Resilience Development Initiative

Overview of Renewable Energy-Based Village Grids (RVGs) in Indonesia

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Summary

To reach 100% electrification, Indonesia must overcome energy poverty in rural locations. Renewable Energy-based Village Grids (RVGs) based on solar photovoltaic (PV), microhydro, and biomass have been established in numerous villages. RVG projects bring the advantages of reduced pollution, enhanced prosperity, and gender equality. However, some projects still encounter inequity and other challenges that obstruct long-term sustainability. This article provides some recommendations to support the deployment of RVGs in Indonesia.

Keywords: electricity, mini-grid, village, solar, hydro, biomass

Introduction

As an archipelagic state with numerous remote areas, Indonesia faces a challenge of energy inequity. In March 2024, The Ministry of Energy and Mineral Resources (MEMR) recorded a total of 112 villages that still had no access to electricity. However, the national electrification ratio is targeted to reach 100% by 2024 (Putra, 2024). Besides grid extension to connect villages with existing main grids, it can be achieved by harnessing renewable energy potential in each village to create mini-grids (Wirawan & Gultom, 2021). The idea of renewable energy-based village grids (RVGs) aligns with the country's goal to reduce greenhouse gas (GHG) emissions up to 41% by 2030 and is supported by its huge potential for renewable energy. According to the Institute for Essential Services Reform (IESR), Indonesia needs 1.700 GW of renewable energy to get to net zero emissions by 2050. It is possible to achieve this with mainly solar PV (1.492 GW) and hydropower (40 GW), making up 90% of the total electricity demand (IESR, 2021). Hydro energy potential is higher during the wet season, while solar energy potential tends to be stable but peaks during dry season (Wahyuono & Julian, 2018).

Current State of RVGs in Indonesia

The massive electrification initiated by the Government of Indonesia is carried out by two main agencies, the State Electricity Company (Perusahaan Listrik Negara/PLN) and MEMR (Wirawan & Gultom, 2021). The electrification programme received support from the German Agency for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit/GIZ) and United States Millennium Challenge Corporation (MCC) to develop solar, hydro, and biogas technology (GIZ, n.d.; Duthie et al., 2024). PLN's electrification program, called Super Ekstra Hemat Energi (SEHEN) and later continued as Lampu Tenaga Surya Hemat Energi (LTSHE), is focused on two types of solar PV: autonomous PV with 12 W capacity and communal PV of 220 W (Sambodo, 2015; Sujatmiko, 2017). PLN manages these plants, and users are required to pay connection fee, monthly fee of Rp14.800, and rental equipment cost for autonomous PV of Rp20.200 (Sambodo, 2015).

Meanwhile, MEMR has a larger budget to build higher-capacity plants (< 100 kW) based on solar PV and micro-hydro. Within 2011-2017, 728 RVGs had been built by MEMR (Wirawan & Gultom, 2021). Each unit is capable of supplying 50-200 households. These RVGs are managed by the community or village cooperatives. Electricity is given for free; users only pay for operational and maintenance (O&M) costs, which is cheaper than the usual electricity tariff (Wirawan & Gultom, 2021). PV plants may be combined with diesel generators to reduce dependence on expensive battery storage. However, the government usually aims for 100% renewable energy since fuel prices can be high in rural areas (Suryani & Dolle, 2020).

Besides that, some RVGs have been established by non-governmental organizations. Clean Power Indonesia, with initial funding from MCC, developed a biomass gasification plant which is sold to the local PLN. Built in the Mentawai Islands, the plant uses bamboo as feedstock, considering it is planted in the Mentawai social forest and has a small ecological footprint. Residents who contribute to supplying bamboo will be given incentives, increasing their capability to purchase the electricity produced (Wahono et al., 2021). In East Sumba, the Dutch organization Hivos built a micro-hydro power plant (MHPP) as part of the Sumba Iconic Island initiative. The plant is operated by village residents and financed through monthly bills, while maintenance is supported by the Indonesian social enterprise PT RESCO Sumba Terang (Prilandita *et al*., 2022).

Benefits of RVGs

1. Poverty Alleviation

RVGs help reduce energy expenditure. For instance, MHPP allows Reno, Flores villagers to save around Rp230.000 and Rp860.000 per month by switching from kerosene and diesel, respectively (Syahni, 2017). These savings can be used for more productive purposes, such as improved lighting, which enables longer study/work periods and may lead to greater income (Wirawan & Gultom, 2021). Some villagers report feeling safer travelling at night due to the availability of street lights, more comfortable taking care of infants at night, can access entertainment services, and they favor that RE plants are not noisy like diesel generators (Suryani & Dolle, 2020). Furthermore, electricity supports agricultural activities by powering tools and irrigation systems, leading to increased demand for labor and skill improvement. It was found that RVG availability is related to the decrease in health insurance recipients and the increase in small industries (Wirawan & Gultom, 2021).

2. Emission Reduction

Before RVGs, many villagers used kerosene-powered lamps, which emit 74-390 kg of CO_2 during their lifetime (Stenemo & Olsson, 2018). Replacement of kerosene lamps is especially necessary to eliminate particulate matter emissions that are linked to respiratory disease and mortality (Ortega et al., 2021). Table 1 compares electricity emissions obtained from life cycle assessments.

Table 1. Electricity Emissions from Different Energy Sources

Energy Source	Emission (g CO_2 eq/kWh)
Solar PV	40
Micro-hydro	40
Biomass Gasification	49
Coal-Fired Power Plant	1.000
Diesel	329

Source: NREL (2012), Ueda et al. (2019), Perilhon et al. (2012), Mann & Spath (n.d.)

3. Investment Cost Reduction

A study on Indonesian villages showed that micro-hydropower has a lower levelised cost of electricity (LCOE) than diesel power. LCOEs were calculated for two scenarios: 1) Basic electrification: a village with agriculture as the main economic activity, electricity is used for 12 hours; 2) Advanced electrification: a village with diverse economic activities, electricity is available all day. Although solar PV is more expensive than diesel, technical development is expected to reduce its cost rapidly, and some costs may be covered by carbon credits. Moreover, RE plants undoubtedly have lower emission abatement costs (Blum, Wakeling, and Schmidt, 2013).

Table 2. Levelized Cost of Electricity (LCOE)

Energy Source	LCOE (Rp/kWh)	
	Basic Electrification	Advanced Electrification
Diesel	4.066–9.017	3.890-8.487
Solar	10.255	9.371
Micro-hydro	2.829	2.475

Source: Blum, Wakeling, and Schmidt (2013)

4. Women Empowerment

Rural electrification potentially supports gender equality. Research in Venezuela found that women take more significant advantage of electricity to access information, study at night, and reduce domestic workload. The number of women completing education increased significantly after electrification (López-González, Domenech, and Ferrer-Martí, 2020). Replacing traditional stoves (biomass, kerosene, or coal-based) with electric stoves is especially beneficial for women. Women are traditionally responsible for collecting firewood,which can be time-consuming and increase the risk of musculoskeletal injuries and cooking, meaning that they are more likely to be exposed to indoor air pollution (WHO, 2023). In Indonesia, women are also included in decision-making processes and leading positions in RVG management (Suryani & Dolle, 2020).

Challenges of RVG Deployment in Indonesia

1. Energy Inequity

Although RVGs are meant to reduce energy inequity between villages and cities, internal disparity is still likely to occur. In several villages in Sumba, some villagers who live on the periphery and have lower socioeconomic status are prone to be excluded from electricity access. They may have participated in communal work for the plant establishment but were not initially informed that their homes could not get electricity. Highly dispersed residential patterns, mountainous topography, and limited resources from donors contributed to the inequity. Households that are located in densely populated areas and near the road are more likely to be chosen for electrification projects (Fathoni, Setyowati, and Prest, 2021).

2. **Unsustainable Operation**

   By 2019, 17% of RVGs built by MEMR have stopped operating (Wirawan & Gultom, 2021). Further, 6 of 23 plants funded by the MCC grants stopped operating, and 13 others encountered substantial problems (Duthie et al., 2024). In Kamanggih Village, a wind-solar PV plant stopped operating due to a storage breakdown. The plant was intended as a pilot project for the company's new technology, and they did not give any funds or capacity building for the repairs. Sumbanese people can not afford the repair cost, especially since they earn significantly less during drought periods. Besides that, social acceptance is important for RVG's sustainability. Villagers of Southeast Sumba were protesting because the metering system was not installed in their homes. The village-owned entreprise (*Badan Usaha Milik Desa*/BUMDes) held the authority to monitor electricity consumption and receive their payments, triggering suspicion toward BUMDes officers. Such disappointments may spur distrust toward future development projects (Fathoni, Setyowati, and Prest, 2021).

3. **Financial Barrier**

   Rural areas have lower electricity demand than big cities with higher populations and economic activity (Indah and Rarasati, 2020). Meanwhile, low-capacity energy plants have higher LCOE than large-capacity plants, rendering them unattractive to private companies (IEA, 2020). Subsidies provided for mini-grid projects are usually allocated for capital costs only. O&M costs are expected to be covered by user tariffs and increasing demand (new customers and growth of economic activities) - which often does not work. Some projects tried to promote economic activity by providing training and agriculture production houses. However, some production houses became inactive, partly due to low access to the market. Further, equipment failures at the early stage may occur due to extreme weather (Duthie et al., 2024). Procurement of tools for repair can be time-consuming and costly due to difficult routes (Suryani & Dolle, 2020).

Recommendation

1. **Promote Inclusivity**

   Rural villagers are not only passive beneficiaries but the subject of development who have the right to participate in decision-making. Interviews with some villagers found that the *Dana Desa* programme has a notable impact on rural development (Manurung *et al.,* 2022). This programme needs to be continued, and if primary infrastructures (healthcare centre, maternity centre, early age education centre) have been established, its utilisation for energy infrastructure should be improved (Redaksi DJPb, 2021). Biogas or biomass gasification plants may be considered for areas with unreliable solar and hydro potential. Biomass with high availability in each village can be used as feedstock, such as palm oil mill effluent (POME) for biogas production in villages near palm oil mills (Adiwibowo, Lestari, and Manalu, 2018). Off-grid solutions such as rooftop solar can be provided for homes that are unfeasible to be connected to the grid (Suryani & Dolle, 2020).

2. **Aim for Long-Term Sustainability**

   Villagers are likely to confront difficulties while maintaining the RVGs. To ensure long-term sustainability, the actors who finance and establish the project must focus on transferring required knowledge to the communities, such as operating the plant, setting tariffs, conducting troubleshooting, and replacing batteries. A peer learning platform can be made so villagers can inherit their knowledge to other areas and the next generation. A clear plan for integrating the mini-grids into the primary grid is necessary if PLN is planning to expand the grid (Suryani & Dolle, 2020). Besides that, electricity tariffs are an important consideration for ensuring energy affordability. As advised by Energy Sector Management Assistance Programme (ESMAP), the electricity cost of 365 kWh/year should be less than 5% of total household income (Bhatia and Angelou, 2015).

3. **Encourage Public & Private Partnership**

   From the economic side, an alternative business model may be implemented to secure financing, in which the government provides funding for installation and a private firm manages the O&M (Suryani & Dolle, 2020). The government redistributing some fossil fuel subsidies to renewable energy for rural areas can encourage the private sector to invest in RVG projects. To support villagers' capability to pay, investors can provide business incubation services, entrepreneurial training, and aid such as agricultural equipment, as well as investing in village roads and communication systems to increase market access. In addition, investors can cooperate with state-owned banks like *Bank Perekonomian Rakyat* (BPR) to provide microloans (Schmidt, Blum, and Walkeling, 2013).

Conclusion

Development should not be limited for the purpose of economic growth. Thus, RVGs should be viewed as a way to actualise basic rights for villagers rather than for-profit practices. The government and private companies can work together to fund RVG establishment, operation, and maintenance. Non-financial support, inclusive approach, clear communication channel, and development of other village infrastructure are also important to support RVG's sustainability.

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