Implementation of Clustering Analysis on Solar Panels Adoption by MSMEs in Banyumas Regency

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Abstract. Micro, Small, and Medium Enterprises (MSMEs) are essential for regional economic growth. In their operations, MSMEs often face technical constraints, one of which is the limited supply of electrical energy that can hamper production. Solar energy as renewable energy has great potential and is an alternative solution to minimize the impact of this problem. However, the readiness and ability of MSMEs to adopt new technologies often differ. Therefore, it is necessary to determine specific policies and strategies to encourage the adoption of solar panels based on the conditions faced by certain MSMEs. This study aims to classify MSMEs into particular groups based on their level of expectation, readiness, and ability to adopt solar panels as an alternative to conventional electricity supply. The hierarchical clustering approach was implemented and resulted in four optimal clusters with the number of members played by cluster 1. Cluster 1 shows the characteristics of MSMEs that are willing, ready, and able to adopt solar panels. Cluster 2 contains MSMEs that are unwilling, unprepared, and unable to adopt solar panels. Cluster 3 has the characteristics of MSMEs that are capable but still hesitant to adopt solar panels. In contrast, cluster 4 is MSMEs that want but need more time to be ready and able to adopt solar panels. Policies to encourage the adoption of solar panels by MSMEs are proposed based on the characteristics of each group, ranging from intensive assistance to resource assistance. The results of this study can provide an overview of the perception of MSMEs on the implementation of solar panels in Banyumas and Indonesia in more general.

Keywords: Solar · Panels · Banyumas · MSME

1 Introduction

Micro, Small, and Medium Enterprises (MSMEs) are one of the main pillars of the economy in Indonesia. MSME activities are essential in increasing per capita income and driving regional economic growth [1]. The rapid product development in MSMEs certainly requires a controlled strategy to achieve the expected target. The MSME sector

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has various strategic roles, but on the other hand, this sector faces multiple challenges. Limited working capital and low human resources cause a lack of mastery of science and technology [2].

One of the biggest challenges that MSMEs must face in the technology aspect is the limited supply of electrical energy. The problem of an unstable electrical energy supply hampers the production process in MSMEs. Currently, power plants in Indonesia still rely heavily on fossil fuels. However, fossil energy is expected to start depleting along with the increasing population and demand for electrical energy [3].

Using renewable energy (EBT) is one solution that can provide a stable electricity supply. The use of renewable energy as an alternative energy source is also one of the government's focuses in the success of sustainable development. One renewable energy source with a high potential for Indonesia is solar energy, reaching 4.8 KWh/m2 or equivalent to 112,000 GWp [4]. The solar panel is one of the technological components that can convert solar power up to 1.5 GWp.

Solar panel technology is widely used as a renewable energy source to replace conventional electricity supplies. At the same time, MSMEs in Banyumas, Central Java, have great potential to adopt solar panels to minimize unstable electricity. Data from the Banyumas Manpower, Cooperatives and MSMEs Office shows a growing number of MSMEs being fostered yearly [5]. However, in practice, MSMEs' readiness level for adopting new technology is often not the same as existing MSMEs. MSMEs often face funding problems that limit them from investing large amounts of money in adopting new technologies [6]. In addition to financial issues, low awareness is one of the barriers to the adoption of PLTS by MSMEs in developing countries. One of the reasons is the doubt about the risks that will be accepted in the future [7].

Many policies have been implemented to encourage using solar panels as a renewable energy source, such as promoting the installation of two-way KW-h to replace the previous one-way meters. This replacement allows solar panel users, households, and businesses to record incoming and outgoing power flows [8]. In addition, the Indonesian Ministry of Energy and Mineral Resources (EMR), together with The United Nations Development Program (UNDP), launched the Sustainable Energy Fund (SEF) program. The SEF program is an incentive grant to encourage the use of solar panels at the household level, MSMEs, and social categories [9]. However, these policies are often not optimal and effective because they are considered not right on target.

Moreover, information is not spread evenly, given that several MSMEs in Indonesia have different characteristics. The impact is that there is no significant increase in solar panel users [8]. Therefore, grouping MSMEs with the same features is one of the optimal alternatives for the government in carrying out specific and individual policies but does not need to focus on MSMEs individually [10]. Therefore, the strategic approaches proposed to encourage the use of solar panels can run more effectively because they follow each MSME's characteristics and conditions.

This study aims to map SMEs in Banyumas based on their level of desire and readiness to adopt solar panels. This grouping of MSMEs will indirectly provide an overview to the local government in making policies to encourage business actors to switch to using solar panels to implement sustainable development and economy. Many studies have examined the level of solar panels adoption by MSMEs in Indonesia and other

developing countries. However, the majority of research still focuses on determining the factors that influence the level of readiness to adopt renewable energy technologies, such as in studies [11, 12], and [13]. On the other hand, the clustering of MSMEs in previous studies is still in the research area, which groups MSMEs based on economic characteristics and size, such as capital, income, and the number of workers [10, 14, 15]. [16] classifying SMEs based on the level of readiness for information technology; this study has a similar goal to the research conducted, but this research focuses on the level of preparedness of SMEs in adopting solar panels. To the best of our knowledge, research on classifying MSMEs based on willingness and desire to use solar panels is still rare. Therefore, this research can provide practical implications for the government as policymakers and decision-makers to determine effective and varied strategies to encourage MSMEs in Banyumas to use solar panels. The broader benefit is that the proposed approaches can be applied nationally.

The clustering method is used to group SMEs as objects into classes based on certain similarities [17]. Clustering is an unsupervised data mining method where clustering will classify data without any knowledge of class labels. This research uses the hierarchical clustering algorithm, where there is no information on the number of groups that will be formed. This algorithm is one of the best alternatives if the researcher cannot identify the specific details of the number of clusters at an early research stage [18].

2 Methods

Data collection regarding the adoption and diffusion of solar panels by MSMEs was carried out by distributing questionnaires to MSMEs in Banyumas. The grouping of MSMEs based on the level of adoption and diffusion of solar panels is elaborated through three main questions, namely (1) the level of willingness of MSME actors to use and install solar panels in their business, (2) the level of readiness of MSEs to use and install solar panels in their business, and (3) the level of ability of MSEs to use and install solar panels in their business. These questions are used to measure the level of desire, readiness, and ability of MSMEs based on the subjective answers of the owners. The questions used were adopted from [13], where these questions were used to measure the level of adoption of solar energy technology in developing countries. The answers to these questions are indicated on a six Likert scale, which consists of strongly disagree to agree strongly.

Respondents from this study consisted of various industrial sectors in Banyumas, dominated by the culinary industry and continued by trade, agriculture, crafts, electronics, automotive, and others. In addition, most MSMEs in Banyumas have fewer workers of less than ten people, and the annual turnover is still at less than 300 million rupiahs. The result shows that most MSMEs in Banyumas are still at the micro level. Several MSMEs are in the small and medium groups but do not show a significant number. Table 1 shows the distribution of MSME respondents in this study.

Table 1. Distribution of respondent characteristics

Characteristics	**Percentage (%)**	**Characteristics**	**Percentage (%)**
Sectors		**Number of workers**	
Food & beverage	54	<10 workers	89
Services	12	10–30 workers	9
Commerce	10	30–100 workers	2
Fashion & textile	10	**Annual turnover**	
Electronics	4	<IDR 300 million	94
Craft	4	IDR 300 million–IDR 2.5 billion	5
Automotive	2	IDR 2.5–50 billion	1
Agriculture	2	**MSME owner's Gender**	
Others	2	Male	29
		Female	71

The primary method used in this research is cluster analysis. Cluster analysis is a machine learning approach that aims to classify several data into k clusters [19]. Clustering works by assessing the similarities between objects and placing the same thing into the same group. There are two main approaches to clustering, namely hierarchical and non-hierarchical, known as the k-means algorithm. Although they have the same goal, these approaches fundamentally differ in grouping objects. The hierarchical method groups object into homogeneous groups by combining them in sequence to build a binary merge tree [20].

Meanwhile, non-hierarchical requires researchers to determine the number and center of clusters and then place objects into the nearest cluster center [21]. This research uses hierarchical cluster analysis, which allows the data to be divided into optimal clusters without determining the number of clusters in the early stages. Hierarchical cluster analysis is the right choice when the number of groups cannot be ascertained [22].

The first step of this research is to do data pre-processing or data cleaning to ensure that there is no wrong, noisy, or missing data. The pre-processing data ensures that all information is correct and as expected. Next is to measure the similarity between objects indicated by the size of the distance between objects. The greater the distance between objects means the two things show less in common, and vice versa. This study's measure of similarity or distance between objects uses the Squared Euclidean Distance approach, shown in Eq. (1). *Dij* is the distance between the *i* and the *j* object, *p* is the number of cluster variables, *xik* is the value of *i* object in the *k* variable, dan *xjk* is the *j* object of the *k* variable.

$$d_{ij} = \sum_{k=1}^{p} \left(x_{ik} - x_{jk}\right)^2 \tag{1}$$

The hierarchical cluster analysis approach was run using the Software Statistical Program for Social Science (SPSS) 22. The algorithm used is an agglomerative approach, which is a bottom-up approach by aggregating each object point into one highest cluster.

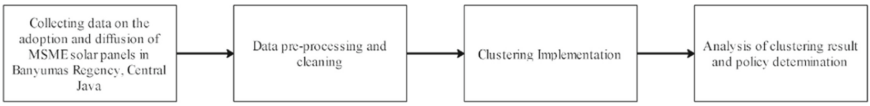

Fig. 1. Research flow

This approach reduces computation time because bottom-up processes can be started in the middle of the hierarchy [23]. The method used to identify similarities between cluster members is the Nearest Neighbor. After knowing the number and the members of clusters formed, further analysis is carried out to identify the specific characteristics of each cluster. These results will be a reference in providing strategies to encourage MSME actors to use the solar panel as an alternative renewable energy source. In general, the stages of this research can be seen in Fig. 1.

Figure 1 shows the research phase starting from collecting data on the adoption rate of solar panels by MSMEs in Banyumas Regency, Central Java, using a questionnaire with six Likert scales. Furthermore, pre-processing and cleaning are carried out to ensure that the data used is free from noise. Only complete or consistent data will be removed from the data set and continued at a later stage. As discussed in the previous paragraph, the method used is clustering analysis with a hierarchical approach. After obtaining several optimal clusters, each cluster will be analyzed and used as a reference in determining policies related to the implementation of solar panels in UMKM Banyumas.

3 Result and Discussion

This study uses a hierarchical clustering analysis approach to map MSMEs based on three main variables: the level of desire, the level of readiness, and the level of ability to adopt solar panels. Characteristics such as the industrial sector and the classification of MSMEs are presented in Table 1. Based on the respondent's data, it can be concluded that most MSMEs in Banyumas are still in the micro-class and dominated by the food and beverage industry. In addition, the owners of MSMEs in Banyumas are dominated by women. The finding follows the initial observations from the Banyumas Micro Small Medium Enterprise Association (ASPIKMAS).

Implementation of hierarchical clustering using SPSS 22 allows researchers to choose a range of clusters formed. In this study, the selected cluster range is two to five sets adjusted to the amount of data processed. The clustering results show that MSMEs in Banyumas can optimally be divided into four clusters. This number can be subjectively determined through the dendrogram and agglomeration schedule coefficients formed. A dendrogram is a structured graph shaped like a tree that aims to visualize how an object combines with other entities and forms a hierarchical cluster. The dendrogram is determined by several factors, i.e., the size of the distance, the clustering algorithm, and the number of variables used [24]. Due to a large amount of data, the dendrogram is difficult to visualize at a scale sufficient for the reader. Therefore, this study chose to illustrate the formation of clusters using the agglomeration schedule coefficient. The agglomeration schedule aims to identify at which point two combined clusters are considered too different to form a homogeneous group [22]. A significant spike indicates

Table 2. Part of the agglomeration schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	124	127	0,000	0	0	3
2	105	126	0,000	0	0	18
3	121	124	0,000	0	1	6
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
81	5	6	0,000	0	73	106
82	106	110	0,453	0	0	83
83	92	106	0,453	0	82	86

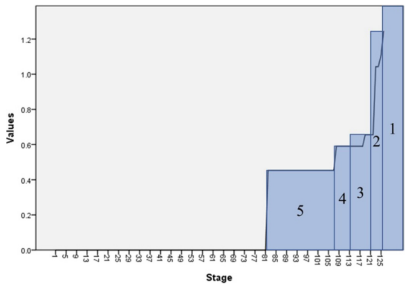

Fig. 2. Agglomeration coefficients graphic

this in the coefficient value. Several pieces of the agglomeration schedule results from this study are shown in Table 2. For example, there was a significant spike in the coefficient value between stages 81 and 82. The increase in the coefficient value is one of the early indications that the first clustering can be stopped after stage 81.

The agglomeration schedule coefficient is depicted in a graph (Fig. 2) to facilitate deep analysis. Figure 2 shows the level of heterogeneity in the cluster solutions found in this study. The greater the distance between the clusters, the better, as long as the differences are useful in decision-making. The agglomeration schedule coefficient results are then further elaborated to determine the characteristics of each cluster. Based on the in-depth analysis results, the five clusters show similarities in the parts of two different clusters. Therefore, it was decided that four clusters are the optimal solution, where each cluster shows significant differences in characteristics.

The results of the cluster analysis show that the four clusters formed based on the level of desire, readiness, and ability of MSMEs to adopt solar panels consist of (1) clusters of MSMEs that want, are ready, and can adopt solar panels, (2) clusters of MSMEs that

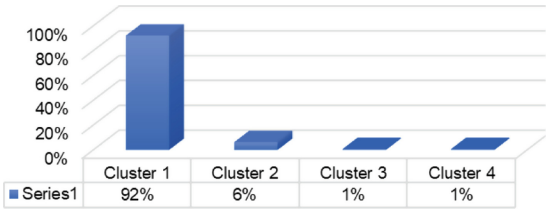

Fig. 3. Cluster members distribution

do not want, are ready, and unable to adopt solar panel, (3) clusters of SMEs who are able, but still hesitant to adopt solar panel, and (4) clusters of SMEs who want, but are not ready and unable to adopt PLTS. The determination of cluster characteristics was based on Likert scale mapping for each variable using Crosstab analysis on SPSS 22. This feature can assist researchers in identifying the distribution of three variables in the four clusters formed. For example, Figure 3 shows the number of members for each cluster. Most MSMEs are in cluster 1, with 92% willing, ready, and able to adopt solar panels.

This result is quite surprising for this study, where MSMEs in Banyumas strongly desire to adopt solar panels. However, no MSMEs in Banyumas have adopted solar panels for their daily business operations. Further analysis is needed to identify the cause of this gap. In addition, the formation of this MSME cluster will impact the government's practical policies in supporting sustainable development. Therefore, the next subsection will discuss each cluster's characteristics and managerial implications.

3.1 Cluster 1: MSMEs that are Willing, Ready, and Able to Adopt the Solar Panel

Cluster 1 shows MSMEs with a high enough desire, readiness, and ability to adopt PLTS. In terms of numbers, most respondents belong to this cluster, where most MSMEs show a positive opinion regarding the desire to implement solar panels as the main source of electrical energy. Further analysis was carried out to determine the profile of MSMEs in this cluster. Because it has the most cluster members, the shape of MSMEs in this cluster shows a fairly diverse profile. One important finding is that all MSMEs belonging to the small and medium levels are in this cluster. The result then supports the main characteristic of this cluster, where MSMEs are ready to adopt solar panels in terms of financial and human resources.

The results of this cluster 1 analysis show that MSMEs in Banyumas have great potential to adopt solar panels. However, in practice, no MSMEs in Banyumas has used solar panels. Based on interviews with several MSME actors in this cluster, one of the main reasons they have not used solar panels is the lack of information and socialization about this technology. It follows a survey conducted in another developing country, where most MSMEs are willing to implement PLTS, but a strong ecosystem is needed in the process [7]. Because the MSMEs in this cluster have shown a positive direction toward a green economy, the local government and the State Electricity Company (PLN) must play a full role in supporting this goal. Business actors and experts believe that customer

service and government support for MSMEs adopting PV mini-grid are important factors [12]. One of the things that can be done is to provide ease of service and administration for registration and licensing. In addition, to encourage the effective adoption of PV mini-grid by MSMEs, the government must ensure that the total potential capacity of renewable energy in Indonesia is adequate to accommodate the community's demands.

3.2 Cluster 2: MSMEs that are Unwilling, not Ready, and Unable to Adopt the Solar Panel

Cluster 2 is characterized by MSMEs with low desire, readiness, and ability to adopt solar panels. The distribution of respondents' answer choices based on the three variables used is on a Likert scale of one and two. These results make this cluster contains MSMEs that require more effort by the government to move towards the adoption of solar panels in the future. Micro-enterprises and several small businesses dominate the MSME group in this cluster. It indicates that many barriers still cause MSMEs' low interest in adopting solar panels. One important obstacle to adopting solar panels by MSMEs is the lack of capital, even for daily business operations. Undeniably, the business size and capital factor are still the biggest obstacles to adopting solar panels [13]. On the other hand, significant technological shifts have not become a top priority for some MSMEs. Micro and small businesses are often faced with thinking that current technology is sufficient to keep their businesses running [25].

One of the efforts that can be made to accommodate this cluster is to take an intensive approach with MSME actors. Another thing that can be done is to provide MSMEs with a comprehensive understanding of the benefits of installing solar panels, such as the economic benefits obtained, such as saving on electricity bills, and even free of charge if you do a full installation. In addition, there is a need for active collaboration between the government and non-profit environmental organizations such as ASPIKMAS to introduce the implementation of environmental sustainability to existing MSMEs. A good understanding of the impact of the green economy is believed to encourage MSME owners as the highest decision makers to have at least awareness of the use of environmentally friendly technology [26].

3.3 Cluster 3: MSMEs that are Able but Hesitant to Adopt the Solar Panel

Cluster 3 comprises MSMEs that can adopt solar panels but are still unsure, as indicated by the moderate value of expectation and readiness (Likert scale 3 and 4). Although the number of members in this cluster is not significant enough, an in-depth analysis still needs to be done to encourage the number of solar panels adoption by MSMEs in Banyumas. The members' main profile in this cluster is MSMEs, which are still at the micro-enterprise level, with the dominant business field servicing. Based on further observations related to the results of this study, MSME actors in the service sector assume that the electricity consumption issued is not as much as that given by MSMEs engaged in the manufacturing industry. Therefore, the adoption of the solar panel is still considered to provide fewer economic benefits compared to the capital that must be spent.

The main keyword of the characteristics of this cluster is that MSMEs are resource-capable, but there are still doubts about the process leading to its application. This doubt is

often influenced by the tendency of MSMEs to only focus on short-term risks and losses when adopting new technologies [25]. Therefore, as a policy maker, the government must provide assistance and information to MSME owners regarding the benefits and energy efficiency measures, one of which is by transitioning to environmentally friendly technologies such as solar panels [27].

3.4 Cluster 4: MSMEs that are Willing but not Ready and Unable to Adopt the Solar Panel

Cluster 4 consists of MSMEs that desire to adopt solar panels but are limited in their level of readiness and ability. This level of preparedness and ability is influenced by the lack of capital and human resources owned by MSMEs. This cluster has the same profile as the previous cluster 3, where micro-businesses dominate members in this cluster with service businesses. However, because they already desire to adopt solar panels, the proposed approach or strategy for MSMEs in this cluster is easier to implement. At least, personal constraints such as intention to use have been minimal in this cluster.

The government must carry out a responsive approach to facilitate the adoption of solar panels by MSMEs to encourage MSMEs in this cluster [28]. One of the approaches taken is to provide funding grants for installing solar panels to MSMEs who have the desire but are limited by the ownership of resources. Through this program, it is hoped that MSMEs can receive benefits and become the embodiment of green economy implementation at the MSME level as one of the pillars of Indonesia's largest economy.

4 Conclusion

This study uses a hierarchical clustering approach to form a group of MSMEs in Banyumas based on the level of desire, readiness, and ability to adopt solar panels as a renewable energy source. There are four clusters formed, where the majority of MSMEs are in cluster 1, which indicates that most MSMEs in Banyumas already have the desire and are supported by the readiness and ability of resources to implement solar panels in their business units. Cluster 2 shows that MSMEs do not want to adopt solar panels and have not been supported by the readiness and capacity of resources. Cluster 3 reflects the characteristics of a group of MSMEs who can adopt solar panels but are still hesitant. Finally, cluster 4 contains MSMEs with hopes of adopting but are still limited by the lack of capital and labor. This clustering process has implications for proposing strategies to stakeholders, such as the Banyumas government and other related units, to encourage the use of solar panels based on the characteristics of each MSME in each cluster. The significant finding in this study is that 92% of MSMEs show a high level of desire, readiness, and ability to adopt solar panels, but in practice, no MSMEs in Banyumas have done so. The leading cause of this condition is the lack of information and socialization regarding environmentally friendly technologies such as solar panels. It then provides an overview of the real conditions in the field that information and socialization related to the solar panel's implementation process have not fully reached MSMEs, especially those in rural areas and far from big cities such as Banyumas. Therefore, as the highest policy maker, it is necessary to have an intensive approach and real assistance from related parties, especially the government.

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