Renewable Energy 93 (2016) 312—322

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Assessing the impact of techno socioeconomic factors on sustainability indicators of microhydro power projects in Indonesia: A comparative study

Widodo Wahyu Purwanto [a, *], Nok Afifah [a, b]

[a] Chemical Engineering Department, Faculty of Engineering, Universitas Indonesia, Depok 16424, Indonesia
[b] Centre of Appropriate Technology Development, Indonesian Institute of Sciences, Subang, Indonesia

ARTICLE INFO

Article history:
Received 11 September 2015
Received in revised form
9 February 2016
Accepted 22 February 2016
Available online 8 March 2016

Keywords:
Techno sosio-economic
Sustainability indicator
Electrification
Microhydro
Rural

ABSTRACT

A review of electricity access projects in rural areas reveals a number of unsustainable features. Each rural area can be very different with regard to the socioeconomic conditions and the dynamics between society and technology. This research is a comparative study to assess the impact of techno socioeconomic factors on the sustainability of two microhydro power projects. The assessment of sustainability projects was based on sustainable development indicators for rural electrification, considering technical, economic, social, environmental and institutional sustainability. The indicators were investigated through a survey. The results show that both projects performed poorly in the economical dimension and positively in other dimensions. The education background of microhydro power project-Rimba Lestari clients was relatively better than those of microhydro power project-Mendolo, in which the earlier project has higher sustainability in the institutional, social, and environmental dimensions. If the income of clients is better, microhydro power project-Mendolo, this would give better economic sustainability.

1. Background

Electricity is a vital factor for improving quality of life. Access to reliable and affordable electricity is a prerequisite for economic growth and poverty reduction. Currently, the responsibility for electrification in Indonesia is borne almost solely by the state-owned utility Perusahaan Listrik Negara (PLN), which owns and operates the country's entire transmission and distribution network, as well as a large proportion of the generation plants [1]. As of 2012, the electrification ratio of Indonesia is 74.4%, meaning there are approximately 25.6% of households without electricity from the total of 62 million populations [2]. The large number of unconnected houses is a regressive problem, because more than 80% of them are in rural areas where three quarter of Indonesian poor populations live [3]. The fragmented geography of the Indonesian archipelago, together with an uneven population distribution, has created problems for the extension of the nation's power grid [4].

Indonesia is endowed with abundant renewable energy resources, such as 75 GW of hydropower with small hydro projects accounting for 500 MW, 50 GW of biomass, 4.80 kWh/m2/day of solar energy, 3—6 m/s of wind energy and 3 GW of nuclear energy. The current installed capacity for all hydropower plants is approximately 4260 MW, of which small units contribute approximately 64 MW [5]. Considering this potential, the utilization of hydropower in Indonesia should be considered as the solution to solve the electricity problems faced by this country.

There are some alternative methodologies that are used for assessing off-grid electrification projects covering sustainability indicators [6]. Sustainability issues are now taken into consideration in all research involving development issues and evaluations in particular [7]. The World Commission on Environment and Development frequently quotes the definition of sustainability as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs,’ i.e., it concerns the distribution of resources between and among generations [8].

Lists of sustainable indicators prepared by different organizations [9,10] are valuable. The choice of an appropriate conceptual framework and corresponding indicators largely depends on the specific purpose of the analysis [11], i.e., how we define rural

* Corresponding author.
E-mail address: widodo@che.ui.ac.id (W.W. Purwanto).

http://dx.doi.org/10.1016/j.renene.2016.02.071
0960-1481/

energy sustainability in this specific context. Many of the suggested indicators are, however, very general in their design and therefore more suitable on a national or strategic level [12,13]. Sustainability is often linked with three pillars (economic, environmental and social) [9]. One or two additional dimensions are sometimes added when analyzing sustainability specifically associated with the rural sector [7,14].

Key Performance Indicators (KPI) was proposed to evaluate the performance of certain microhydro power projects in Sulawesi and Sumatera, Indonesia [15]. The same method was applied to analyze sustainability of the rural energy infrastructure of MHPP in Sulawesi, Indonesia [16]. This framework presented the sustainability in four dimensions, technical, social, environmental and economic, with 10 indicators. Each indicator was scored on a scale of -1 to $+1$, with $+1$ representing the best performance.

A more complete concept for assessing rural electrification projects is presented by Ref. [7]; it adds a fifth dimension, institutional, and has 39 indicators. The fundamental requirement for sustainability is that the services must be economically sustainable, which cover the tariff and promote economic development. The technical dimension focuses on maintaining the energy services during the economic lifespan of the project. The institutional sustainability covers issues of how the project is managed. The services must also be environmentally sustainable as defined by national or local regulations. The social/ethical dimension focuses on equitable distribution of the benefits offered by electrification [7,17]. This method was clearly applied and kept the stakeholders' participation in mind [6] via a survey, which provided more tangible results. In addition, the method can also capture qualitative factors, and it is flexible in that any factor that is not relevant can be removed and additional factors can be added for better assessment.

Some studies to assess the sustainability of rural electrification projects using the Ilskog framework have been previously conducted [16–18]. Ilskog and Kjellstrom [18] present an assessment of seven rural electrification areas in Eastern and Southern Africa using 31 of these indicators. Each indicator was scored on a scale of 1–7, with 7 representing the best performance. The use of ranking in this study is problematic because it can either reduce large absolute differences or exaggerate small absolute differences and be suggested to define target levels for the indicators [18]. The other study was performed to assess the sustainability of the San Benito Poite solar power project in Belize by considering the target level [19]. The results were measured against the target level or minimum level and determined to be positive if they fell within the range and negative if they fell outside the range. In other words, it is difficult to present an absolute sustainability value.

A large variety of business models for off-grid rural electrification can be categorized as market based public-private partnership, and community based, or the hybrid types of these models. Off-grid MHPP schemes in Indonesian rural areas are usually owned and operated by the rural community [20]. These are a form of technology transfer from the technology provider to the rural community as users. In acculturation of renewable energy technology (RET) into a rural community, the adopter needs sufficient time and resources, and the facilitator should have sufficient capacity to transfer it [4]. To understand possible 'sustainable energy' transformations requires attention to social theory, specifically to agency, structure and the interplay of power, contingency and practice [21]. An 'energy cultures' conceptual framework was built to understand the factors that influence energy consumption behavior [22]. Some studies were conducted to understand household electricity consumption and its driving factors under a variety of cultural backgrounds, including the societal and economic characteristics [23,24]. This means that the success and sustainability of the projects are related to the socioeconomic characteristics of the user, including the capacity of the facilitator, and this is supported by Ref. [25].

Nevertheless, there is no comprehensive study that demonstrates the importance of local driving factors in assessing off-grid electrification sustainability. To address that goal, this paper explores whether techno socioeconomic characteristic of a village community as the technology adopter impact the sustainability of microhydro power projects in rural Indonesia.

2. Method

This study comprises a descriptive survey of census results from customers and the management of MHPPs and a review of available written documentation. The respondents were deeply interviewed via a face-to-face rapport. The total number of respondents was 50 customers and 6 staff from each of the two MHPPs. The written documentation covers mainly operational data, client databases, and financial reports.

The survey was conducted in February–March 2014 for two microhydro power projects. MHPP-Rimba Lestari is in Tangsi Jaya Hamlet, Gunung Halu of West Bandung, West Java, while MHPP-Mendolo is in Mendolo Hamlet of Pekalongan, Central Java; the map is given in Fig. 1. This study wants to capture how social conditions related with sustainability so local language skills are very important to understand the essence of the interview. These projects were selected because of the similarity of their project characteristics, but they do have differences in ethnicity, language, and traditions. MHPP-Rimba Lestari was selected to represent Sundanese culture, while MHPP-Mendolo represents Javanese culture. Java, the majority ethnic population is Javanese and Sundanese, was considered as a location for the survey due to the author as interviewer has a background of both cultures. Other considerations are time constraints, financial limitation, and ease of access to the site.

2.1. West Bandung, West Java

West Bandung Regency lies between 6°,3 73′–7°,1 31′ South Latitude and 107°,1 10′–107°,4 40′ East Longitude. The total area of this regency is 1305.77 km^2, containing 165 villages. Its population is 1,572,806, and most of the population is Sundanese [26].

2.2. Pekalongan, Central Java

Pekalongan Regency is one of the regencies in Central Java Province, which is located alongside North Java Coast. Its location stretches along the equator between 6°–7°23′ South Latitude and between 109°–109°78′ East Longitude. It has a total extension of ±836.13 km^2. In this region, there are 285 villages with a total approximate population of 861,366. Most of the population is Javanese [27].

Assessment of the MHPP sustainability adopts a framework suggested by Ref. [7]. This study uses 29 sustainable development indicators. Determination of the sustainability indicators based on the preliminary survey to one MHPP in Subang, West Java and lesson learned from similar projects in Indonesia. The number/value of indicators is resulted from the survey and determined by equations in the Appendix. The score of a sustainable development indicator (SDI) is determined by comparing the value/numbers of indicators to their level targets. The target level is a measure of sustainability. The target level for each indicator is defined according to electrification project literature, mainly from the best practice of microhydro projects. The value of each target level is given in Table 4 (Section 3.2).

For the minimum target level, if the values of indicators reach