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Original article

Energy payback time analysis and return on investment of off-grid photovoltaic systems in rural areas of Tanzania

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ABSTRACT

Owing to a vast land area, abundant solar radiation, and overseas support, the use of photovoltaics (PV) as a source of electricity is rapidly spreading in Sub-Saharan Africa. To understand the actual application situations, two cases of PV electricity generation systems in the rural areas of Tanzania were investigated via life cycle assessment. The energy payback time (EPBT) calculated from the utilisation of the PV systems, taking into consideration the inventory data of the International Energy Agency, revealed an unsatisfactory performance. Specifically, the EPBTs based on actual power generation at the sites greatly exceeded the expected value-based solar radiation calculations. At one site, the EPBT even exceeded the lifespan of the PV panel, indicating that energy recovery was impossible. With respect to the energy return on investment (EROI), it was evident that the income generated from the investments was insufficient to cover current operational costs, suggesting negative returns on investment. Conversely, diesel power generation appeared to be more suitable in these areas owing to the low and discontinuous demand for power. Furthermore, the operation of a more efficient PV system would require improved maintenance and management, as well as an increase in the demand for electricity.

Introduction

African countries that are experiencing economic and population growth are attracting worldwide attention as major potential new markets. However, Sub-Saharan Africa contributes only 3% to the global energy demand [1]. The power generation capacity of this region is particularly low, even though it is home to 15% of the world's population. Particularly, Tanzania has one of the lowest levels of power generation per capita in Africa (0.033 kW/person) [1]. The average electrification rate in this country is 33%, and only 17% in the rural area [2]. A large-scale project to increase the electrification rate in Tanzania has been underway since 2010 with the support of the World Bank [3].

Japan also provides considerable international support to this country. For example, a collaborative study on Tanzania titled "Development and Dissemination of Innovative Oil-Extracting Technology from Crop Process Residue for Rural Electrification and Value Addition of By-Products" is being conducted by Japanese and Tanzanian researchers under the framework of the Japanese international joint research program, "Science and Technology Research Partnership for Sustainable Development (SATREPS)." This is a unique program whereby the Japan Science and Technology Agency (JST), the Japan Agency for Medical Research and Development (AMED), and the Japan International Cooperation Agency (JICA) are collaborating to promote international research with the aim of solving global issues based on the needs of developing countries [4]. The aforementioned study involves an attempt to use oil extracted from agricultural residues as fuel that can be used to generate electricity in rural areas. Electricity generation from diesel is currently the main source of rural electrification in Tanzania [5] and will continue to be indispensable as a back-up power source for the intermittently generated wind or photovoltaic (PV) power. Furthermore, the use of locally produced biofuels in agricultural machinery can be sustained even after power has been supplied to the rural areas via electric grid.

Off-grid power supplies play a major role in Tanzania, where the population density is low and widely distributed over a vast area of land, especially in rural areas. The number of independent micro-grids powered by renewable energy sources is increasing throughout the country. With Tanzania's vast land area, abundant solar radiation, and overseas support, PV power generation is gradually replacing diesel power generation as the main form of rural electrification in the country. Several

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