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The African electricity deficit: Computing the minimum energy poverty line using field research in urban Nigeria

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ABSTRACT

Energy poverty has long been defined in Developing-Rural or Western-Urban contexts. For the parts of the world classified as energy-poor, the Developing-Rural context is used, but the population density of the energy poor is much higher in the urban areas of developing states and this trend is expected to continue over the next 30 years. Moreover, computations of energy use in developing states have been based on electricity use in industrialized states. Drawing on extensive qualitative and quantitative methods, and using field research in Nigeria, this article describes a context-specific way to compute actual energy consumption, with electricity as the proxy. It proposes a minimum energy poverty line of 3068 kWh/cap yr (350 W/cap), which is sufficient to provide for basic needs in an urban household. With the energy poverty line representing an energy-secure household, three scenarios were modeled for name-plate capacity generation based on data collected: low-consumer, high-consumer, and energy-secure households. These scenarios were compared to current generation capacity for select sub-Saharan West African countries. I found that these countries all produced insufficient power to supply all their citizenry, even if the entire populace were comprised of low-energy consumers. I found no relationship between actual household electricity consumption and electricity bills.

1. Introduction

High levels of energy poverty in Africa are the driving force for African governments, donors and NGOs to increase electricity access in Africa, whether by fossil fuels or renewable energy, the subject of this Special Issue. Discussions about increasing wind energy [1] and capacity-building through PhD engineering programs [2], among other issues identified in this Special Issue, must consider what we mean by energy poverty, a term that is usually defined in two main contexts: Western-Urban and Developing-Rural.

Western-Urban refers to industrialized states. In this context, energy poverty is defined in terms of social exclusion and material deprivation [3,39–42]. Energy poverty creates class distinctions and prevents ownership of luxury goods. This definition is often subjective and can vary widely within a small geographic area. Developing-Rural is specific to rural areas in developing states. This definition of energy poverty is computed based on estimated energy required to provide electricity for lighting and energy-dense fuels for cooking in a rural locale [7,14,35–37]. Almost by definition, world regions that are predominantly classified as energy poor are comprised mostly of developing states: this includes the 2.5 billion people who rely on biomass as cooking fuel, and the 1.6 billion people without access to electrification [38]. The population density of the energy poor is higher in urban than in rural areas, with the rural-to-urban migration trend expected to increase over the next 30 years. The energy poverty problem cannot be solved without first determining what per capita energy consumption is for urban areas in developing states [4,5].

The quantitative benchmarks that exist in the energy poverty literature are computed for the lack of access based on physiological needs and purchasing power for a fixed amount of basic needs in goods and services. For the Developing-Rural context, two minimal energy poverty lines have been computed: 1000 W per capita [6] and 300 W per capita [7] which convert to an annual consumption of 8765.8 kWh/cap and 2629.7 kWh/cap respectively. But in urban areas, people need more energy than just electricity for lighting and energy-dense cooking fuels; they also need energy to run cottage industries, which contribute 50% of GDP in sub-Saharan Africa [8]. Note that these electricity levels (W/cap) indicate the amount of electricity that needs to be supplied continuously per person and directly infer what the name-plate capacity for electricity

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generation should be for a given population. (name-plate capacity is the maximum output of a generator or other electric power equipment under conditions set by the manufacturer). This is different from the total electricity consumed or produced per year, i.e. kWh/yr. For the purposes of simplicity, all subsequent electricity consumption units will be kWh.

The definition of basic needs varies by standard of living and regional locations; developing countries consume a fraction of what industrialized states consume per capita (Krugmann and Goldemberg, 1983). The definition depends on (1) the definition of well-being, (2) cultural understanding of harm or suffering, and (3) relative possibilities at the time.

The definition of well-being is subjective and tied to concepts like *functionings* (the various things a person may value doing and being) and *capabilities* (what a person is able to do). Functionings and capabilities may be cultural norms or codified laws. An example of something that is both a functioning and a capability is the ability of women to participate in community leadership [40–42]. A woman may be capable of leading but prevented from doing so by norms or laws. In such a case, the woman is effectively, but not actually, incapable of community leadership.

Secondly, cultural and individual understanding of harm or suffering varies from one place to another. For instance, in Nigeria it is quite common to see unaccompanied groups of three- to five-year olds walking for up to 20 min to and from their elementary schools on weekdays. This is a norm and has gone on for generations. Similarly, primary- and secondary-school students trek for up to an hour or more daily to and from school. Describing this time spent trekking in the hot sun as a hardship would only elicit blank stares among average Nigerians; it is the norm and not perceived as hardship, but rather as time for socializing.

Finally, the relative possibilities available at the time determine what would be considered a basic need within the given context. These possibilities depend on factors that influence energy consumption habits, such as geographical environment, income, production, culture, and hierarchy of energy choices.

The Goldemberg [6] estimation of the annual minimal energy poverty line at 8765.8 kWh/cap is based on energy consumption between 1978 and 1982, with assumed non-commercial energy use of 3506 kWh/cap annually. It estimates in a year, 12,272 kWh, 14,901 kWh, and 15,778 kWh per-capita of electricity is required to satisfy basic human needs in Africa, Latin America, and Asia, respectively. These calculations are based on historical Energy-to-GNP correlations. Assumptions of residential energy-use levels are based on levels in Western Europe, Japan, Australia, New Zealand, and South Africa, all of which have very different climates, nutritional requirements, cultures, and energy choices. In addition to being based on aggregate data and very different energy consumption habits, this estimate is outdated.

The annual average of 4382.9 kWh/cap proposed by Pachauri and Spreng (2002) also aggregates energy consumption across urban and rural households, while incorporating direct and indirect energy consumed. Subsequent computations (Pachauri, 2004) calculate household energy consumption based on embedded energy content in household goods and services produced. This method limits determination of the amount of energy a region requires to provide for electrification and cooking fuel; these two requirements define the energy poverty line in developing states.

Existing energy poverty benchmarks are either outdated or based on non-contextual definitions of basic needs. I argue that a contextual energy poverty benchmark is needed for sub-Saharan Africa, which is home to half of the world's energy-poor populace [9]. Furthermore, a per capita energy benchmark should include electricity as a proxy for cooking fuel because of the danger of household fires in the sub-Saharan African region, as well as to simplify determination of energy profiles at different spatial scales.

Researchers have estimated the direct and indirect disaggregated household energy requirements for developing states such as India [7,10] and South Africa [11]. However, these estimations are few and difficult to find and, as mentioned above, they focus on rural locales. This article is the first published attempt to estimate and analyze disaggregated urban household electricity consumption and to model future electricity needs for an urban locale in a sub-Saharan African country.

I computed the minimal energy poverty line based on disaggregated household energy data collected in urban regions in Nigeria, using reported activity levels and household energy consumption. Using Nigeria as a case study, the model determines the per-capita minimal household end-use energy needs for urban sub-Saharan West Africa. Nigeria is significant in sub-Saharan Africa because it contains most of the region's urban settlements, thanks to its long-established and varied pre-colonial urban traditions [12]. The levels of energy poverty in southwestern Nigeria are representative of other urban centers in sub-Saharan Africa, and as such, for urban energy poverty in the region as a whole. Also, the conversation on electricity supply in Nigeria, and most of sub-Saharan West Africa, is moving from favoring a centralized government-run institution to favoring decentralized providers in the form of independent power providers (IPPs) (The White House [Press Release], August 5, 2014; [13]). While literature holds that the energy poor spend a significant proportion of their income on energy [3,14], electricity prices are subsidized in Nigeria, and consumers need pay only a portion of their bill to continue receiving service. Energy poverty thus arises from inadequate supply rather than from limited consumer capacity to pay for electricity. To estimate how privatization of power generation will affect energy poverty in sub-Saharan Africa, we must first know how much power is supplied, what proportion of income the average household spends on energy, and how much power is consumed by households. This study provides that information for urban areas in southwest Nigeria.

2. Data and methods

2.1. Study area

Southwestern (SW) Nigeria is one of the six geopolitical zones of the country. (See Fig. 1 for a map of the geopolitical zones.) It consists of Oyo, Osun, Ogun, Ondo, Ekiti, and Lagos states. Though poverty levels in southwestern Nigeria are the lowest in the country (because Lagos is one of the wealthiest states in the country), the region is an appropriate zone of study because it experiences pervasive energy poverty [15]. In addition, this region is the most politically and religiously stable part of the country, unlike the other five geopolitical zones, which are fraught with Boko Haram terrorism activities (NW, NE, and NC zones), kidnappings (SS, SE, and NC zones), and civil unrest (NC and SS zones).

Southwestern Nigeria lies in latitude 6°21′8″ North and longitude 2°31′6″ East (NPC, 1991). It has a tropical climate with wet and dry seasons, belonging to the Af (tropical rainforest climate) and Aw (tropical wet and dry or savannah climate) Köppen–Geiger climatic zones. Temperatures range from 21 °C to 34 °C (69.8–93.2 °F), and annual rainfall ranges between 150 cm and 300 cm [16].

The three states of Lagos, Oyo, and Osun are the most densely populated in the southwestern region, and also account for the largest rural–urban migration for that geopolitical zone. The study was conducted in urban areas in the three states. The survey sites were selected based on the definition of an urban area according to GOI [17] criteria: population greater than 5000, population density