Barrier Analysis for Deployment of Renewable Energy Mini-grids in Myanmar Using AHP

Masako Numata*, Masahiro Sugiyama*, Gento Mogi

*Institute for Future Initiatives, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033 Japan,

bDepartment of Technology Management for Innovation (TMI), School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033 Japan

E-mail: m.matsuo-numata@05.alumni.u-tokyo.ac.jp

Abstract. Energy access is still a challenge for many countries, as demonstrated by Sustainable Development Goal (SDG) 7. Though the government of Myanmar set a target of 100% electrification by 2030, currently only less than half of households are connected to national grids. To accelerate electrification, decentralized approaches should be considered more. Mini-grids are an effective option that can fill the gap between a solar home system and a national grid. However, many of the existing mini-grids in Myanmar are powered by diesel generators. In rural areas, diesel fuel is much more expensive than in urban areas because of transportation cost. Under this condition, mini-grids powered by solar photovoltaics and batteries are already cost-competitive with diesel generators. Nevertheless, the deployment of mini-grids powered by renewable energy is still slow. In this study, we analysed barriers to the deployment and the prioritization of these barriers. We conducted a questionnaire survey with stakeholders using the analytic hierarchy process (AHP) to identify the prioritization of each barrier factor. To see tendencies, we used k-means for clustering results. The results showed that opinions were divided among stakeholders. There is no single silver bullet for the mini-grids and overcoming the barriers needs steady work.

1. Introduction

Among the United Nations SDGs, “Goal 7: Affordable and Clean Energy” states that access to electricity is still an issue worldwide [1]. The global population without access to electricity finally dropped to less than 1 billion, 840 million, in 2017 [2]. At the same time with improving access to electricity, it should be achieved by renewable energy rather than by fossil fuels. Sub-Saharan Africa attracts the most attention because of the large population that lives without access to electricity. However, in Asia, Myanmar has nearly the same electrification rate as Sub-Saharan Africa [3]. The Myanmar government has set a target of 100% electrification by 2030 [4] and the number of households connected to the national grid has grown from 34% in 2016 [5] to 42% in 2018 [6]. Still, more than half of total households lack access to electricity. As of 2017, only 24.7% of households in the rural area were connected to the national grid, in contrast with 42.2% in urban area [7]. The rural electrification is an urgent matter for universal access in Myanmar.

Mini-grids have recently begun to attract attention as being a bridge between household electrification methods such as solar lanterns and home systems and large-scale national grids [8,9].
According to the estimation by IRENA, the national grid would supply the 37% of additional power source to achieve universal energy access in developing Asian countries and then mini-grids would supply 44% of it [10]. In Myanmar, the national grid accounts for about 13% of the source of electrification in rural areas and mini-grids account for almost same with 13% though the national grid covers over 80% of the electrification in urban areas [7]. Mini-grids could contribute more for rural electrification.

In rural areas, roads are often not well-developed, and fuel prices are higher than urban area because of the transportation cost. In areas where diesel fuel is expensive, solar photovoltaics (PV) backed up with batteries are estimated to be cost-competitive with diesel generators as a power source for mini-grids [11]. However, in Myanmar, diesel generators are still dominant as a power source of mini-grids. It supplies power in 13,000 villages, whereas micro-hydropower, biomass, and solar energy are used as power sources in 2,400, 1,200, and 150 villages, respectively [12]. Various international aid agencies promote the introduction of mini-grids combining solar power and storage batteries [13,14], but mini-grids powered by renewable energy are still not expanding rapidly enough.

Myanmar is committed to "implement mitigation actions in line with sustainable development needs" in its Intended Nationally Determined Contributions (INDCs) to the Paris Agreement [15]. Also, Myanmar is a resource-rich country in terms of renewable energy, as estimated that 27GW for the potential capacity of solar power, 0.23GW for small and medium hydropower, and 100GW for large-scale hydropower [16,17]. Those abundant resources should be utilized for mini-grids as well as large scale generation [18].

In a prior study [19], we constructed a barrier typology based on discussions with stakeholders (international organizations, private companies, non-governmental organizations, and field researchers) and a bibliographic survey. In this study, we conducted a questionnaire survey of stakeholders based on an analytic hierarchy process (AHP) to analyse the priority of each barrier. The results were clustered using K-means methodology to see tendencies.

2. Barrier factors

We identified the barrier factors below in prior study [19] and chose 4 of them from each category to analyse prioritization in this study. The factors without citations were based on stakeholders’ interview.

2.1. Social/cultural barriers
S1: Negative externalities caused by international organizations
Existing local mini-grid businesses were mostly non-commercial and social welfare purpose, but the introduction of business models has changed the mindsets of operators and/or customers. Then it caused to break trust relationship between operators and customers.

S2: Ethnic or language difference
Residential areas with minor ethnic groups overlap with off-grid areas. Language and cultural differences hinder project implementation.

S3: Education gap
The educational gap hinders financing for local companies from international organizations that provide lower capital costs. The language barrier (non-English speakers) is part of the reason.

S4: Perception of inferior quality [20,21,22]
Especially in the early stages, it is difficult to offer a 24-hour, seven-days-a-week service.

2.2. Regulatory barriers
R1: Lack of regulatory framework [23,24,25]
There have not been regulations for mini-grids yet though the off-grid mini-grid legal system has been developed under the DRD and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), and was submitted to the Ministry Of Electricity And Energy (MOEE) [26].

R2: Lack of technical standards[24,27,22,28] Without technical standards or codes, it is difficult to maintain a certain level of quality for mini-grids. Moreover, rules for industrial waste, tar, and lead-acid should be established for sustainable development.

R3: Institutional capacity[29,30,22,18,25] Institutions are attached to their current work, and it is difficult to coordinate priorities between ministries and/or other institutions.

R4: Threat of grid extension [30,31,22,32,33] Mini-grid operators do not know what happens after the national grid reaches their customers’ villages.

2.3. Technical barriers
T1: Technology gap Indigenous technologies were sometimes different from international standards in many aspects, but it should not be flatly dismissed.

T2: Lack of interoperability with national grid [22] Mini-grids might be designed without connections to the national grid due to the absence of technical rules.

T3: Intermittency [27,22,25] The energy supply fluctuates over the day or season (typical for intermittent renewable energy sources).

T4: Operation and maintenance (O&M) [34,22,29] Appropriate operation and maintenance often fail to be maintained.

2.4. Economic barriers
E1: Small market size [24,35,30,25] The Myanmar market is in its initial state, despite the rapid development of the international market.

E2: Low demand [24,35,30,29] Creating demand in addition to basic use, such as for lighting, is still a challenge for operators.

E3: Tariff structure: cost-revenue gap [30,27,22,29,32,33] The design of the tariff structure affects the business model.

E4: Fee collection uncertainty [21,30,36,32] Operators must ensure that customers pay for the electricity, sometimes using new technologies such as Pay As You Go.

2.5. Financial barriers
F1: Access to financing [34,23,29,27,25,28] Due to the lack of familiarity with project financing through a financial institution, obtaining loans is difficult. Moreover, immature stock and debt markets limit the options for financing arrangements.
F2: High cost of capital [24,23,34,22,25,28]
Even if funds are arranged, financing costs are high. In the case of loans, interest rates are higher and loan fees are costly.

F3: Insufficient customers’ capital [24,34,22]
Customers’ financing methods are also limited. Microfinance is relatively new, and unofficial money lenders are expensive.

F4: Currency risk [34,37]
If financing is based on foreign currency, companies are exposed to exchange rate risks because their revenue and expenses are in different currencies.

3. Methodology

3.1. Analytic hierarchy process
The Analytic hierarchy process (AHP) is a decision-making method developed by Saaty in the 1970s and has been widely used since then [38,39,40]. A problem is hierarchically decomposed into key factors and each factor is compared in pairwise. Then the ranking of each factor is defined. The procedure is as follows [41];

(1) Model the problem considering the hierarchy of the key factors
(2) Determine the importance of the elements by comparing pairs based on knowledge and emotion, and score them on a five-point scale from 1 “equal importance” to 9 “extreme importance”
(3) Calculate the priority of each factor based on the scores

The result obtained is a square matrix (we chose 4 factors so here 4 × 4) with a diagonal component of 1. It is necessary to check if the obtained results are consistent; this is done using the random index (0.89 for a matrix of n = 4) [42]. The consistency ratio is set to 0.1 as suggested in many papers [41,43,44] and the only answers whose consistency score are lower than 0.1 are used for the analysis.

There are various multi-criteria decision-making methods that can be applied to energy planning [45,46], but we chose AHP because it is used widely and is easy to understand. AHP has been applied to barrier analysis for renewable energy development in Nepal [47]; for small-scale power sources in Sri Lanka [48]; for the adaptation of renewable energy in India [25]; for cooking stoves and biogas fermenters in rural Thailand [49]; for energy efficiency in small-scale industries in India [50]; and for cleaner production by small and medium-sized enterprises (SMEs) in China [51]. Also, it has been applied to other energy topics; the prioritization of the energy technologies to allocate research budget [52]; of decentralized power in Iran [53] and Jordan [54]; to develop energy in rural China [55]; and to select suitable locations for wind power generation [44].

In this study, we applied AHP to analyse the main barrier to the dissemination of mini-grids powered by renewable energy in Myanmar. A questionnaire survey was conducted during the period between September 2018 and February 2019. Questionnaires were sent by email or passed in person. Table 1 shows the list of respondents. Energy-related stakeholders were selected from among various occupations. We sent 53 and received 42 answers to analyse.

| Table 1. Number of respondents of the survey |
|---------------------------------------------|
| No. of respondents (individuals) | Sent | Answered |
| NGO (international + local) | 8 | 8 |
| Government | 8 | 7 |
| Private Company | 25 | 15 |
| Media | 2 | 2 |
| Academia | 6 | 6 |
| International organization | 4 | 4 |
| **Total** | **53** | **42** |
3.2. K-means

K-means is a non-hierarchical clustering algorithm. The values are partitioned to the nearest cluster which has the nearest mean value within the cluster. The number of clusters $k$ is given. The elbow method was used to investigate the number of clusters in this study [56].

4. Results

In AHP, a problem is hierarchized as shown in Figure 1. We identified four factors for each category prior to the questionnaire survey. Respondents were asked to compare one factor to another factor within the same category and continued to other categories. Only answers passed consistency check were used to analyse.

The number of clusters was examined using the elbow method. However, since most of the barrier categories did not display a clear elbow shape, the number of clusters was set to three based on the balance with the number of valid answers. For all barrier categories, the number of clusters was set as the same in a way that was easy to understand. Within each category, the scoring results obtained from the respondents were clustered into three groups and analysed. After the consistency check using the consistency ratio 0.1, the number of valid answers was 17 for regulatory category, 13 for the social and cultural category, 12 for the economic category and for the technical category, and 8 for the financial category of 42 responses.

4.1. Social/cultural barriers

Figure 2 shows the clustering results of priorities of the social and cultural barrier factors. The valid responses were divided into three clusters using k-means, and the weight of each barrier factor within the same cluster was averaged. The vertical axis in the figure shows the averaged value of prioritization score for each factor. In the social and cultural category, Clusters 1 and 2 have six valid responses each. “S4: Perception of inferior quality” was considered the most important factor in Cluster 1, and "S3: Education gap" the most important in Cluster 2. These factors are the most important by far in their Clusters (S4 has a weight of 0.63 in Cluster 1 and S3 has a weight of 0.60 in Cluster 2). Other barrier factors, S1 and S2 are relatively less prioritized in those two majority clusters. Minority group, cluster 3 shows a different tendency.
4.2. Regulatory barriers

Figure 3 shows the clustering results of priorities of the regulatory barrier factors. Cluster 1 is the majority and "R3: Institutional capacity" was the most prioritized. In Myanmar, electrification by the extension of the national grid is under the jurisdiction of the MOEE, and electrification by off-grid components such as SHS and mini-grids are under the jurisdiction of the Department of Rural Development of the Ministry of Agriculture, Livestock and Irrigation (DRD). The respondents commented that the coordination between the ministries was not smooth.

4.3. Technical barriers

Figure 4 shows the results of the technical barriers. Cluster 1 includes five valid answers, slightly more than other clusters which have the same number of answers. Cluster 1 prioritizes "T1: Technology gap" among factors. The tendency of prioritization is different among clusters. However, “T3: intermittency” is relatively less prioritized in all clusters.
4.4. Economic barriers

Figure 5 shows the clustering results of the priorities of economic barrier factors. Cluster 1 prioritizes "E1: Small market size" (weight of 0.33) and "E3: Cost-revenue gap" (weight of 0.31). Cluster 2 prioritizes "E2: Low demand" (weight of 0.46) and E3 (weight of 0.41). E3 is evaluated as relatively important in common by the top two clusters.

4.5. Financial barriers

As a result of the consistency check, many responses in the financial category were inconsistent. This result indicates that it is difficult to decide the main barrier factor in the financial category.

5. Discussion and Conclusions

Results were different by categories. Some categories showed high agreement and other categories not. Clear prioritization was not observed unlike other countries; e.g., the threat of the national grid
extension in India [22]. The results indicate that there are many kinds of barriers to the deployment of renewable energy mini-grids in Myanmar, and Myanmar is still at a stage where the many barriers remain still to be tackled.

In the social and cultural category, the opinions were divided among respondents and "S4: Perception of inferior quality" and "S3: Education gap" were evaluated as the greatest barrier factor. The solar and hydropower are intermittent by dry/rainy seasons, and day/night in case of solar. Solar PV needs back up such as batteries or diesel generator to secure its power supply. Micro hydropower needs to be designed carefully with a decrease in flow during the dry season in mind. It is important that consumers understand the characteristics of renewable energies. It leads to decrease dissatisfaction when electricity shortage occurs.

The education gap has an impact on mini-grids business. The school enrolment rates are different between the urban and rural area in Myanmar. The high school enrolment rate is 60% in the urban area though it is 39% in the rural area in 2017 [7]. International donor organizations have entered Myanmar and they have provided soft loans. However, well-developed documents e.g., excel-based financial plan, are needed to access these low-interest loans and it is difficult for existing developers/operators to prepare. The soft loan provider should consider to whom they would like to provide and take measures to make their loan easier to use such as consultation service.

In the regulatory category, a considerable degree of agreement about institutional capacity was observed. The power sources generating 30 MW or more, and any power generation connected to the national grid are under the jurisdiction of the MOEE according to The Electricity Law 2014 [57]. Power generation under 30 MW without connection to the national grid are under the jurisdiction of the state and regional governments. However, the off-grid electrification of the National Electrification Project (NEP) funded by the World Bank [58] is being promoted by the DRD. Off-grid components are supposed to be installed where the national grid will not reach in certain years. Therefore the coordination between ministries is needed. However, it seems not going smoothly. The regulatory guideline was drafted by DRD and circulated in the second half of 2018 [26] and has not published yet.

Under the technical category, the technology gap was evaluated as most important by the majority group. Before its democratization of 2011, Myanmar had been closed to foreign countries and the indigenous technology in small-scale hydropower and biomass has been developed. It sometimes differs from current international practices. However, there have been many cases that high-level technology was installed and discarded after a breakdown without repair. In a rural area, it takes a few days to arrange engineer from an urban area and to obtain repair parts. Therefore, those difficulties discourage to keep using. When technology is installed, it should be considered if it is an affordable level for operation and maintenance in the area.

In the economic category, the cost-revenue gap was evaluated as relatively important by the two major clusters. The importance of the cost-revenue gap shows how difficult to balance tariff and customers’ ability to pay. Unlike diesel generator, renewable energy mini-grids are capital intensive, and developers are intended to be paid back by tariffs. The rural consumers' ability to pay is often limited and consumers may refrain from using electricity if a tariff is felt as too expensive. It is necessary to balance the consumers’ ability to pay and the recovery of cost. Also, the range of acceptable tariff depends on the reference price. If villagers previously relied on diesel power, the tariff of solar-powered mini-grids could be felt cheaper. If villagers refer the subsidized national grid tariff, villagers answered that they would not like to pay tenfold tariff.

There are some limitations in this study. Ideally, it is desirable to define prioritization among categories following to prioritization of the factors. However, since the paper-based and e-mail based questionnaire survey was conducted, it was difficult to conduct superior prioritization of categories which needs the calculated results of prioritized factors. We placed emphasis to collect opinions of various stakeholders. We used the consistency ratio of 0.1 which is suggested in most of the extant literature, but some of the prior studies mentioned the range of consistency ratio from 0.1 to 0.2 [59,60]. Sensitivity to consistency ratio could be analyzed for further research.
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