 2 (Flat)	Solar Collector 3 (Vacuum Tube)	Solar Collector 4 (Vacuum Tube)	Solar Collector 5 (Flat)	Solar Collector 6 (Flat)	Solar Collector 7 (Flat)
Variant I for the qualitative and environmental criteria "of little importance"							
r_d	0.61	0.31	0.30	0.69	0.63	0.71	0.80
Ranking	5	6	7	3	4	2	1
Interpretation	satisfactory	unsatisfactory	unsatisfactory	satisfactory	satisfactory	beneficial	distinctive
Variant II for the qualitative and environmental criteria "of medium importance"							
r_d	0.65	0.33	0.28	0.70	0.59	0.67	0.80
Ranking	4	6	7	2	5	3	1
Interpretation	satisfactory	unsatisfactory	unsatisfactory	beneficial	moderate	satisfactory	distinctive
Variant III for the qualitative and environmental criteria "of importance"							
r_d	0.72	0.41	0.29	0.72	0.51	0.61	0.81
Ranking	2	5	6	2	4	3	1
Interpretation	beneficial	sufficient	unfavorable	beneficial	moderate	satisfactory	distinctive

It was observed that considering the purchase price of solar collectors changed the rankings from the MAP analysis (where the purchase price was omitted and only the quality and qualitative–environmental levels were estimated for various weight variants of environmental criteria). The summary of the results and their interpretation are presented in Section 5. However, in the next stage of the method, the most favourable product for the customer was selected.

Stage 8. Choice of best product for customer

In order to select the solar collector that will be the best for the customer, the values of indicators from stage 7 were ordered in a single ranking. The first position in the ranking has the highest value of r_d, i.e., the solar collector which is the most satisfactory for the customer in view of quality, impact on the natural environment, and price of purchase. Due to the lack of differences between the ACJ rankings in different interpretation variants, it was possible to select the flat collector marked with the number 7. It has the first position in each ranking of the ACJ method, i.e., $r_d = 0.80 \div 0.81$. According to the relative state scale, the choice of this collector allows for distinctive satisfaction of the customer. This collector is suitable for the customer in terms of quality (satisfaction with use) and environmental criteria (environmental impact) and has a purchase price appropriate for the customer.

The choice of this collector resulted from the assumption that environmental criteria and price of purchase are important for the customer. In the case of the omitted price of purchase, the best solar collector was a collector with conventional designation 4. Moreover, the weight of environmental criteria caused changes in the ranking of ACJ, where considering the price, collector 4 occurs in place 3 (for little weight of environmental criteria) and place 2 (for medium and high weight). The introduction of the price to the ranking means that, regardless of the importance of environmental criteria, collector 7 is always at the top of the selection list, as its price is relatively low compared to other collectors. It is also worth noting that the best collectors in terms of quality without taking into account environmental features (collector 5 and collector 6) obtain a different assessment result when taking into account environmental features, regardless of their importance.

5. Discussion

Renewable energy sources (RESs) are a key element in reducing negative climate changes [39]. The use of these devices to convert green energy (GE) is increasingly popular [40–42]. The most popular are photovoltaic (PV) panels. However, the choice of these devices by customers is still problematic [43–45]. Although different analyses of the choice of these products were carried out, e.g., [15,20], the choice was not realized by simultaneously considering customer expectations, the price of purchasing these products, and their impact on the natural environment. Therefore, the purpose of this study was to develop a method to select devices converting GE, including qualitative and environmental criteria and their price. This method was developed based on the following techniques: SMARTER method, brainstorming (BM), MAP method (alternative-punctual method, Czechowski method), ACJ method (price–qualitative analysis), and scale of relative states. The method test was carried out for solar panels, as summarized in Table 7.

Table 7. Comparison of results for MAP method and ACJ method for quality and qualitative–environmental criteria.

	MAP		ACJ		MAP		ACJ		MAP		ACJ		MAP		ACJ	
	Qualitative Criteria				Variant I				Variant II				Variant III			
	q_i^q	Ranking	r_d	Ranking	q_i^{qe}	Ranking	r_d	Ranking	q_i^{qe}	Ranking	r_d	Ranking	q_i^{qe}	Ranking	r_d	Ranking
C1	0.59	5 (u)	0.61	4 (z_1)	0.59	5 (u)	0.61	5 (z_1)	0.65	6 (z_1)	0.65	4 (z_1)	0.75	5 (z_1)	0.72	2 (k)
C2	0.65	4 (z_1)	0.31	6 (n_1)	0.66	4 (z_1)	0.31	6 (n_1)	0.70	5 (z_1)	0.33	6 (n_1)	0.78	4 (z_1)	0.41	5 (d)
C3	0.83	2 (w)	0.30	7 (n_2)	0.83	2 (w)	0.30	7 (n_1)	0.84	3 (w)	0.28	7 (n_1)	0.86	2 (w)	0.29	6 (n_1)
C4	0.83	2 (w)	0.68	3 (z_1)	0.83	2 (w)	0.69	3 (z_1)	0.87	2 (w)	0.70	2 (z_1)	0.93	1 (z_1)	0.72	2 (k)
C5	0.97	1 (z_2)	0.64	5 (z_1)	0.96	1 (z_2)	0.63	4 (z_1)	0.92	1 (z_2)	0.59	5 (z_1)	0.84	3 (w)	0.51	4 (u)
C6	0.97	1 (z_2)	0.72	2 (k)	0.96	1 (z_2)	0.71	2 (k)	0.92	1 (z_2)	0.67	3 (z_1)	0.84	3 (w)	0.61	3 (z_1)
C7	0.79	3 (k)	0.80	1 (w)	0.79	3 (k)	0.80	1 (w)	0.81	4 (w)	0.80	1 (w)	0.84	3 (w)	0.81	1 (w)

Variant I—for the qualitative and environmental criteria "of little importance"; variant II—for the qualitative and environmental criteria "of moderate importance"; variant III—for the qualitative and environmental criteria "of important"; z_1—satisfactory; n_1—unsatisfactory; n_2—unfavorable; k—favorable; w—distinctive; u—moderate; z_2—excellent.

It was observed that considering the purchase price, the collector marked with the number 7 became the best solar collector for the customer. However, this collector occupies position 3 or 4 in the ranking for verified variants (as in Table 2 in the MAP method). Another phenomenon that was observed was the fact that the weight of environmental criteria has a significant impact on the final ranking of the choice of solar collectors. Additionally, the price of the purchase has a significant impact on this ranking. Even when the quality of the collector was rated as high, the combination of the weights of environmental criteria and the purchase price adopted for the purposes of the article had a significant impact on the customer's satisfaction with the choice. In addition, the proposed method assumed that environmental criteria will usually be fewer than qualitative criteria. Hence, the environmental criteria should be interpreted as "important". Based on the calculations, it would be advisable to choose solar collector number 7, but only because of its much lower price than the prices of other products. This shows the essence of price in relation to quality and the environment.

It was observed that the proposed method allows controlling the customer's decision in the case of choice of the products depending on different weights and assessments of qualitative and environmental criteria, but also after including the price of purchase. Therefore, the main advantages of the developed method are as follows:

- The ability to adapt the product to individual customer needs;
- Ensuring the verification of any products, e.g., those converting green energy (GE);
- Adjusting product selection in line with sustainable development, i.e., taking into account customer expectations regarding product quality, purchase cost, and impact on the natural environment;
- The possibility of reducing the negative impact on the natural environment by promoting the choice of devices that are less harmful to the environment.

The main limitations (disadvantages) of the proposed method are the possibility of using this method only for an individual customer, the lack of repeatability of results caused by changes in ranking resulting from the needs and preferences of the individual customer, and the possibility of verifying only one type of product.

Therefore, future research will be concentrated on extending this method to allow for including expectations obtained from more customers. In addition, it is planned to include other types of techniques to reduce uncertainty and inconsistencies in customer expectations.

6. Conclusions

Negative climate change generates the need to implement RESs. Despite their popularity, the adaptation of green energy processing devices to customer needs remains a problem. Hence, the purpose of this study was to develop a method to select devices converting GE in which qualitative and environmental criteria and price are included. The concept of the method relies on the assumption that, in dependence on the need of the customer and the knowledge of the expert, it is possible to select the best product for the customer considering its needs, but also the price of purchase and impact on the natural environment. In the proposed method, different techniques were used in a hybrid way (sequential, combined). These techniques were the SMARTER method, brainstorming (BM), MAP method (alternative-punctual method, Czechowski method), ACJ method (price–qualitative analysis), and scale of relative states. The method test was carried out for solar panels. Criteria assessments are marked on a scale from 0 to 1 with an accuracy of hundreds of times, where 1 is the ideal quality (criterion quality standard) and 0 is the criterion with the lowest theoretical possible level. Assessments can be selected on the scale of the relative state. Assessments of assumed criteria are used in the MAP method to calculate the quality of the product considering the environment. Uncomplicated quality calculations are characterized by the need to determine the importance of each criterion. The weights of the criteria are constant and are equal to 50, important criteria; 10, medium–importance criteria; and 1, criteria of little importance. In the ACJ method, based on the quality calculated by the MAP method and on the price of products, the decision function value is calculated (by calculating some transitional indicators). From a mathematical point of view, the most favorable product for the customer is the one with the highest value of this indicator. In this case, it was observed that considering the purchase price, the collector marked with the number 7 became the best solar collector for the customer.

It has been shown that depending on the customer's needs and expert knowledge, it is possible to select the most beneficial product for the customer considering not only the customer satisfaction (quality of product), but also the impact on the natural environment and the price of purchasing the product (in accordance with sustainable development). It was shown that it is possible to select devices converting green energy based on a method that ensures customer satisfaction and simultaneously minimizes the negative impact on the natural environment.

This model has the following implications: the choice of any product, considering customers' expectations, reduction of waste by achieving customer satisfaction, and adjusting the sale of products in view of the individual preference of the customer. The model is dedicated to any entity (enterprise, expert, or broker), mainly for RES products. Furthermore, any customer can be a recipient of this model; i.e., having knowledge of the product or not having knowledge of the product, the customer can rely on the opinion of an expert. Additionality policy implications refer to the possibility of increasing the ability to comply with environmental laws. In addition, this method can support continuously improving products in a pro-environmental context by including the environmental criteria of the product. Hence, the policy implications concern minimizing the negative impact on the environment by verifying the quality of products while taking into account their impact on the natural environment.

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