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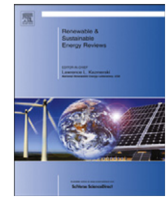

Rural electrification through village grids—Assessing the cost competitiveness of isolated renewable energy technologies in Indonesia

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A B S T R A C T

Isolated grids in rural areas powered by independent renewable energy sources ('renewable energy based village grids') are widely considered a clean and sustainable solution for Indonesia's rural electrification challenge. Despite the advantages of renewable energy based village grids, the number of conventional rural electrification solutions – such as costly grid extension (on-grid) or diesel powered village grids (off-grid) which are characterized by high operating costs and high greenhouse gas emissions – is much larger. One reason for the low diffusion of renewable energy based village grids can be attributed to the lack of private sector investments, leaving the responsibility of rural electrification predominantly on the shoulders of the government who often prefer the centralized and conventional solutions. To better understand this situation in this paper we perform a literature review on the economics of renewable energy based village grids in Indonesia, which reveals a gap in terms of cost data. Therefore, we calculate the levelized cost of electricity (LCOE) of solar photovoltaic (solar PV) and micro hydro powered village grids, and compare them to the conventional diesel solution. For solar PV, we additionally investigate different system configurations including a reduced supply contingency and a hybridization approach. Finally, we determine the CO_2 emission abatement costs and reduction potentials. Our results show that micro hydro powered village grids are more competitive than diesel powered solutions (at least when taking out Diesel and other subsidies). Solar PV powered solutions increase their competitiveness with the remoteness of the village grid is and when reduced supply contingency is applied. From an environmental perspective, micro hydro powered village grid solutions are found to have negative abatement costs with significant potential to reduce emissions. We conclude by discussing our results addressing the question which measures could support private investments into renewable energy-based village grids.

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1. Introduction

As an emerging economy Indonesia needs to respond to multi-faceted challenges in its growing energy sector. This includes providing modern energy services to the poor, reducing oil dependency, and decoupling economic growth from greenhouse gas emissions [1–3]. Today Indonesia's electrification rate is 71%[1] [4]. Of the remaining 29%, about 80% reside in rural areas and almost all outside of the most populated islands, Java and Bali [3,5]. Most of Indonesia's poor are living in regions which are difficult to access; either located in the countryside or on small islands, and therefore they have limited access to reliable and affordable electricity services. At the same time, rural electricity demand is rapidly growing.[2]

Currently, the responsibilities for electrification are 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. PLN itself has long faced many challenges associated with being the dominant actor in the monopolized electricity sector. First, the expansion of the electricity network is very capital-intensive due to the geographically challenging nature of the archipelagos of Indonesia. Options for grid extension to remote areas or deployment of submarine cables into remote islands are typically very expensive [6]. Second, a large proportion of PLN's budget is dedicated to relieving the pressure of aging infrastructure, leaving little allowance for access expansion.[3] Despite these facts, some remote rural areas are already being electrified by the PLN, yet these electrification attempts are mainly based on diesel generators. Third, the Indonesian low grid electricity tariff is set by the government, in a bid to provide affordable electricity to the general population. This eventually caps PLN's revenue from electricity sales, making it difficult to recover the high production and distribution costs [7,8].

Recognizing the urge for electricity access in remote areas and for replacing conventional by renewable energy sources, the Government of Indonesia has recently set the target of 90% electrification by 2020, as a subset of its "Vision 2025: Building New Indonesia strategy"[4] and aims at implementing policies which foster renewable energy technologies. In recent years, a number of promising reforms have taken place designed to invite the participation of local government and the private sector in renewable energy based rural electrification efforts. This includes amongst regulations on small scale power purchase agreements [9], a proposed US$43 m program to increase renewable-based rural electrification and reduce diesel content,[5] a framework which coordinates budgetary contribution of central and local governments to rural electrification advancement [3,10,11], and a 1000 remote island PV electrification program [10].

Due to its geography, most non-electrified villages in Indonesia are too remote, complex and expensive for grid extension to take place.[6] Hence, off-grid solutions (predominantly diesel) become the basic electrification solution for these areas. As an alternative to diesel, renewable energy based village grids are widely considered as a feasible solution to improve rural electrification access which provides a platform to encourage rural economic growth [11–14] and do not result in additional greenhouse gas emissions [15]. However, despite the aforementioned efforts in improving rural electrification access and the benefits of renewable energy based village grids, only a small number have been realized. Efforts are still needed to scale up the diffusion of these solutions.

According to Indonesian rural electricity practitioners (who we interviewed during our study), investments in remote, renewable energy based rural electrification are almost entirely dependent from grants or charities from socially-inclined private organizations, aside from PLN. The literature review we perform (see Section 2) reveals a lack of data on the economics of renewable energy based village grids in Indonesia, making it difficult for decision makers to implement measures that foster their diffusion and attract private investments. In this study, we therefore address this data gap by tackling the following main research question: How competitive are isolated renewable energy based village grid solutions compared to the standard conventional solution? Specifically, we analyze two sub-research questions; first, what are the levelized costs of electricity generation (LCOE) of various solutions? and second, what are the costs and potentials of CO_2 emission abatement of these solutions?

To this end, first, we develop two electricity demand scenarios for a generic Indonesian village, reflected through daily load profiles. Second, we design standalone conventional, renewable and hybrid power generation systems to supply the village grid. Third, we calculate the LCOE for the baseline (conventional diesel powered village grid) and compare it to different micro hydro powered and solar PV powered solutions. Fourth, we calculate the abatement cost (AC) and emission reduction potentials of the renewable energy based and the hybrid solutions, compared to the diesel baseline.

This paper is structured as follows. While Section 2 reviews recent literature on the economics of RVGs in Indonesia, Section 3 describes the method applied in the study. This includes the quantitative approach to estimating Indonesian village electricity demand estimation, generation plant technical parameter sizing, and the calculation of LCOE, AC and emission reduction potentials. Section 4 outlines the results of our techno-economic model, followed by a discussion and conclusion in Section 5.

2. Literature review on the economics of RVGs in Indonesia

A review of literature published in the past five years on the economics of RVGs (or micro-/mini-/island-grids) in Indonesia

[1] This number reflects general access to electricity, but does not reflect the quantity and quality of the accessed electricity.

[2] PLN's projections and findings from our own in-depth interviews with a number of Indonesian renewable-energy based rural electrification project developers suggest that demand growth is expected to be 10% per year until 2018 [72].

[3] PLN's 2009–2018 supply plan outlines a proposed spending of $32b in generation, $14b in transmission and $13b in distribution [72].

[4] Vision 2025 Building New Indonesia lists a set of targets to achieve by 2025 focusing in the areas of economics, poverty eradication, and equal access to vital utilities across the nation [73].

[5] Diesel currently serves as the conventional solution for remote rural electrification due to its perceived low cost, scalability and accessibility. PLN statistics show that they operate 936 decentralized diesel power plants (50–500 kW) with a total capacity of 987 MW across Indonesia [74].

[6] Based on our Indonesian field interviews with practitioners, the ideal distance between independent power plants and PLN's grid needs to be between 5 and 10 km to guarantee project profitability.

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