Article

Assessing the Sustainable Development of Micro-Hydro Power Plants in an Isolated Traditional Village West Java, Indonesia

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Abstract: The sustainable development of micro-hydropower (MHP) plants is a challenge for rural electrification in developing countries, especially in Indonesia, which has diverse ethnic groups, cultures, and traditions in several isolated locations due to its complex terrain. The uniqueness of a social situation in a location can affect the sustainable electrification development. This study aimed to assess the sustainable development of MHP plants in the Kasepuhan Ciptagelar, which has unique traditions and cultural characteristics. The assessment was conducted using the sustainable development indicator (SDI) method, the Ilskog method, which can include social, economic, environmental, technical, and institutional dimensions. Data were collected through field investigations and qualitative dialogs to understand the culture and ways of thinking. The results of the Ilskog method analysis revealed that the environmental dimensions had the highest scores, whereas economic dimensions had the lowest scores, indicating that the cultural background of the Kasepuhan Ciptagelar impacted the SDI scores. This was attributable to the decision of Kasepuhan's traditional leader, which strengthened the community commitment to renewable energy use. However, the cultural background adversely impacted monetary income to sustain MHP plants. This study proposed that community innovation and microcredit availability could improve productive activities, resulting in better economic conditions to sustain MHP plants.

Keywords: sustainable development; traditional village; electrification; micro-hydropower; rural; sustainability indicator

1. Introduction

One of the most important renewable energy technologies for rural electrification in developing countries is micro-hydropower (MHP) generation [1], especially in mountainous areas with adequate water supply [2]. This is because MHP generation is environmentally friendly and inexpensive; it provides the best economic choice and is of great importance for the sustainable future [3,4]. Indonesia has enormous renewable hydropower energy potential, reaching 75 GW [5], and approximately 19,385 MW can be developed into mini- and micro-hydro plants [6]. Considering its potential and favorable geographical position, MHP may be the best choice for priority development in Indonesia.

Micro-hydropower is an environmentally friendly power plant, but it can negatively impact society and the environment for larger capacities such as small hydro to hydropower. A hydropower construction has serious social and ecological impacts [7], including reducing sediment transport and severe alteration in river hydrology [8,9]. Wang et al. [10] showed that 236 small hydropower plants impacted river connectivity to some extent, leading to a range of environmental problems. Many countries have applied MHP. However, the classification of hydropower depends on each country's circumstances [11]. Some countries such as the USA, India, and Brazil classify MHP as a power plant with a capacity below 100 kW [12]. MHP is a run-of-river power plant, therefore, it does not need a reservoir that can limit the emergence of social and environmental impacts because the river is not converted into a lake, and the shape of the flow is not changed [11]. With minimal social and environmental impacts, this power plant is preferred to be developed, especially in remote areas.

Many MHP plants have been installed and distributed around rural areas of Indonesia, where some locations have a specific situation, such as villages with unique cultural characteristics. However, it has been reported that many MHP plants (MHPPs) have stopped functioning in rural areas due to failures caused by natural disasters and human errors [13]. However, their sustainability performance has not been well documented, and the relationship between rural conditions and sustainability is still not well understood. Very few studies have been conducted on sustainability issues, especially those related to social and cultural situations. Purwanto and Afifah [14] studied the impact of techno-socioeconomic factors on sustainability in Indonesia; they concluded that economic factors performed negatively and positively in various dimensions, including the social, technical, environmental, and institutional dimensions. The results of an independent survey by the Ministry of Energy and Mineral Resources on MHP development in remote areas from 2011 to 2016 show that as many as 14% of the 65 MHPPs have suffered damage, generally due to issues related to social, technical, and environmental factors [15]. Sustainability assessments of MHPPs need to be conducted to comprehensively understand sustainability issues, especially in remote locations.

There are several alternative methodologies for evaluating the sustainability of electrification projects in rural areas, such as indicator-based analysis, the optimization technique, the multi-criteria decision-making (MCDM) method, system analysis approach [16], and the key performance indicator (KPI) approach [17,18]. The United Nations [19] has suggested sustainability indicators, which were explicitly introduced with stakeholder involvement consistent with the participatory process [16]. Previous researchers have applied sustainability indicators in their studies [14,20]. Compared to other methods, the advantages of the sustainability indicator method are to convey information and better understand a development project [21]. It can provide a solid basis for decision making at all levels [18]. However, few studies have applied this method to the assessment of rural electrification in remote villages with unique traditions and cultures.

MHPPs will continue to be developed in Indonesia consistent with the government's target to increase the renewable energy share. However, achieving sustainable development remains challenging, especially for MHPPs located in remote locations.

This study assessed the sustainability of two MHPPs in a remote village with unique cultural characteristics in West Java, Indonesia, where people live under distinct local traditions using a sustainable indicator framework. This study provides insight into how a village with substantial traditional factors can sustain its electrification under renewable energy technology.

2. Materials and Methods

2.1. Site Description

The study area is Kasepuhan Ciptagelar, located in Sinaresmi Village, Cisolok District, Sukabumi, Indonesia (6°48′ S, 106°29′ E, 1121 m.a.s.l.). Figure 1 shows the Sukabumi district and the study area. Due to its location in the mountainous region, access is challenging,

especially during the rainy season. Kasepuhan Ciptagelar is a home of the Sundanese indigenous people and was originally part of the Padjajaran-Bogor kingdom and was founded in 1937. The people of Kasepuhan live in 568 hamlets, primarily located in three districts: Lebak, Bogor, and Sukabumi. In addition to these three districts, some people of Kasepuhan also live and work in other areas outside of West Java and Banten, and even outside Java. They still identify themselves as members of the Kasepuhan community.
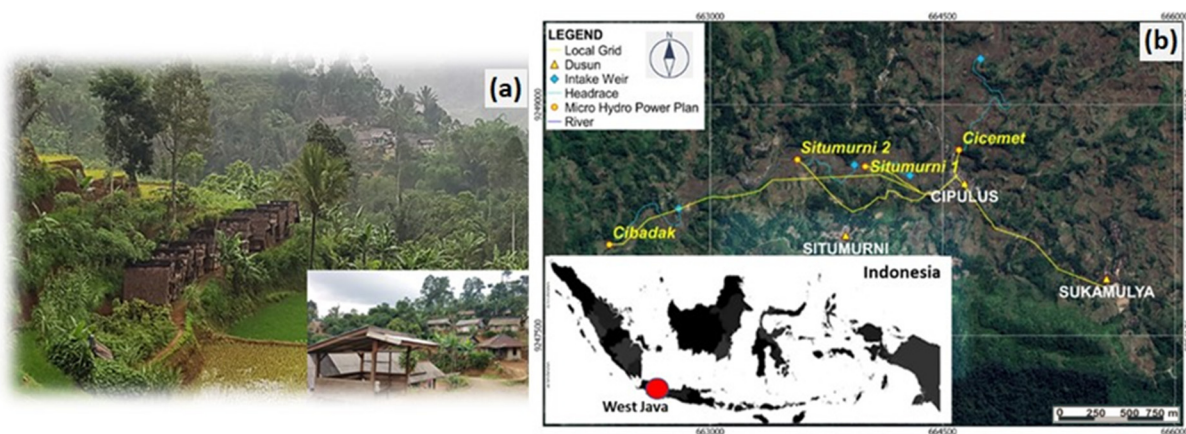

Figure 1. (**a**) Landscape of the Ciptagelar village. (**b**) Study location and layout of four MHP plants.

Kasepuhan Ciptagelar is a traditional community with a unique social structure; it has local wisdom in managing natural resources and lives under its leader's orientation. Every person in Kasepuhan Ciptagelar works as a subsistence farmer. The people of Ciptagelar believe that the rice entity is imprinted in the realm of values and thought and is reflected in ritual and daily life. They prioritize the balance between humans and nature, and this concept of balance is implemented in agriculture and forest management whereby humans can take advantage of nature for their lives but must not cause damage. The highest leader of the Kasepuhan community is called Abah, and his role and influence are significant in the community. The leader plays a role in determining the entire cycle of customary activities, including agriculture and forest management and resolving social problems that occur in the community by providing warnings and reprimands for those who are culpable. The traditional leader is believed to have a relationship with their ancestors, and every decision is part of their blessing.

There are four MHPPs in Kasepuhan Ciptagelar: Cicemet, Situmurni 1, Cibadak, and Situmurni 2 (Figure 1). MHPPs have been developed under the Indonesian local government's support along with non-governmental organizations (NGOs), the Korea International Cooperation Agency (KOICA), and the Japan International Cooperation Agency (JICA). All MHPPs are located on the Cisono River in the Cibareno watershed, which has an area of ±229,834 m². Currently, the Cicemet MHPP, which started operations in 1998, is damaged. In addition, the Situmurni 1 MHPP, which began operation in 2001, cannot supply electricity to the communities. They have been broken since March 2016 due to massive floods, landslides, and thunderstorms caused by extreme weather conditions. The other two MHPPs, Cibadak and Situmurni 2, remain in operation and are generally in good condition; they have been used for the sustainability assessment.

2.2. Investigation and Analysis

2.2.1. Sustainable Development Indicator Analysis

This study proposed a sustainable indicator framework by Ilskog [21], which covers multiple sustainability dimensions, including social, economic, environmental, technical, and institutional dimensions (IDs). In total, 29 indicators were used to assess the MHP plants, which were selected based on a preliminary survey and their field applicability. The investigations were conducted through surveys, interviews, and document checking.

Household electricity consumption was calculated by checking the ownership of electronic devices in the customer's book and verified during the interview process; data were collected between November 2019 and January 2020.

The value of each indicator was obtained from the survey and determined using the indicator equation. The level of sustainable development indicators (SDI) is calculated by comparing its value with its target level. The target level for each indicator was derived from literature that offers the experience of the best hydropower projects. In choosing the target levels, the standard value was purposely set high to show the sustainability dimensions' positive results [22]. The equations to determine the indicator values and their target levels can be seen in the Appendix A (Table A1). The SDI score of each indicator was 100% if the indicator reached the target. If the indicator's value was below the target with the minimum requirement, the SDI score was calculated using Equation (1). Conversely, if it exceeded the target with the maximum target, the SDI score was calculated using Equation (2) [14]. The total SDI value for each MHPP resulted from the arithmetic averages of all SDI values, which also indicated that each indicator had the same weight. Equations (1) and (2) are calculated as follows:

$$SDI\ (\%) = V_i / V_t \times 100\% \tag{1}$$

$$SDI\ (\%) = 100\% - (V_i - V_t)/V_t \times 100\% \tag{2}$$

where:

SDI: score of the sustainable development indicator;
V_i: value of the indicator;
V_t: value of the target level.

2.2.2. Social Surveys

In-depth interviews with respondents were conducted face-to-face, in a semi-structured way to obtain broad and comprehensive information. The respondents were asked questions related to their education, livelihood, income, and perception of MHPP. The documents checked were a financial book that records consumer contributions. The population consisted of 508 households with an electrical connection to an MHPP within three hamlets: Cipulus, Situmurni, and Sukamulya. The number of samples was determined using the Slovin equation, and the critical value was set to 10%. The sample size was 84, representing a family head in each household. Respondents were selected using the random walk sampling method because the area of each hamlet is not too large. The calculation of electrical device ownership was based on the customer's book and confirmed during the interview.

2.2.3. Land Cover Analysis

Cibareno's watershed land cover was analyzed using satellite imagery and a geographical information system (GIS). GIS software can analyze and display geographical referenced (spatial) information to aid decision-making processes [23]. The image source was the Landsat 8 onboard operational land imager (OLI) in 2019. Spatial analysis of the vegetation index was used to classify land cover into six parts: river, paddy and wet areas, settlements, barren land, medium-density forests, and high-density forests. The vegetation area was the sum of the areas classified as medium-density and high-density forests. The regulation of the Minister of Forestry of the Republic of Indonesia was used as a reference to determine watershed conditions.

3. Results

3.1. General Situations for Kasepuhan Ciptagelar

The social investigation obtained information related to education level, livelihood, and monthly income. The academic history of most people in Kasepuhan Ciptagelar is of elementary school graduation. The primary school in Kasepuhan Ciptagelar was established in 2003. Most people work as farmers and some people earn additional income

by working as temporary laborers and selling local handicrafts. They face uncertain monthly payments. As many as 31% of people earn an income between USD 60 and USD 110 per month, and 69% earn incomes below USD 60 per month. Most have one or two children. Farmers in Kasepuhan usually work from 8.00 a.m. to 3.00 p.m.

The life of the Kasepuhan community is oriented toward traditional leaders, to whom they are very obedient. Traditional leaders (Abah) are seen as symbols and must be respected by the community. There is a belief in society that Abah's orders must be fulfilled, and every decision he makes is part of a blessing from the ancestors. They believe that his orders will do good, and if they are not followed, they will incur losses. A small organization led by the Kasepuhan leader operates the two MHPPs, indicating that the MHPP presence is crucial for the lives of the people of Kasepuhan. The organization consists of six staff members, two of which have technical capabilities from the training held by the local government and contractor.

The semi-structured interview revealed the reasons for the community's strong commitment to the MHP. According to a quote from one of the traditional elders, "The existence of the MHP in Kasepuhan was initiated by traditional leader and built by the extraordinary work of the Kasepuhan community in cooperation; therefore, it must be maintained and utilized for the benefit of the Kasepuhan community". The majority of respondents also convey this perception.

The MHPP tariff in Kasepuhan Ciptagelar uses a fixed scheme of Rupiah (Rp) 400 watt^{-1}. This tariff was the same as when the MHPPs were established in 1997. There was a compromised wattage calculation chosen by the previous leader that the watts for each electronic device owned by the customer were only half of the specification values. This means that each household pays based on the type of electronics they own.

Field investigations included checking all MHPP conditions and calculating household electricity consumption. Currently, only two MHPPs remain in operation, Cibadak and Situmurni 2. The characteristics of all the MHPPs are presented in Table 1. In the surveys, people were asked about their electronic device use habits. Electricity for each house was limited to 2 amperes by a miniature circuit breaker (MCB). Based on the calculation of equipment ownership and use habits, the average value of electricity consumption was 217 kWh year^{-1} household^{-1}.

Table 1. Characteristics of micro-hydro technology.

MHP Plants	Turbine	Head (m)	Flow (L/s)	Output (kW)	Generator
Cicemet *	Cross flow	17	348	60	-
Cibadak	Cross flow	15	300	58	Synchronous
Situmurni 2	Cross flow	13.5	349	48	Synchronous
Situmurni 1 *	Turbo Propeller	11.5	397	40	Synchronous

* out of operation.

3.2. Land Cover

The Cibareno watershed has an area of ±22,983 ha and is classified as shown in Figure 2. The land cover of the Cibareno watershed is divided into five areas: river bodies covering ± 282 ha (1.23%), agricultural land and rice fields covering ± 2272 ha (9.89%), residential open land covering ± 255 ha (1.11%), dry soil with sparse vegetation covering ± 4970 ha (21.63%), and medium-high density vegetation covering ± 15,203 ha (66.15%).
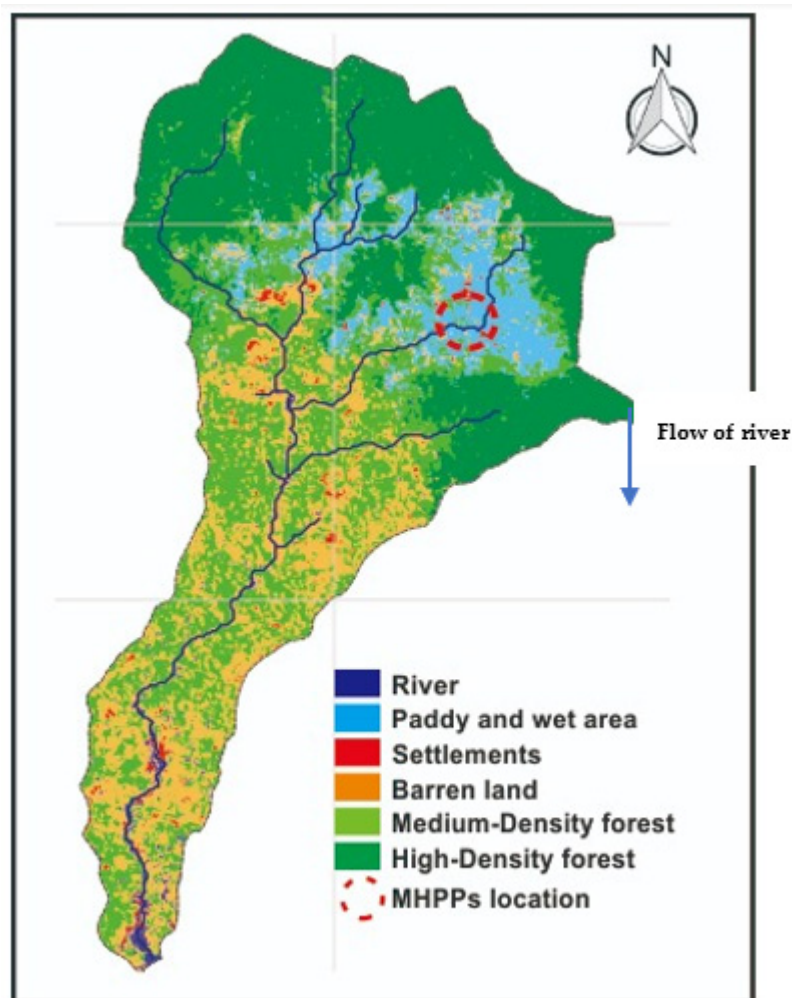
Figure 2. Land cover of the Cibareno watershed.

3.3. Sustainable Development Indicators Score

The assessment covered the five sustainable development dimensions. Table 2 provides the value of each indicator based on the data collected during the field investigation.

In general, most technical indicators approached their target level, except for the capacity factor indicator, which only reached half of the specified target. The grid system at the Cibadak plant was better than that at the Situmurni 2 plant because it followed the national network's standard technology. The opposite result was found for the economic dimension indicators, where the majority of indicators produced values below the specified target level. The indicator exceeding the target was the profitability indicator, which showed the percentage of income after deducting operational costs (salary). Currently, there is a Ciptagelar coffee production unit that utilizes electricity from the Cibadak plant.

Social indicators (SIs), environmental indicators (EIs), and institutional indicators (IIs) showed different results. Most SIs were close to reaching the target level (>70%). The unavailability of micro-credit facilities and streetlights comprised the two social dimension indicators, which provided low values. The EIs showed the best sustainability because almost all indicators reached the target levels. Only the indicator of electricity utilization for cooking (EI4) was low. The IIs showed only two indicators, staff turnover (II2) and number of years in business (II3), that reached the target levels; the indicator of satisfaction level (II5) was slightly below its target level, and the indicators related to non-technical losses (II4) and financial audits (II6) received low scores.

The total SDI scores of the Cibadak MHPP and Situmurni 2 MHPP were 67% and 61%, respectively, and the average score was 64% (Figure 3). The environmental dimension (ED)

showed the highest score among all dimensions, followed by the institutional (ID), social (SD), technical (TD), and economic dimensions (BD).

Table 2. Result of indicator value.

|	Sustainability Indicator	Target Level	Indicator Value	
			Cibadak	Situmurni 2
	Technical Indicators (TI):			
-	Capacity factor (TI1)	Min 95%	49.5%	55%
-	Compatibility with future grid services (TI2)	Yes	Yes	No
-	Daily operation services (TI3)	24 h	24 h	24 h
-	Availability of services (TI4)	100%	91%	94%
	Economic Indicators (BI):			
-	Profitability (BI1)	Min 35%	63%	41%
-	Share of profit set aside for re-investment (BI2)	100%	9%	8%
-	Tariff lag (BI3)	Min 21%	0%	0%
-	Share of electricity consumed by businesses (BI4)	Min 5%	0.95%	0%
-	Share of electricity households for income (BI5)	Min 5%	2.6%	0%
-	Business development (BI6)	Min 1 unit	1	0
	Social Indicators (SI):			
-	Share of health centers and school with electricity (SI1)	Min 90%	100%	100%
-	Number of streets lights in the area (SI2)	Min 1/40	0	0
-	Micro-credit possibilities available for connection (SI3)	Min 1 unit	0	0
-	Share of population with primary school education (SI4)	Min 80%	92%	95%
-	Share of population with access to electricity (SI5)	Min 90%	100%	100%
-	Subsidies offered for electricity services (SI6)	Max 1%	0.97%	2.47%
-	Share of economically active children (SI7)	Max 5%	2%	1%
	Environmental Indicators (EI):			
-	Share of renewable energy in production (EI1)	100%	100%	100%
-	Emissions of carbon dioxide from production (EI2)	0 Ton CO_2/yr	0 Ton CO_2/yr.	0 Ton CO_2/yr.
-	Share of electrified households where electricity has replaced other energy source for lighting (EI3)	100%	100%	100%
-	Share of electrified households where electricity has replaced other energy source for cooking (EI4)	Min 50%	0%	0%
-	Any serious local environment impact identified (EI5)	No	No	No
-	Extreme weather condition (EI6)	Never	Never	Never
	Institutional Indicators (II):			
-	Share of staff with appropriate education (II1)	Min 50%	33%	33%
-	Staff turnover in organization (II2)	0%	0%	0%
-	Number of years in business (II3)	Min 5 yr.	7 yr.	6 yr.
-	Share of non-technical losses (II4)	0%	20.21%	20.77%
-	Level of satisfaction with energy services (II5)	100%	98%	96%
-	Auditing of financial reports on yearly basis (II6)	Once/yr.	0	0
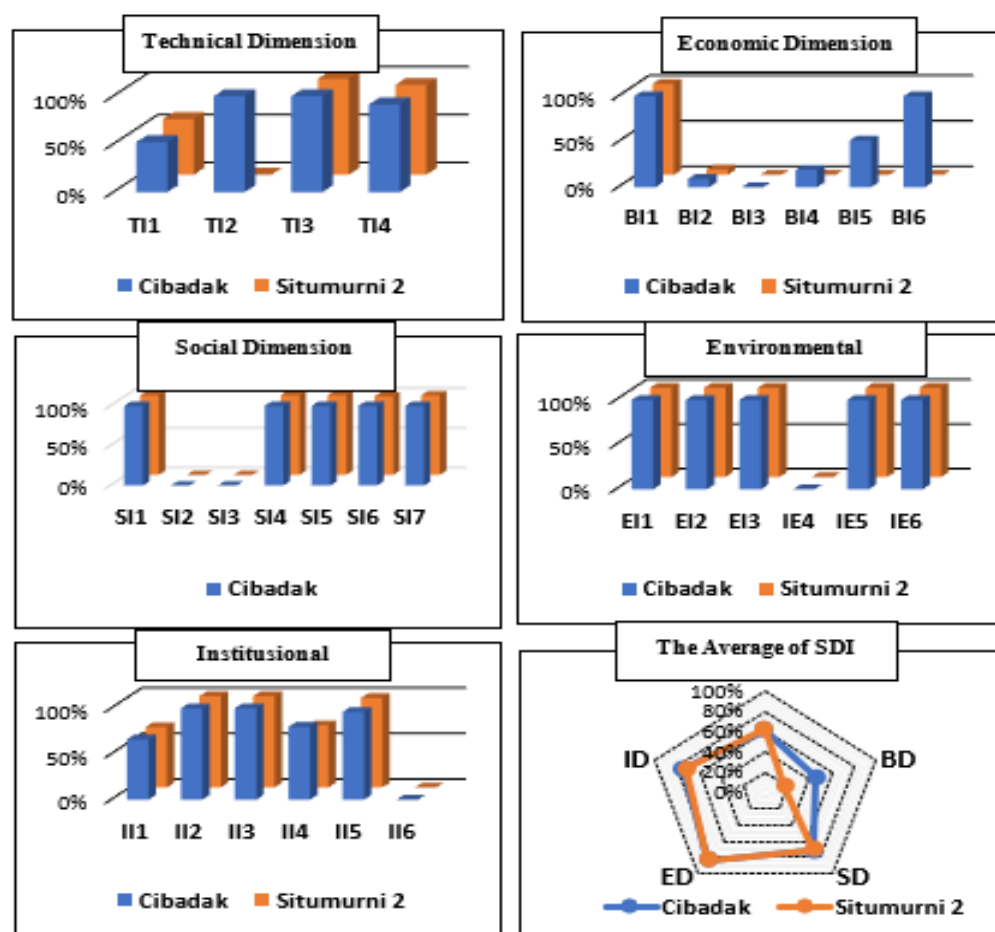
Figure 3. Sustainable development indicator (SDI) scores. See Table 2 for the abbreviations in the figure.

4. Discussion

Environmental sustainability can be seen as a global and local factor. Global environmental sustainability's primary considerations relate to the emission of greenhouse gases, such as CO_2, while the local factors relate to natural resource disruption [21]. The indicators of the share of renewable energy and carbon emissions represent global impact factors, which approached the target level. Based on the field survey, MHPPs were the only electrification resources for people in the Kasepuhan Ciptagelar, which emit no CO_2. The qualitative study found that the strong commitment of people in the Kasepuhan area was always to utilize MHPPs. This was largely attributable to the Kasepuhan leader's decisions. The village people explained that the presence of the MHPP was an extraordinary result accomplished by their leader, together with people in Kasepuhan. Moreover, the Kasepuhan leader regularly asked people to commit to preserving all MHPPs so that electricity can be utilized from generation to generation. The traditional leader in Kasepuhan Ciptagelar is a figure who is able to enforce community involvement in participatory activities, and his order must be followed and executed by the communities [24].

Among the EIs, only EI4 did not reach the target level. Kasepuhan Ciptagelar has customary rules in how rice is cooked; it must be cooked using firewood. Only some people, about 31% of households, were gas owners allowing them to prepare other meals, such as meat, vegetables, or side dishes. People received wood from their gardens or bought it from a supplier. A survey by the World Bank [25] found that approximately 40%, or 25.5 million households, use firewood for cooking, especially in remote villages. Firewood is preferable because it is easy to find and free. However, electricity for cooking could reduce the 13–35 ton-CO_2 year^{-1} emissions [26]. One challenge is how residents should prevent their forest from being overexploited considering the high demand for wood for

cooking and other purposes. In Ciptagelar, based on customary rules, forest utilization is divided into three zones: a close zone (Leuweung Tutupan), an open zone (Leuweung Bukaan), and a security zone (Leuweung Titipan). Even though there is no clear border between the zones, the people of Kasepuhan know the area's characteristics precisely. People can only exploit open-zone forests to support their lives. The commitment of the community to protect forests based on customary rules impacts forest preservation. This supports the sustainability of the ED, especially the indicators related to local factors (EI5 and EI6). Based on the satellite image analysis, the land cover of the Cibareno watershed by vegetation with high-medium density was more than 60%. Areas with high-medium vegetation density between 60% and 80% were characterized as having low restoration [27]. However, traditional leaders and forest caretakers (Pasmswakarsa) still have to regularly supervise the forest to avoid illegal logging that causes environmental damage. Waddell and Bryce [28] reported that forest preservation is a crucial factor in sustainable environmental determination. MHP generation as an energy source is a tool to achieve the final goals, including high living standards and a clean environment [29].

The BD was the weakest point in the sustainable development of rural electrification. The indicators (BI) showed that the community's economic activity was low; ultimately, it impacted the ability of the community to increase electricity fees over time. Rice farming is the main economic activity in the community. However, the customary rules prohibit people from selling paddies. Moreover, rice can only be planted once per year. They believe that whoever buys or sells rice will receive bad luck from their ancestors. This situation might impact the income of Kasepuhan. At present, electricity from the Cibadak MHPP has been utilized for coffee processing since 2014. To overcome this financial situation, the Kasepuhan community should increase its economic activity.

Based on the field investigation, the first important factor in generating productive activities is capacity building, creating markets, and providing credit facilities. Capacity building will improve the ability of people to think more innovatively, where the markets offer people the opportunity to sell their products. People need credit facilities to help them acquire capital to develop businesses. According to Sukma [30], approximately 69% of the Kasepuhan community had experience in borrowing money, such as from banks. Potentially, some traditional handcrafts from wood and iron materials could be developed commercially, such as rattan bags (called Kaneron), bracelets, rings made from fern trees (called Simpay), machetes (Bedog), and a tool for paddy cutting (called Etem). External assistance is needed to promote economic activities for the Kasepuhan communities. The local government could be a triggering party and facilitator for other stakeholders in realizing open market and credit activities. Innovation and capacity building are the basic requirements for creating productive activities [23], which could increase the communities' income; thus, the sustainable economy of MHPs can be achieved [31]. People living in villages in developing countries will benefit from MHPPs for economic growth if the energy is optimally used for productive activities [1,32].

Traditional leaders have a strong influence on Kasepuhan's lives. The Kasepuhan community express their leader as a symbol, and everyone must follow his orders. They believe that it will affect their welfare if they participate in the leader's orders. This perception could be the best way to support sustainable MHP development in Kasepuhan Ciptagelar. For example, the decision of traditional leaders to provide electricity subsidies to older people and social infrastructure helps SIs reach the target levels. For IDs, the decision of traditional leaders to keep staff members unchanged in the MHP organization supports institutional sustainability, especially turnover staff indicators. One determining factor for an institution's sustainability is staff turnover [33,34]. Meanwhile, the challenge in the ID concerns the non-technical indicator showing the obedience of customers in paying electricity bills. The role of the leader is crucial in monitoring financial management, including an audit of the MHP management organization in collaboration with external parties. It is necessary to make and implement acceptable rules, especially those related to the payment of contributions. There is no negotiation in terms of payment for electricity

bills [35]. The concept of sustainable institutions requires the implementation of strict rules. Simple and acceptable rules with accountable supervision are the key successes of institutional management in achieving sustainable development [36].

5. Conclusions

The SDI method could identify and understand the strongest and most vulnerable dimensions related to the sustainability of MHP plants in Kasepuhan Ciptagelar. This study revealed that the EDs were the strongest in terms of the sustainability of MHPPs, whereas the economic dimension was the weakest. The strong commitment of the community to preserve MHPPs as the primary source of electricity supports environmental sustainability. In Ciptagelar, there has been a community perception that MHP is a part of their culture, which has to be preserved from generation to generation. However, strict customary rules and subsequent low monetary incomes have made it difficult to sustain MHPPs. Therefore, communities need to participate more willingly in productive activities based on MHP generation. Capacity building, creating markets, and providing credit facilities are the main factors that trigger productive activities, which could be achieved through cooperation with external parties such as the local government, NGOs, and other stakeholders.

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Appendix A

Table A1. Equations to determine the indicator values and their target level.

No.	Indicator *	How to Measure *	Unit	Target Level Determination **
	Technical			
1	Capacity Factor	The gross energy (kWh) divided by the total installed capacity (kW) when the plant operated for 8760 h/yr	%	Capacity factors of hydropower projects worldwide yield between 23% and 95%
2	Compatibility with national grid	Field Survey	Yes/No	To increase its sustainability, MHPPs should be readily interconnected in the future, and follow the national grid standard installation.

Table A1. *Cont.*

No.	Indicator *	How to Measure *	Unit	Target Level Determination **
3	Daily operation Services	Hours of daily's operation hours	Hour	Electricity is essential, and people need it all the time. The target is 24 h a day.
4	Service availability	Number of hours electricity's in the planning minus hours of outages; divided by the number of hours electricity's in planning	%	The best service availability is 100%
	Economic			
5	Profitability	Total profit (revenue − O&M cost) (Rp/yr), divided by total revenue (Rp/yr) × 100%	%	The average profitability of micro-hydro in Indonesia is around 35%
6	Share of profit set aside for re-investment	The total profit (revenue − O&M cost) (Rp/yr), divided by the total cost of equipment depreciation (Rp/yr) × 100%	%	The visibility of a good project has an investment rate of at least 100%.
7	Tariff lag	The ratio between the change of electricity tariff (%) and change in inflation (%) × 100%	%	The economic feasibility analysis of the MHP projects in Wonosobo, Indonesia, determined that the tariff increases annually by 3%
8	Share of electricity consumed by businesses	The ratio between electrification for businesses (kWh/yr) and the net of electrical production (kWh/yr) × 100%	%	As much as 5% of the minimal of electricity consumed for the business to generate income and significant change of economic
9	Share of electricity households for income	The ratio between electrifying use for household businesses (HH) and the total number of households electrification (HH) × 100%	%	The minimum is 10% for the target level
10	Business development	Number of businesses development on yearly basis	unit	One business has been developed as the minimum target
	Social			
11	Share of health centers and school with electricity	The ratio between the number of electrified public center (unit) and the total number of public center (Unit) × 100%	%	The electricity share for health facilities and schools is between 70–100%. Set the target at 90%
12	Number of streetlights in the area	Streetlights are available every forty meters	unit	The target number of streetlights is one for every 40 m
13	Micro-credit possibilities available for connection	Number of microcredits available in the area	unit	At least one microcredit service is available
14	Share of population with primary school education	The ratio between the number of adult inhabitants with elementary school education (person) and the total number of adult inhabitants × 100%	%	Electricity is provided for the entire household.
15	Share of population with access to electricity	The ratio between number of electrified households (person) multiplied by average inhabitants per household and the total number of inhabitants	%	Electricity is provided for the entire households
16	Subsidies offered for electricity services	Number of electricity bills that are subsidized (Rp/yr) divided by the total number of electricity bills (Rp/yr)	%	Set as maximum 1%
17	Share of economically active children	Number of economically active children (person) divided by the number of children (person)	%	Set the maximum share of economically active children as 5%
	Environment			
18	Share of renewable energy in production	Gross electricity production from micro-hydro (kWh/yr) divided by total electricity production (kWh/yr)	%	Set the highest target as 100%

Table A1. *Cont.*

No.	Indicator *	How to Measure *	Unit	Target Level Determination **
19	Emissions of carbon dioxide from production	Gross electricity of MHP (kWh/yr), multiplied by emission factor (ton CO_2/kWh)	Ton CO_2/kwh	For Sustainable development, the target is set as 0 ton CO_2
20	Share of Electrified households where electricity has replaced other energy source for lighting	The ratio between the number of Households that use electricity for lighting (HH) and the total households (HH)	%	The target minimum is set as 100% for electricity as a source for lighting
21	Share of Electrified households where electricity has replaced other energy source for cooking	The ratio between the number of Households that use electricity for cooking (HH) and the total households (HH)	%	The target minimum is set as 50% for electricity as a source for cooking
22	Any serious environment impact identified	Survey identification	Yes/No	The PLTMH causes no environmental impacts
23	Extreme weather condition	Number of times the project disturbed by extreme weather	Times	The target set that there were no extreme conditions that would disrupt the operation of the MHPPs
	Institutional			
24	Share of staff with appropriate education	The ratio between the number of staff with technical background and the total staff	%	At least two staff members have technical skills. This study set minimum staff as many 50%
25	Staff turnover in organization	The ratio between the number of staff that leave and total staff	%	Staff turnover will have a negative impact. A minimum target is set to be no turnover
26	Number of years in business	Total number operation of MHP	Year	The operation time of MHP was approximately 66 months.
27	Share of non-technical losses	Total unpaid bills (Rp/yr), divided by total bills (Rp/yr)	%	The smaller, the better; the minimum value was set to be 0%
28	Level of satisfaction with energy services	The ratio between the number of electrified households that are satisfied and the total number of households	%	The more people satisfied, the better. This study set the maximum value as 100%
29	Auditing of financial reports on yearly basis	Number of times audited report on a yearly basis	times	Set the minimum target as one time audit in this study

* Adaptation from Ilskog (2008); ** Adaptation from Purwanto dan Afifah (2018).

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