Renewable Energy 118 (2018) 685–694

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Design of a solar energy centre for providing lighting and income-generating activities for off-grid rural communities in Kenya

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A R T I C L E I N F O

Article history:
Received 10 July 2017
Received in revised form
4 November 2017
Accepted 17 November 2017
Available online 22 November 2017

Keywords:
Solar energy centre
Off-grid rural communities
PVSyst
Solar home systems
Income-generating activities

A B S T R A C T

One of the biggest challenges in the developing world is the provision of affordable and reliable electricity access to rural and marginalized people where grid extension is prohibitively expensive. Many off-grid schemes to date have focused on household lighting with mixed success. Some of the greatest difficulties have been around affordability and sustainability of the service provided, with systems being abandoned or removed due to broken equipment or inability of the user to continue paying for the service. It has been reported that key to the success of the best programs has been the means to improve the economic prospects of the users. In this paper the design of a solar energy centre for a rural village in Kenya, that enables income-generating activities for the community in addition to basic lighting and mobile phone charging provision, will be reported. We have found that it is possible to use the energy centre model to provide power for activities that could offer a source of income for the community, at an affordable cost with equipment available in Kenya today. It is believed that this will allow the community to develop economically and therefore ensure the sustainability of the off-grid power supply.

1. Introduction

According to the UN [1], 1.5 billion people worldwide have no access to electricity and a further billion people have highly unreliable connections. In sub-Saharan Africa 620 million people have no access to grid electricity [2]. In Kenya 35 million people or 75% of the population are in this situation [2]. Indeed, in 2010 only 8.1% of rural communities in Kenya had access to grid electricity [3].

In 2014, the per capita energy consumption in Kenya was just 167 kWh per year [4]. The IEA recommends that the minimum level of access to electricity should be 250 kWh per year for a rural household and 500 kWh per year for an urban household [2]. To put it in context, 250 kWh per year would allow the use of two compact fluorescent lights, mobile phone charging and the use of a fan for 5 h per day for a household of 5 people. Without electricity, communities rely on kerosene lamps for lighting and biomass for cooking, which are expensive, unhealthy and damaging to the environment. The price of kerosene was on average $0.60/l[1] in Kenya in 2015 [5], placing a heavy financial burden on poor, rural households.

Kenya established a state corporation, the Rural Electrification Authority, in 2006 with the aim of accelerating rural electrification. Recently the Government of Kenya announced that it was reducing the once-off connection fee from $320 to $147 [6] but households must pay for electrical wiring before a connection can be made. According to the World Bank [7], the gross national income of Kenya for 2011 was just $1160. Therefore, even the reduced connection fee is likely to be beyond the means of poor rural communities. A working paper from the National Bureau of Economic Research in the US [8] backs this up, finding that large numbers of houses in rural Western Kenya within 600 m of transformers are not connected to the grid, essentially living under the grid.

A World Bank report in 2004 [9] found evidence that rural electrification schemes are generally unsuccessful unless the communities being connected have sufficient economic success to be able to afford appliances such as TVs, refrigerators and improved lighting. However, economic progress often depends on the availability of electricity. Off-grid systems can offer communities limited, affordable electricity supplies that bridge the gap and pave the way for grid electrification by creating a market for it.

In Kenya, the high level of solar insolation (>5 kWh/m^2/day) makes photovoltaic (PV) systems an attractive off-grid power

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[1] Conversion rate for Kenyan Schillings to US Dollars on 16 August 2015 was 1 Ksh = $0.0098.

https://doi.org/10.1016/j.renene.2017.11.053
0960-1481/

solution (see Fig. 1). Three different models for off-grid PV systems for rural communities have been tried around the world: solar home systems (SHS) [10], mini- or micro-grids [11–13], and community energy centres [14,15].

Solar home systems (SHS) have been widely deployed in the developing world, particularly in Bangladesh and India as part of their rural electrification programs [16–19], but also in Sub-Saharan Africa [20,21]. A typical SHS consists of a solar module, battery, charge controller, compact fluorescent lights or LEDs, mobile phone charging point and possibly a power point for small DC appliances such as TVs, fans or radios. Although they are the most popular solution for off-grid rural electrification to date, there have been a number of issues with them including difficulty for users to find the upfront capital costs to purchase a system, over-use resulting in shorter battery life, poor-quality products and/or installation and insufficient system maintenance [17].

An alternative model to the solar home system is the minigrid (also called a microgrid or picogrid depending on the system size). Minigrids consist of centralized power generation e.g. an array of PV modules, a bank of batteries, an inverter to convert from generated DC to AC power and a distribution system including poles, wires and consumer units [13,23]. In addition to providing power to homes, minigrids can be used to power services such as water pumping and street lighting. Another advantage of minigrids is that by supplying AC, appliances are more readily available and cheaper for the consumers. Loka et al. [12] reviewed a PV-based microgrid in India and found the levelized cost of electricity (LCOE) for an equivalent diesel generator was estimated to be more than twice the cost of the PV microgrid. They reported that the key factors to the success of the project were: active involvement of the community from the outset, having a comprehensive maintenance plan and providing spare parts for the system. Ulsrud et al. [11] looked in detail at a well-established solar minigrid in India. Over time the electricity needs of the community outstripped what the scheme could supply leading to battery degradation and illegal connections to the distribution system. The authors noted the importance of planning in advance for system growth to meet this increasing demand. In some cases, households installed a SHS in addition to using energy from the minigrid. There were also issues with maintenance and acquiring spare parts and setting an

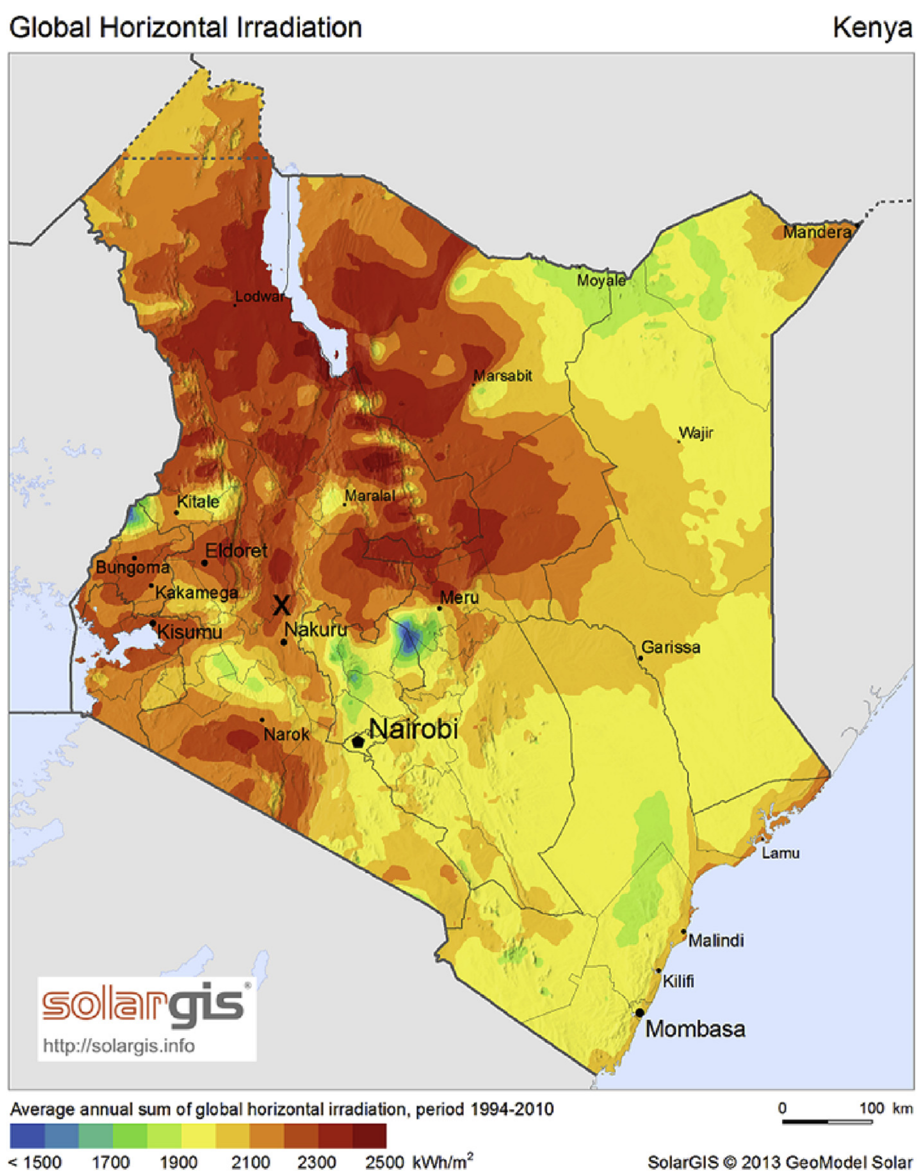

Fig. 1. Map of Kenya showing annual average global horizontal irradiation [22]. The location of the village considered in this paper is marked with “X”.