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Satisfying the rural residential demand in Liberia with decentralized renewable energy schemes

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ABSTRACT

With the lowest access to electricity in the world, the country of Liberia, West Africa, has efforts underway for electrification through a fossil based centralized scheme around its capital city and possible connections to the larger Western Africa Power Pool network. These plans leave a large part of the rural population with no access to electricity.

This work analyzes the potential of decentralized generation to provide electricity to the rural Liberian population. The suppressed demand of the rural population is calculated at 235 GWh/yr. There is sufficient renewable energy potential to supply this demand. The capital costs and electricity prices of decentralized generation with different fuels are calculated and compared to the ability and willingness to pay of rural Liberians.

Small diesel units have the lowest capital cost but photovoltaic, small hydropower and small biomass projects provide lower electricity prices. Biomass and small hydro electricity are affordable for Liberians at $0.08/kWh and $0.11/kWh respectively. Diesel and photovoltaic, with levelized cost of electricity of $0.62/kWh and $0.33/kWh respectively, exceed Liberians' willingness to pay.

Centralized and decentralized electricity developments are not mutually exclusive; both may be used within a comprehensive electrification plan. Decentralized generation with emphasis on rural areas can complement the existing plans to achieve the Government of Liberia's goal of universal access to electricity, providing social equity and economic progress. In order to become a reality, rural decentralized electrification will need policy support and focused funding.

Contents

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1. Introduction

1.1. Background

After a 14-year civil war, Liberia, West Africa, is moving towards redevelopment. With little remaining infrastructure and the lowest level of electrification in the world [1], the country seeks to reinvigorate its economy and provides general services to its population. Sub-Saharan Africa has been identified as the biggest challenge for development in the energy sector [2]. As Table 1 shows, Liberia has the largest electricity tariff and the lowest access to electricity in the region [1], highlighting the considerable challenges to electrifying its population.

A small diesel powered grid is available in the capital city of Monrovia, with electricity tariffs of $0.43/kWh [1]. Expansion of the centralized grid is under way. Electrification plans include expansion of diesel generating capacity, installation of heavy fuel oil generation, rehabilitation of a large hydropower plant at Mount Coffee, and integration to the Western Africa Power Pool (WAPP) [1]. Liberia is expected to join the WAPP by the year 2015 through a transmission project between Ivory Coast, Liberia, Sierra Leone, and Guinea (CLSG), and an additional low voltage connection to Ivory Cost [1].

The published electrification plans place emphasis on the urban and industrial sectors in Liberia but raise issues of demographic coverage, reliance on fossil fuels, and dependence on large centralized infrastructure. Centralized, fossil fuel based pathways like the one planned in Liberia have been shown to create environmental issues, external debt, social divides, and poor quality of service, leaving large segments of the population with no access to electricity [3,4]. In Liberia, urban areas will receive the majority of the benefits. More than 50% of the rural population in Liberia will remain with no access to electricity by the year 2040 [1].

The WAPP projects are key to Liberian electrification and will lower generation costs. Gnansounou et al. [5] state that integrating the electricity systems in the region will bring significant benefits through deferred capital investments, increased efficiency, and better reliability. However, the WAPP has been criticized for unrealistic goals and its lack of African ownership and clear objectives. As Pineau [6] notes, the level of integration and functionality to which the WAPP aspires has not been achieved by countries in the European Union or by the United States and the success of the WAPP given the lack of institutional capacity in the region is unlikely.

Table 1
Access rates and electricity tariffs in selected countries of West Africa.
Sources: [1,2,10,11]

Country	Liberia	Ghana	Ivory Coast	Sub-Saharan Africa	World
Access rate to electricity (%)	~1.6%[a]	60.5	47.3	28.5	79
Rural access rate (%)	<2	23	18	11.9	65.1
Urban access rate (%)	0.58	85	78	57.5	93.6
Electricity tariff ($/kWh)	0.43	0.075	0.125		

[a] Estimated by authors from source data.

In the published plans, the Africa Energy Unit acknowledges these concerns and calls for efforts that run parallel to central grid and WAPP connections [1]. The Government of Liberia (GOL) has issued the National Energy Policy (NEP) and the Poverty Reduction Strategy (PRS) outlining a variety of development objectives, including "providing universal access to electricity" [7,8]. Further, it has established the Rural Renewable Energy Agency (RREA) to address rural electrification and undertake a National Rural Electrification Master Plan (REMP) [1,9].

Although analyses have been conducted on the economics and feasibility of the centralized grid, little attention has been given to the feasibility of supplying rural demand with renewable, decentralized electricity, which is the focus of this paper. This paper quantifies the suppressed electricity demand for the residential sector in rural Liberia and analyzes the possibilities for decentralized electricity generation. The suppressed demand is defined as electricity demand that would be present if service was available. The renewable energy potential in Liberia from different fuels is then estimated and an economic analysis of decentralized generation (DG) through these fuels is conducted. Solar photovoltaic (PV), small hydro, and biomass direct combustion are used as the feasible fuels in Liberia. Wind power is ignored due to low wind speeds throughout the country [10]. For comparison, the economics of small diesel fuel generation are presented due to its current use in rural areas of Liberia. The economic analysis includes overnight capital costs and simplified calculations of resulting levelized cost of electricity (LCOE). These costs are compared to the ability and willingness to pay of rural Liberians. Finally, tradeoffs of the fuel options are presented.

1.2. Reaching rural populations in Liberia

Grid expansion (GE) and decentralized generation (DG) are two methods that can be used to reach rural electrification goals. GE extends the centralized generation capacity by creating transmission and distribution networks to rural populations. DG uses smaller generation units located close to the rural load centers, avoiding large distribution networks. DG may involve the use of micro-grids joining a few communities or load centers and may eventually be connected to a larger grid.

Due to the current electrification plans in Liberia and the lack of existing centralized infrastructure, this paper places emphasis on DG for rural areas. DG is more economical than GE in situations with low population density, low electricity demand per person, lack of centralized generation infrastructure, and difficult terrain [1,2,11,12]. Zerriffi and Wilson [13] point out that the scalability of DG is particularly well suited for the low demand and sparse population of rural areas. Further, Levin and Thomas [14] use an algorithm to determine the optimum economic choice between DG and GE for each load center in a series of countries. When the algorithm is applied to Liberia, DG is more economical for 72–77% of the population and 95–98% of the load centers [14]. This distribution reflects the urban and rural demographics of Liberia, with the capital city of Monrovia being the only truly urban center and holding around 28% of the population [15].