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ScienceDirect

Energy Procedia 93 (2016) 108 – 112

Energy Procedia

1.1. Africa-EU Renewable Energy Research and Innovation Symposium, RERIS 2016, 8-10 March 2016, Tlemcen, Algeria

Electrification modelling for Nigeria

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Abstract

Reliable access to electricity still remains a challenge in many regions of Nigeria. For achieving a rapid electricity access for large geographic regions alternative electrification pathways apart from grid connection need to be taken into account. Therefore, sophisticated planning tools to determine techno-economic optimized electrification pathways are necessary. Here, an approach for such a tool is presented and combines GIS and energy system simulation tools. The approach is based on the identification of consumer clusters, determination of status of electrification and assignment of a suitable electricity supply option. Three options are taken into account: Grid extension, PV-hybrid mini-grids and solar-home systems (SHS). Within this study we have identified 47,489 consumer clusters for entire Nigeria and found that 46 % of the people living in these clusters are currently not supplied with electricity. A connection of all customers within a 20 km zone around the existing grid would have the largest impact with delivering electricity to 57.1 million people. Outside this grid zone, a population of 12.8 million is most suitably supplied by PV-hybrid mini-grids and 2.8 million by SHS. Therefore, a PV capacity in a range of 671 to 1,790 MW for mini-grids and 84 MW for SHS would be required.

Peer-review under responsibility of the organizing committee of RERIS 2016

Keywords: Nigeria; electrification planning; spatial analysis; PV-hybrid mini-grid; solar-home systems.

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Peer-review under responsibility of the organizing committee of RERIS 2016
doi:10.1016/j.egypro.2016.07.157

2. Introduction

Reliable access to electricity still remains a challenge in many regions of Sub-Saharan Africa as well as for many regions of Nigeria [1]. Advancing renewable energy technologies and storage systems open up novel perspectives for decentralized supply structures of electricity. As a consequence, new planning methods are required to account for innovative solutions comparing existing electrification options.

For achieving a rapid electricity access conventional options based on central power generation and the extension of large transmission grids need to be reconsidered, taking into account alternative electrification pathways for regions where access to electricity is still lacking or is insufficient [2]. Such alternatives are represented by hybrid mini-grids, which can combine different power generation and storage technologies to efficiently supply local loads [3]. The increased options and complexity of rural electrification underline the need of sophisticated planning tools to determine the techno-economically optimized electrification pathway. Only few tools exist for this target and their application is quite rare.

The presented approach enables comprehensive electrification planning by the use of GIS (geo-information systems) and energy system simulation tools. By that the conventional electrification approach via grid-extension is compared to electrification by hybrid mini-grids along several steps. For this study, a more simplified approach is applied for entire Nigeria in the context of the preparation of a policy directive "On the promotion of the use of energy from renewable sources and procurement of capacity" by the Federal Ministry of Power (FMP). This study supports the Policy Directive by providing quantities on the potential of photovoltaic (PV) systems for rural electrification by solar home systems (SHS) and PV-hybrid mini-grids for entire Nigeria. The attempt is complex because essential data on population distribution, the current status of electricity supply and load demands in rural areas is lacking and profound work-arounds need to be established. Therefore, a GIS database and spatial modelling is applied to understand where the consumers are located and whether or not they are reached by the grid or supplied with electricity already. Based on that, priority areas for different electrification approaches are assigned and capacity needs for PV-hybrid mini-grids and SHS are defined.

3. Methods

For this analysis, a combination of GIS tools, energy system simulation and literature analysis is chosen to derive an overview of the potential of SHS and PV-hybrid mini-grids for rural electrification in Nigeria. The approach is based on a step by step procedure: First, consumer clusters (such as villages, points of energy consumption, etc.) are identified. Second, the status of electrification for each consumer cluster is defined. Third, based on the location and population characteristics of each consumer cluster it is determined whether grid connection, PV-hybrid mini-grid or SHS are the most suitable electricity supply option. During this process, a large amount of different datasets is applied to ensure the accuracy of the analysis (Fig. 1).

3.1. Identification of consumer clusters

In order to identify populated areas for Nigeria, a population raster data set [4] is used as base source. This base source is extended with a school data set [5] and polling unit data set [6] as it is assumed that areas around both points are usually inhabited. Around each feature of these input data sets, a buffer zone of 500 m is added, which refers to a common threshold for connecting clusters in low voltage grids. Thereby, the spatial extension of consumer clusters is determined. Subsequently, the number of inhabitants is calculated per cluster. For this, first the population raster dataset [4] is taken into account. Second the population in smaller villages and towns (< 20,000 inhabitants) is scaled according to the average number of students per cluster (derived from school data [5]).

3.2. Determination of electrification status

The general approach to define the electrification status of the consumer cluster is based on two steps: Step 1 builds on night light imagery [7]. These images are satellite data which show light emissions during the night. These visible emissions are usually based on street lamps or other lights in villages or communities. A high amount of light