Proceedings of the 1st Faculty of Industrial Technology International Congress
International Conference
Bandung, Indonesia, October 9-11, 2017
ISBN 978-602-53531-8-5

Off-grid Renewable Energy Program for Sustainable Rural Electrification in Indonesia

Ilyas Taufiqurrohman
Energy Change Institute, The Australian National University (ANU), Canberra - AUSTRALIA
Corresponding author e-mail: u6295529@anu.edu.au

Abstract

There are many rural areas in Indonesia without electricity, especially in remote islands. It is challenging to provide electricity to remote areas through the electrical grid from existing power plants. One of the solutions for rural electrification is providing diesel generators, but it has an issue with the fuel shortage and negative impact on the environment. To overcome the issue related to the lack of rural electrification and dependence on fossil fuel, the off-grid renewable energy system can be the appropriate solution. There is an enormous potential of renewable energy resources, such as solar energy, micro-hydro, and wind energy. These resources are available as local energy resources in remote areas and can be utilized for generating electricity. However, there is another issue related to the sustainability of rural electrification program. For example, many infrastructures that have been built for rural electrification are not able to operate for long term period. This paper analyses factors that hamper the implementation of sustainable rural electrification based on renewable energy and discusses how to involve local community participation to ensure a sustainable program. The application of rural electrification based on renewable energy not only just to provide the electricity and increase rural electrification rate, but it also needs to provide the program that can be used by the local community to support their productive activities.

Keywords: off-grid system, renewable energy utilization, sustainable rural electrification, local community participation, community empowerment

1. Introduction

There is a significant gap in the electrification rate between urban and rural areas in Indonesia. It has been reported that Indonesia's national electrification rate is 81% with the ratio of urban electrification is 94%, but the ratio of rural electrification is only 66 % (World Energy Outlook, 2015). There are many rural areas without electricity because they are in remote areas which are challenging to access. It is challenging to bring electricity to rural areas through the electrical grid from existing power plants. Most of the existing power plants in Indonesia are still generated from fossil fuel, such as coal and oil (Tharakan, 2015). Extending electrical grids to transmit electricity from those existing power plants to remote areas can be very expensive and inefficient. Electrical grids from existing power plants, which have high electric capacity transmission, are not efficient for rural electrification because low electricity demand in the rural areas. A suitable solution for the problems related to rural electrification would be to utilize local renewable energy resources by implementing the off-grid system in the remote areas.

Indonesia has a huge local potential in relation to renewable energy resources that can be used for generating electricity. For instance, Indonesia has potential of hydropower about 75,000 MW, and potential of wind energy about 970 MW, potential of solar energy about 4.8 kWh/m²/day, potential of biomass about 32,654 MWe, and potential of geothermal about 12,386 MWe (Agency for the Assessment and Application of Technology, 2016, p. 18). However, the utilization of renewable energy resources for generating electricity is still low. In 2016, only 2% of electricity was generated from the total potential of all available renewable energy resources in Indonesia (Agency for the Assessment and Application of Technology, 2016). Rural areas without access to existing electrical grids can utilize the renewable energy resources that available in their areas. These resources can be categorized as their domestic energy resources which mean accessible and non-vulnerable to supply.

This paper discusses how the implementation of off-grid renewable energy program can provide the sustainable rural electrification. The following section, Section 2 introduces the objectives of this paper to provide the off-grid renewable energy program as the appropriate solution to rural areas which do not have access to existing electrical grids and to discuss the active participation of local community as the key factor to achieve the sustainable off-grid renewable energy. Section 3 provides the methods that are used in this paper. Then, Section 4 discusses and analyses in terms of issues of previous off-grid renewable energy projects for rural electrification, the application of off-grid renewable energy program, and how to understand the local community needs and involve their active participation in the off-grid renewable energy program. The last section, Section 5 is the conclusion of the discussion.

2. Objectives

The paper has following objectives:

- Provides that the application of off-grid renewable energy can be the appropriate solution for rural electrification to remote areas which are difficult to access.
- Discusses how to involve local community participation to ensure a sustainable program for rural electrification based on renewable energy.

3. Methods

We use literature-based to collect information and analyse it to address the objectives in Section 2. There are procedures that we do before we get the results and conclude it.

- Analyses factors that hamper the application of sustainable rural electrification based on off-grid renewable energy.
- Identifies factors that are important in the implementation of off-grid renewable energy program in rural areas.
- Identifies the needs of the local community in rural areas to empower the society through off-grid renewable energy program.

4. Analysis

4.1. Issues of Off-Grid Renewable Energy for Rural Electrification

Providing electricity to remote areas in Indonesia is a very challenging task. Blum et al. (2013) suggest that because of the challenging geographical nature of Indonesia, a decentralized off-grid is the appropriate technology for rural electrification, especially for remote and rural areas in mountainous areas or on isolated islands. This off-grid systems can be supplied by fossil fuel or renewable energy. Most of off-grid systems for rural electrification are still supplied by diesel generators (Blum et al., 2013). Diesel generators are mostly used in rural areas because of their long track-record for generating electricity and the communities are more familiar with this technology, it makes diesel generators as a standard for rural electrification solution (Schmidt et al., 2013). However, this solution cannot be used as the sustainable solution for rural electrification because fossil fuel is depletable resource and fossil fuel not only generates electricity, but also produces greenhouse gas emissions. Therefore, by shifting diesel generator to the renewable energy system, it can increase the rural electrification rate and at the same time not produce the greenhouse gas emissions.

However, there are some issues from previous rural electrification projects for the application of the off-grid renewable energy. Rural electrification programs by the utilization of renewable energy resource tend to be characterised by scattered low-income consumers, and high initial capital costs (Urmee et al., 2008). These are the reasons why most of the utilization of renewable energy for rural electrification to be funded by either the government or donor organisations. Over dependence on donors and the limited availability of financing can be the factors that hamper the implementation of sustainable rural electrification based on the off-grid renewable energy. Institutional weaknesses are also identified as factors that affect the off-grid renewable energy program (Urmee et al., 2008). If local institutions that has the responsibility to manage the off-grid system have no management capacity to administrate the services and no ability to handle technical issues, it will be a big problem (Feron, 2016). All these factors are the reasons why many off-grid renewable energy infrastructures that have been built for rural electrification are not able to operate for long term period. To provide sustainable rural electrification through the off-grid renewable energy, we have to address these issues.

4.2. The Implementation of Off-Grid Renewable Energy Program

The provision of electricity in Indonesia is handled by Perusahaan Listrik Negara (PLN), State Electricity Company. PLN is a state-owned company which has a monopoly to responsible on electricity distribution across Indonesia. The Ministry of Energy and Mineral Resources has the responsibility as the policy making body and regulator for PLN and other ministries are also stakeholders in the electricity sector (Schmidt et al., 2013). Since 2009, Indonesia has opened the market of power generation for competition (Schmidt et al., 2013). This policy is taken by the government to increase the capacity of electricity generation and to fulfil the growth of annual energy demand, so small scale Independent Power Producers (IPPs) can produce electricity, but they are still required to sell the electricity to PLN for distribution, only rural electricity cooperatives can generate and distribute electricity independently (Schmidt et al., 2013). Figure 1 shows a schematic diagram of government and industrial stakeholders in the Indonesian electricity sector. To encourage the implementation of off-grid system and involve the participation of local community in rural areas, this system can be done in cooperatives.

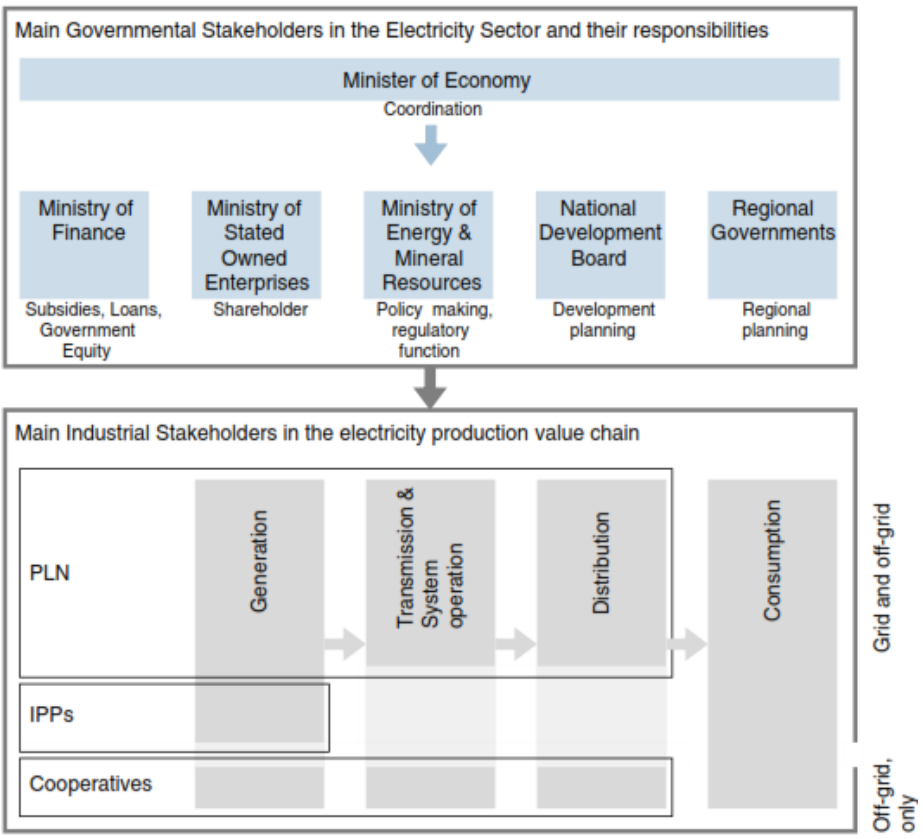

Fig. 12: Governmental and industrial stakeholders in Electricity Sector. (Schmidt et al., 2013)

Off-grid renewable energy program needs to consider the potential local energy resources in the specific areas. It means that the government cannot generalize to implement the rural electrification by only using single solution, such as providing the photovoltaic system to all rural areas. For example, if there is a potential of micro-hydro in that areas, it should generate electricity by implementing micro-hydro power plants. Micro-hydro power plants are already the proven technologies which are more reliable and require less maintenance rather than other renewable energy resources, such as solar energy or wind energy (Veldhuis and Reinders, 2015). However, micro-hydro is only available in the mountainous areas or area that has stable water flow with different elevation. For the areas without the potential of micro-hydro, photovoltaic system can be the solution because there is a huge potential of solar energy across Indonesia. Regarding the implementation of off-grid PV system, Table 1 describes the indicators for the sustainability of off-grid PV system (Feron, 2016). These indicators can be used to qualitatively evaluate the sustainability of the program. Therefore, the renewable energy program can be implemented by considering the availability of local renewable energy resources in rural areas.

Table 5: Indicators for the sustainability of off-grid PV system (Feron, 2016)

Institutional	Economic	Environmental	Socio-Cultural
Stability (durability) and long-term vision	Cost effectiveness	Environmental awareness	Accessibility (disparity, equity)
Regulation, standards and enforcement	Reliability	Environmental impact	Social acceptance
Decentralization and openness to participation	Funding (initial investment; operation and maintenance)		Accuracy
Adaptability (ability to meet future needs)	Contribution to the income of users		Cultural justice
Expert know-how			

There is an issue related to the technology of off-grid renewable energy system that can be identified as unfamiliar technology to rural inhabitants. Most rural inhabitants usually use a generator based on diesel fuel. The technology which is used in the off-grid renewable energy system is totally different from a diesel generator. If local communities in rural areas are not ready to use this technology, utilization of renewable energy cannot be a sustainable solution for rural electrification. In order to overcome this problem, an adequate training and support system need to be provided to rural inhabitants. A good example of implementing the program for the utilization of renewable energy is demonstrated by Cinta Mekar Village, Subang, West Java. Cinta Mekar Microhydro Power Plant Project has been in operation since 2005 and it became the prototype for providing rural electrification based on renewable energy because the project, which was initiated by IBEKA, a Jakarta-based NGO, has successfully involved the local community in the maintenance of micro hydro power plant (Utomo, 2015). IBEKA also provides rural electrification based on renewable energy not only to fulfil household electricity, but also encourage the local community to use electricity for supporting their productive activities, such as small enterprises and domestic industries. By eliciting active participation of rural inhabitants in the implementation of renewable energy, it can make them become more aware and expand their knowledge and responsibility in maintaining the operation of the infrastructure over long periods of time. This can be achieved by educating rural inhabitants in terms of understanding the technology used for renewable energy power plants before building the infrastructure, and then providing them with knowledge about how to operate and maintain this system. Therefore, the technology of renewable energy system can be implemented appropriately in rural areas.

A further issue that should be considered relates to the cost of the renewable energy infrastructure. Renewable energy power plants require a higher investment cost rather than fossil fuel power plants (U.S. Energy Information Administration, 2016). For example, photovoltaics system has a high investment cost with a low conversion rate from solar energy to electrics, and the system still requires battery units for saving energy (Sandhu and Thakur, 2014). More solar panels and batteries need to be implemented in solar power plants to make the system robust, but this infrastructure also requires more funding. However, there is a trend in the photovoltaics systems which have progressively low cost and the investment cost of solar PV can be more affordable (Pauser et al., 2015). Another solution that is provided by the government for rural electrification is diesel generator. However, local communities still need to buy diesel fuel to produce electricity for their daily use and consequently, the diesel generator has a high operational cost (Blum et al., 2013). There are also several issues in relation to fuel shortage and the higher price of fuel because the fuel comes from outside of the rural areas. As a result, operational problems may arise depending on the availability of stocks of diesel fuel in rural areas. In contrast, renewable energy, such as solar energy is the local resource that are available in rural areas. There is no needed to import fuel to operate a renewable energy system, but local communities in rural areas still have a responsibility to pay a fee for maintaining the infrastructure. The utilization of renewable energy, such off-grid photovoltaic system is more competitive than diesel generator in economic terms (Blum et al., 2013). Hence, the off-grid renewable energy system has a lower operational cost than a diesel generator.

4.3. Local Community Needs and Their Active Participation

To achieve sustainable rural electrification based on renewable energy resources not only depend on affordable cost, the implementation of appropriate technology, and understanding the technology, but also requires more attention to social, cultural and political issues in the rural areas. Every community has their own characteristics, included different social and cultural attitudes, failure to appropriately address these socio-cultural and policy dimensions can also cause failure in the implementation of rural electrification based on renewable energy which means wastage of resources and time (Urmee and Anisuzzaman, 2016). It is very important to understanding the community in the rural areas as the subject of the rural electrification, not only as the object of the program. Therefore, policies and programs related to the implementation of rural electrification should fulfil local community needs as a main target and involve their active participation in the programs.

Figure 2 shows the framework for integration of social, cultural, and policy issues regarding the off-grid renewable energy program for rural electrification. This framework also considers some aspect regarding technology and institutional, but more focus on social, cultural, and policies dimension to provide the sustainable rural electrification program (Urmee and Anisuzzaman, 2016).

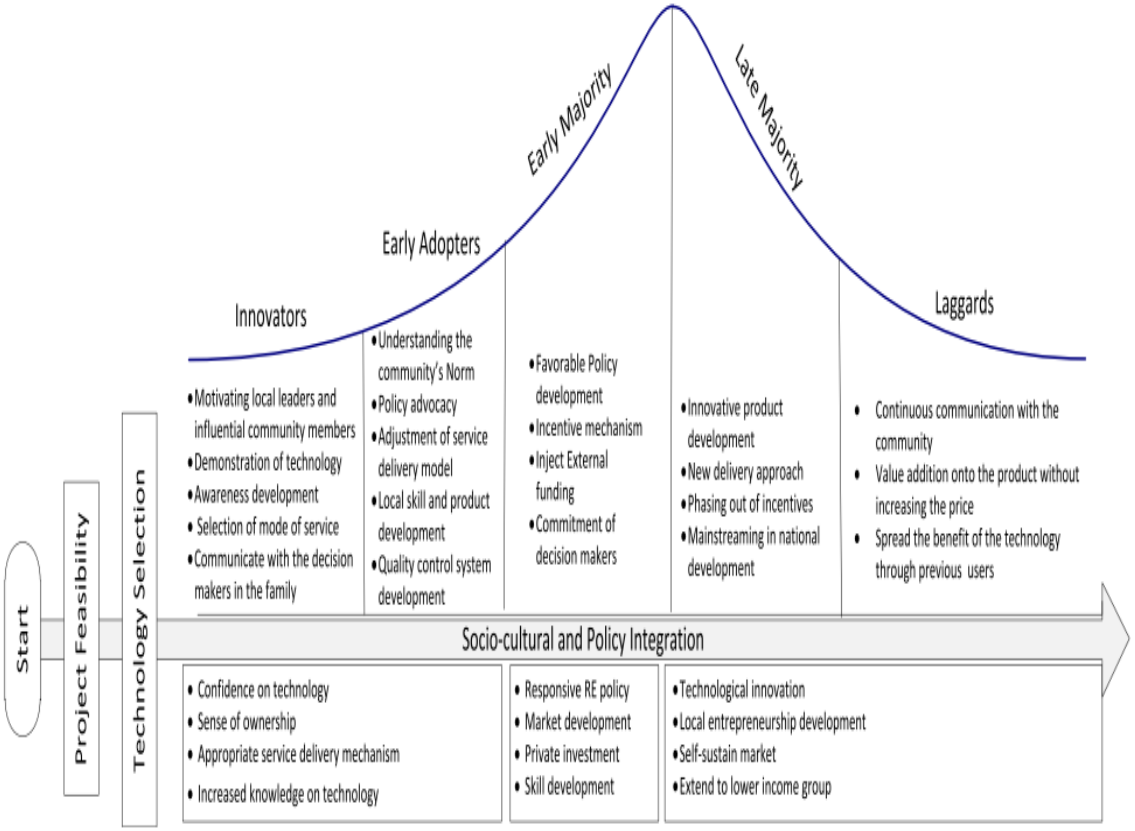

Fig. 13: Framework for integration of social, cultural and policy issues in an off-grid rural energy delivery program (Urmee and Anisuzzaman, 2016)

The implementation of rural electrification not only to provide the electricity in rural areas and increase the rural electrification rate, but it also needs to provide the program that can be used by local community to support their needs, especially for the productive activities. Understanding the community needs is the main point to encourage active community participation. For development projects, such as rural electrification programs, active community participation is the key process where advantages not only receive the benefits directly of the project, but also has an impact on the direction and execution of the project (Urmee and Anisuzzaman, 2016).

Access to the electricity is the important factor in the economic and social development. The off-grid renewable energy program for rural electrification is not only used to provide electricity for the household needs, but also provide electricity to support their economic activities. Therefore, off-grid PV system can be used to support their productive activities and increase their welfare.

5. Conclusion

The off-grid renewable energy program can be the sustainable solution for rural electrification in Indonesia. There are many rural areas without access to electricity due to the challenging geographical nature of Indonesia. Indonesia has a huge potential of renewable energy resources, such as micro-hydro and solar energy are available as the local energy resources. The off-grid renewable energy system can be implemented appropriately in rural areas by analysing the potential renewable energy resources in the regions. By eliciting active participation of rural inhabitants in the off-grid renewable energy program, it can make them become more aware and expand their knowledge and responsibility in maintaining the operation of the infrastructure over long periods of time. It can be achieved by educating rural inhabitants in terms of understanding the technology and assisting them with management capability to handle the infrastructure. Another key factor is providing the empowerment program to the local community that can encourage and assist them to use electricity for supporting their productive activities, such as domestic industries. Therefore, the sustainable rural electrification not only just provides electricity to fulfil the household need and increase national electrification rate, but also has to support their social and economic life, then increase their welfare.

6. References

Agency for the Assessment and Application of Technology, 2016. Indonesia Energy Outlook 2016, available at: http://repositori.bppt.go.id/index.php?action=download&dir=_data%2FDownload%2FOUTLOOK+ENERGI+2016&item=BPPT+-+Outlook+Energi+Indonesia+2016.pdf&order=name&srt=yes&lang=en, accessed on April 15, 2017.

Blum, N. U., Sryantoro, W. R., Schmidt, T. S., 2013. Rural Electrification through Village Grids—Assessing the Cost Competitiveness of Isolated Renewable Energy Technologies in Indonesia. Renewable and Sustainable Energy Reviews, 22, 482-496. doi:10.1016/j.rser.2013.01.049.

Feron, S., 2016. Sustainability of Off-grid Photovoltaic Systems for Rural Electrification in Developing Countries: A Review. Sustainability, 8(12).

Pauser, D., Fuente, K., Djerma, M., 2015. Sustainable Rural Electrifcation. State University of New York College of Environmental Science and Forestry.

Sandhu, M., Thakur, T., 2014. Issues, Challenges, Causes, Impacts, and Utilization of Renewable Energy Sources - Grid Integration. International Journal of Engineering Research and Applications 4 (3), pp. 636-643.

Schmidt, T. S., Blum, N. U., Sryantoro, W. R., 2013. Attracting Private Investments into Rural Electrification — A Case Study on Renewable Energy Based Village Grids in Indonesia. Energy for Sustainable Development, 17(6), 581-595. doi:10.1016/j.esd.2013.10.001.

Tharakan, P., 2015. Summary of Indonesia's Energy Sector Assessment. Asian Development Bank, available at: https://www.adb.org/sites/default/files/publication/178039/ino-paper-09-2015.pdf, access on April 15, 2017.

Urmee, T., Harries, D., Schlapfer, A., 2008. Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific. Renewable Energy, vol. 34, no. 2, pp. 354-357.

Urmee, T., Anisuzzaman, Md., 2016. Social, cultural and political dimensions of off-grid renewable energy programs in developing countries. Renewable Energy, vol. 93, pp. 159-167.

U.S. Energy Information Administration, 2016. Annual Energy Outlook 2016 with Projections to 2040, available at: https://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf, accessed on July 10, 2017.

Utomo, S., 2015. Improving Rural Electrification in Eastern Indonesia through Institutional Capacity Development. International Institute of Social Studies.

Veldhuis, A. J., & Reinders, A. H. M. E., 2013. Reviewing the Potential and Cost-Effectiveness of Grid-Connected Solar PV in Indonesia on a Provincial Level. Renewable & Sustainable Energy Reviews, 27, 315-324. doi:10.1016/j.rser.2013.06.010.

World Energy Outlook, 2015. Electricity Access Database, available at: www.worldenergyoutlook.org/media/weowebsite/2015/WEO2015Electricityaccessdatabase.xlsx, access on April 15, 2017.