Renewable and Sustainable Energy Reviews 112 (2019) 853–864

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Energy poverty in Ghana: Any progress so far?

Frank Adusah-Poku*, Kenji Takeuchi

Graduate School of Economics, Kobe University, Japan

ARTICLE INFO

Keywords:
Energy poverty
Multidimensional
Ghana
Deprivation

JEL classification:
D12
Q41
013
I3

ABSTRACT

This paper investigates the dynamics of energy poverty in Ghana using two nationwide cross-sectional datasets (Ghana Living Standards Surveys Round 5 and Round 6). Employing the Multidimensional Energy Poverty Index (MEPI) as a measure of energy poverty, this paper estimates that the share of energy poor people decreased from 88.4% in 2005/2006 to 82.5% in 2012/2013. The results indicate that although there has been a significant decline in the overall energy poverty in Ghana during the study periods, the incidence of energy poverty remains high. Moreover, the study findings show a large gap between urban and rural energy poverty over the two periods; rural people are almost twice as energy poor as urban people. These findings suggest the need for the incorporation of energy poverty reduction strategies into income poverty reduction strategies to help improve not only access to modern energy but also in terms of affordability.

1. Introduction

Every developed economy ensures access to modern energy sources as the underpinning of its economic prosperity. Although energy was not included in the United Nation's Millennium Development Goals (MDGs), it played an important role in reducing poverty and attaining the MDGs. This was emphasized by the former Secretary-General of the United Nations (UN), Ban-Ki-moon: 'Development is not possible without energy, and sustainable development is not possible without sustainable energy.'[1] The importance of energy in this modern era has led the UN to include energy in its Sustainable Development Goals (SDGs). Specifically, goal seven of the SDGs is to ensure universal access to affordable, reliable, sustainable, and modern energy by the year 2030.

Access to modern energy services is a persistent challenge to many developing countries, particularly sub-Saharan African (SSA) countries. Among the 1.2 billion people in developing countries who do not have access to electricity, more than 634 million people live in SSA countries [1]. The International Energy Agency (IEA) reports that more than 2.7 billion people in developing countries depend on traditional biomass (e.g., wood, agricultural residues, and animal dung) for cooking. In SSA countries alone, more than 753 million people rely on traditional biomass for cooking. The heavy reliance on traditional biomass exposes people to indoor pollution that causes several respiratory diseases.

Energy poverty was defined by Ref. [2] as 'the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic and human development.' In the energy poverty literature, the terms "energy poverty" and "fuel poverty" are used almost interchangeably. While fuel poverty is often used in the context of developed and relatively wealthy countries (e.g., New Zealand and the United Kingdom), energy poverty is typically used in studies that focus on developing and relatively poor countries (e.g., Ghana, India and SSA countries).[2] In addition, the former entails fuel use for heating. This paper addresses only energy poverty and not fuel poverty because Ghana is a developing country.

There are studies that address various aspects of energy poverty. Examples include the examination of household determinants of energy poverty [4,5], the estimation of an energy poverty line [6,7], and the construction of various energy poverty measures [8–10]. However, none of these studies examined the dynamics of energy poverty, i.e., the change of energy poverty between time periods.

In Ghana, several programs have been undertaken over the years to reduce the high dependence on traditional biomass. Notable among them is the National Liquefied Petroleum Gas (LPG) promotion campaign, which began in the early 1990s with the aim to encourage the

* Corresponding author.
E-mail address: fadusahpoku@yahoo.com (F. Adusah-Poku).

[1] A Framework for Action on Sustainable Energy for All by "The Secretary-General's High Level Group on Sustainable Energy for All," January 2012. http://www.se4all.org/sites/default/files/l/2013/09/SE_for_All_-_Framework_for_Action_FINAL.pdf.

[2] For a comprehensive review of the differences between energy poverty and fuel poverty, see Ref. [3].

https://doi.org/10.1016/j.rser.2019.06.038
Received 11 July 2018; Received in revised form 30 March 2019; Accepted 16 June 2019
Available online 24 June 2019
1364-0321/

use of LPG as an alternative cooking fuel to the traditional biomass. However, after years of implementation, minimal work has been done to ascertain the effectiveness of these programs in reducing the use of traditional biomass. This leads to an important question: have the various programs engendered any significant transition from the use of traditional biomass to modern energy? This study attempts to answer the question by examining the dynamics of energy poverty in Ghana during the period from 2005 to 2013.

This paper serves three purposes. First, this study examines the dynamics of energy poverty in Ghana using two nationally representative cross-country datasets: the Ghana Living Standards Survey conducted in 2005/2006 (GLSS V) and 2012/2013 (GLSS VI). By comparing energy poverty in two periods, this study is able to assess the effect of energy poverty alleviation policies for SDG attainment. Second, this paper compare energy poverty between rural and urban areas. Of those who depend on traditional biomass, 80% live in rural areas giving an indication that people living in rural areas are more energy poor than those living in urban areas [1]. By comparing urban and rural areas in two time periods, this paper can examine the differences in energy poverty between these areas and determine whether the energy poverty gap is widening. Third, this paper compares regional differences in energy poverty. In terms of income poverty, there are wide differences between the three northern regions and the remaining regions.[3] Therefore, it is expected that energy poverty in the three northern regions will be highest among all regions.

The remainder of the paper is organized as follows. Section 2 discusses three consequences of energy poverty, including its impacts on health, the environment, and the economy. Section 3 provides an overview of policy interventions relating to energy poverty in Ghana. Section 4 explains the data and the methodology used to measure energy poverty. Section 5 presents the results whiles the last section concludes and offers some policy recommendations.

2. Consequences of energy poverty

2.1. Impacts on health

In general, households in developing countries are highly dependent on traditional biomass for cooking. Traditional biomass is usually burnt in homes, thereby exposing household members to indoor air pollution. The use of candles and kerosene lamps as sources of lighting also creates indoor air pollution, which contains high levels of particulate matter (PM) and toxins that are hazardous to the respiratory system. Approximately one-third of the total world population (2.7 billion) relies on traditional biomass for cooking [6]. Out of this number, 754 million people are in Africa and 1.9 billion people are in developing Asia.

Indoor air pollution caused by traditional biomass is characterized by high levels of carbon monoxide, aromatic compounds, and suspended fine particles. These suspended fine particles are known to contain ash, soot, and metal elements. Suspended fine particles with diameters of 2.5 μm or less are known as $PM_{2.5}$, and those with diameters of 10 μm or less are known as PM_{10}. The World Health Organization (WHO) estimates that in homes where combustion of traditional biomass occurs, PM_{10} concentrations tend to vary daily between 303 and 3000 μg/m3, which is two to twenty times as high as the U.S. regulation standard of 150 μg/m3 [11].

Geo-referenced data on indoor air pollution in four neighborhoods in Accra, Ghana were analyzed by Ref. [12]. The study found that PM concentrations vary among neighborhoods and socioeconomic status (SES) of communities. Specifically, $PM_{2.5}$ concentrations from traditional biomass use in high and low-SES neighborhoods vary between 21 and 29 μg/m3 and 23–33 μg/m3, respectively. However, in two low-SES slums, $PM_{2.5}$ and PM_{10} concentrations were estimated to vary between 62 and 80 μg/m3 and 114–150 μg/m3, respectively.

Medical studies have found that PM engenders health problems, particularly among children, the elderly, and women. Inhaling PM causes asthma, lung cancer, cardiovascular diseases, and respiratory diseases. There is a causal relationship between exposure to PM and children's acute respiratory infections, particularly pneumonia, which might increase the death rate of children under five years old [13]. Indoor air pollution doubles the risk of pneumonia in children under five years old [11]. The same study also reports that women who use traditional biomass as their source of cooking energy are three times more likely to suffer from chronic obstructive pulmonary disease than those who cook with electricity.

Almost 1.3 million people are estimated to die prematurely each year from indoor air pollution resulting from the use of solid fuels [14]. It is also reported that 85% of these deaths can be attributed to biomass use, with the remaining 15% attributed to the use of coal. The number of premature deaths caused by indoor air pollution is highest in Southeast Asia and SSA.

2.2. Impacts on the environment

High dependence on traditional biomass has positive and negative impacts on the environment. A positive impact is the displacement of fossil fuel use leading to a reduction in air pollution and acid rain. Another positive impact is the recycling of atmospheric carbon dioxide emissions (CO_2). However, overexploitation of biomass use increases deforestation, desertification, and changes in land use.

One-third of the earth's land surface is covered by forests that provide many benefits, e.g., ecosystems provide sources of food and water for the population, and soil conservation brings biodiversity. However, biomass use erodes all these benefits via deforestation. Deforestation is a concern for developing countries because it shrinks tropical forest areas, causing a loss of biodiversity, and enhancing the greenhouse effect [15]. From 1990 to 2015, the global forest area reduced by approximately 129 million hectares [16]. A relationship between energy poverty and the environment exists via land use changes, for instance, forests converted to other land uses such as hunting and agriculture [17]. It is estimated that 7 million hectares of forest have been lost per year in tropical climate regions, which increased agricultural land area by six million hectares from 2000 to 2010 [16].

Ghana lost an average of 135,000 ha of forest per year between 1990 and 2000 [18]. Moreover, Ghana's forests decreased by 115,000 ha between the period 2000 and 2005. As a result, Ghana lost 26% of its forest cover from 1990 to 2005 making it one of the countries with the highest deforestation rates in the world at 2% per annum. In Ghana, most wood removals are used for household cooking, with the remainder used for industrial purposes. Deforestation in Ghana is also driven by other factors, such as slash and burn agriculture, rising demand for fuelwood, timber harvesting, and wildfires [19].

2.3. Impacts on the economy

One of the key components of energy poverty is the lack of access to electricity. Approximately one-fifth of the total world population (1.2 billion people) had no access to electricity in 2013 [1]. Of this number, 635 million people are in Africa and 526 million people are in developing Asia. In total, 99.8% of the total global population with no access to electricity is in developing countries. The greatest challenge to addressing electricity access is in SSA, where only 32% of the population has access to electricity, representing the lowest level in the world [1]. A lack of electricity is a major cause of poverty in most SSA countries [20].

Researchers have attempted to examine the link between access to electricity and economic development. On a macro level, some studies

[3] Ghana has 10 administrative regions. The three northern regions are the Upper East region, Upper West region, and the Northern region.

have examined the impact of electricity on different development outcomes, such as productivity, growth, and poverty reduction. Some of these studies found positive relationships between access to electricity and productivity [21–23], access to electricity and economic growth [24,25], and access to electricity and poverty reduction [21,26]. At the micro level, several studies have shown that access to electricity enhances firm productivity, creates employment, and improves household income [27,28]. In terms of education, empirical evidence shows that countries with higher levels of access to electricity tend to have higher literacy rates and lower drop-out rates, and devote significant time to reading and studying [29]. These empirical studies emphasize the importance of access to electricity in enhancing economic growth.

The IEA estimates that 7 million people in Ghana are without access to electricity. Although the electrification rate in Ghana (72%) is one of the highest among SSA countries, a major concern is the stability of the electricity supply.[4] Multiple factors such as the breakdown of thermal power plants, financial difficulties in purchasing gas from Nigeria Gas to power thermal plants, unexplored renewable energy resources, a monopolized distribution regime, distorted tariff systems, and intermittent rainfall patterns, have all accounted for the unstable electricity supply over the past years [30]. A lack of stable electricity supply is a major constraint to business activities in the country and that Ghana lost approximately 1.8% of GDP during the country's 2007 power crisis [31].[5] Similarly, a report by Ref. [32] showed that Ghana loses approximately $2.2 million daily and $686.4 million annually (translating into approximately 2% of GDP) due to the crisis.

3. Overview of interventions to energy poverty in Ghana

3.1. Electricity

Until 1990, hydropower was the only source of electricity generation in Ghana. Because of a rising population and the increasing demand for electricity from households and the industrial sector, Ghana began to use other sources of electricity such as thermal power energy (e.g., light crude oil, natural gas, and diesel fuel) and solar energy. Currently, hydropower accounts for 48.62% of the total electricity generation capacity, while thermal power and solar energy account for 50.69% and 0.69%, respectively [33]. Ghana has set a target to achieve universal access to electricity by 2020, which requires sizable investments and policy support. The nation's electrification rate currently stands at 72% compared with 31% in 1990. This increase has been attributed to a combination of policy mechanisms and institutions [1].

Ghana initiated the Economic Recovery Programme (ERP) in 1983 to reverse the continuing economic decline of the 1980s. After the economy recovered in the early 1990s, the government recognized the importance of electricity in sustaining the economy and initiated the 30-year National Electrification Programme (NEP). In 1998, the government of Ghana reduced the import duty and value-added tax (VAT) on solar and wind energy products to promote the use of renewable energy.[6] The Renewable Energy Service Project (RESPRO) was initiated to manage and extend solar energy to poor and needy communities and was coupled with the design and installation of 2000 solar panels in schools and households in 1999. The shift from hydropower to other renewable sources was further boosted in 2006 when the target for the use of renewable energy was increased to 10% in the Strategic National Energy Policy, with a plan to further increase it to 30% in rural areas by 2020. In 2010, the Ghana National Energy Policy developed a renewable energy development program to enhance the use of waste for energy production. In 2011, the Renewable Energy Law was passed to provide a legal basis for the promotion of renewable energy use.

During the focus period of this study (2005–2013), there has been a 32% increase in the country's electricity generation capacity, from 1730 MW in 2006 to 2280 MW. This can be attributed to investments in thermal and hydropower plants, such as the Tema Thermal 1 and 2 power plants (160 MW), Sunon Asogli Thermal power plant (200 MW), and Bui Hydroelectric power plant (400 MW). In 2013, Ghana began to invest in solar energy by completing the Navrongo solar power plant station, which adds approximately 3 MW to the electricity generation capacity. We expect a reduction in energy poverty in Ghana due to the significant increase in electricity generation capacity and access to electricity.

3.2. Biomass

Traditional biomass has been the main source of energy for household cooking in Ghana. Fig. 1 shows the trend in biomass consumption in Ghana from 2000 to 2015. Total biomass consumption decreased by 23.2% from 3432 ktoe in 2000 to 2784.7 ktoe in 2015. The consumption of firewood also decreased during this period, while that of charcoal increased. The decline in the consumption of biomass, particularly from 2000 to 2010, can be attributed to several programs and policies (e.g., the National LPG Programme) that have been initiated by successive governments.

A continuous increase in charcoal consumption from 2000 to 2015 might be attributed to the diffusion of efficient charcoal-burning stoves. In the early 1990s, an Ahibenso stove was introduced as an efficient stove that could reduce the consumption of biomass and indoor pollution. Available data indicate that by 1993, almost 40,000 Ahibenso stoves had been sold to households, which could save up to 18.4% of charcoal consumption. After the success story of Ahibenso stoves, the Gyapa stove was also introduced in 2002, and over 200,000 stoves were sold. This stove can save households $37 per year and conserve more than 27,606 ha of forest [34]. In addition, the use of Gyapa stoves could decrease the average $PM_{2.5}$ and carbon monoxide (CO) concentrations by 52% and 40%, respectively [35].

The UN advocates that developing countries intensify programs that encourage the use of modern cooking energy services to meet the SDGs.[7] One such modern cooking energy service is Liquefied Petroleum Gas (LPG). The government of Ghana began promoting the use of LPG as an alternative cooking fuel to traditional biomass in the early 1990s by establishing the National LPG Programme. The main targets of this program were urban households, public institutions requiring mass catering facilities, and small-scale food vendors. Although the main targets were urban households, rural households were not completely excluded. The government initiated a Unified Petroleum Price Fund (UPPF) to compensate oil companies that transport petroleum products such as LPG, to rural areas outside a radius of 200 km. Although there has been an increase in the National LPG penetration share from 6% in 2000 to 18% in 2010, Ghana failed to achieve the National LPG target of 50% in 2016 because of limited distribution outlets nationwide. In 2014, the government of Ghana launched the LPG cookstove program to freely distribute 350,000 LPG cylinders and stoves in the rural districts by the end of 2016.[8] We expect that energy poverty in Ghana in relation to biomass use has been reduced because of the various programs outlined above.

[4] Energy poverty does not directly measure power outages. Ghana has been experiencing a power crisis over the past few years.

[5] Some of the main reasons for the 2007 power crisis include poor rainfall and the non-availability of sufficient reliable thermal power generators.

[6] As of 2002, a zero import duty has been applied to solar, wind, and thermal generating sets as well as solar cells and panels (http://www.ghanaweb.com/GhanaHomePage/economy/import_duty.php).

[7] http://www.unfoundation.org/what-we-do/issues/energy-and-climate/clean-energy-development.html.

[8] http://www.graphic.com.gh/news/general-news/govt-launches-lpg-cook-stove-programme.html.

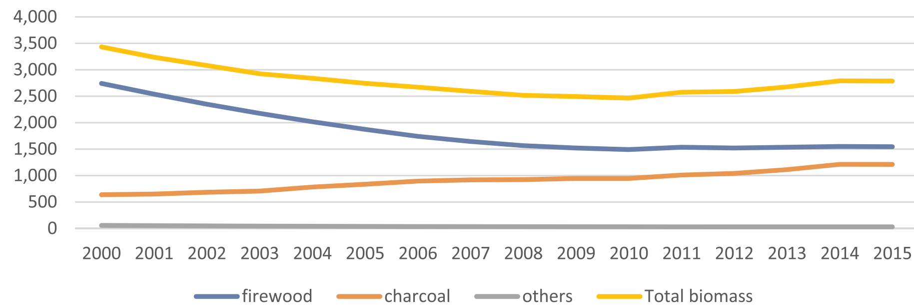

Fig. 1. Biomass Consumption, 2000 to 2015 (in ktoe).
Note: Others include saw dust, saw mill residue, agricultural residue, and animal dung.
Source: [36,37].

Table 1
Dimensions and respective indicators with cut-offs including relative weights in parentheses.

Dimension	Indicator (*weight*)	Variables	Deprivation cut-off (energy poor if …)
Cooking	Modern cooking fuel *(0.205)*	Type of cooking fuel	Any fuel use besides electricity, LPG, kerosene, natural gas, or biogas.
	Indoor pollution *(0.205)*	Food cooked on stove or open fire (no hood/chimney), indoor, if using any fuel beside electricity, LPG, natural gas, or biogas.	True
Lighting	Electricity access *(0.20)*	Has access to electricity	False
Services provided by means of household appliances	Household appliance ownership *(0.13)*	Has a fridge	False
Entertainment/education	Entertainment/education appliance ownership *(0.13)*	Has a radio OR television	False
Communication	Telecommunication means *(0.13)*	Has a phone land line OR mobile phone	False

Source: [8].

4. Methodology and data

4.1. Data

Data for this study were extracted from the fifth and sixth rounds of the Ghana Living Standards Survey (GLSS V and GLSS VI) conducted by the Ghana Statistical Service in 2005/06 and 2012/13, respectively. The GLSS V and VI are nationwide household surveys designed to collect detailed information including demographic characteristics, education, health, employment and time use, migration and tourism, fuel use, housing conditions, household agriculture, access to financial services, and asset ownership [38]. The GLSS V covered a nationally representative sample of 8687 households, whereas the GLSS VI covered 16,772 households. This study uses 8312 households from GLSS V and 14,918 households from GLSS VI because these households have complete information on main cooking fuel, electricity access, and household appliance ownership.

Several studies have used the GLSS to investigate household fuel choice in Ghana [39–42]. However, these studies mainly focused on the determinants of cooking fuel choice. In contrast to these studies, our study addresses the dynamics of energy poverty.

4.2. Methodology

This study employs the Multidimensional Energy Poverty Index (MEPI) constructed by Ref. [8] as a measure of energy poverty. The MEPI captures a set of energy deprivations that may affect a household. The methodology of MEPI is based on the Oxford Poverty and Human Development Initiative [43] inspired by Amartya Sen's contribution to the discussion on deprivations and capabilities [44]. The index is originally composed of five dimensions representing basic energy services with six indicators (Table 1).

In constructing the MEPI, the five dimensions can be equally weighted so that each dimension is given a 0.2 weight. However, because of the importance of the cooking and lighting dimensions to energy poverty, these two dimensions are given higher weights compared with the other three dimensions. In addition, because cooking is one, if not the most basic, energy need in a typical Ghanaian household, it is given a slightly higher weight compared with lighting. Thus, each indicator in the cooking dimension is weighed slightly higher than the indicator for lighting. This leads to a weight of 0.205 for each of the two indicators in the cooking dimension and a weight of 0.20 for lighting. The remaining weight of 0.39 is shared equally among the last three dimensions, which are contingent on electricity access.[9] A sensitivity analysis with regards to the choice of weight is discussed in Section 5.4.

The mathematical model for constructing MEPI is as follows [8]. Assume that there are n individuals and d dimensions. Then, $Y = [y_{ij}]$ represents the $d * n$ matrix of achievements for individuals across variables. Each row vector $y_i = (y_{i1}, y_{i2, \ldots,} y_{id})$ represents individual i's achievement in the different variables, and each column vector $y_j = (y_{1j}, y_{2j\ldots,} y_{nj})$ gives the distribution of achievements in the variable j across individuals. A weighting vector w is defined as $\sum_{j=1}^{d} w_j = 1$. z_j is defined as the deprivation cut-off in variable j to identify all individuals deprived in any of the variables. Let $g = [g_{ij}]$ denote the deprivation matrix with an element defined as $g_{ij} = w_j$ when $y_{ij} < z_j$, and $g_{ij} = 0$ when $y_{ij} \geq z_j$. A column vector c_i represents the *ith* entry of deprivation and is defined as the sum of weighted deprivations suffered by individual i: $c_i = \sum_{j=1}^{d} g_{ij}$. A cut-off, $k > 0$, is set so that a person is considered multidimensionally energy poor if the weighted deprivation count c_i exceeds k. Therefore, $c_i(k) = 0$ when $c_i \leq k$, and $c_i(k) = c_i$ when $c_i > k$.[10] Following [8], k is set at 0.33, implying that a person is energy poor if deprived of at least one-third of total deprivations.

[9] The assignment of weights as argued by Ref. [8] is an arbitrary and value-driven process. In our study, we basically retain the weights used in Ref. [8] for the ease of comparison.

[10] $c(k)$ denotes the censored vector of deprivation counts and differs from c in that it counts zero deprivation for persons not identified as multidimensionally energy poor.

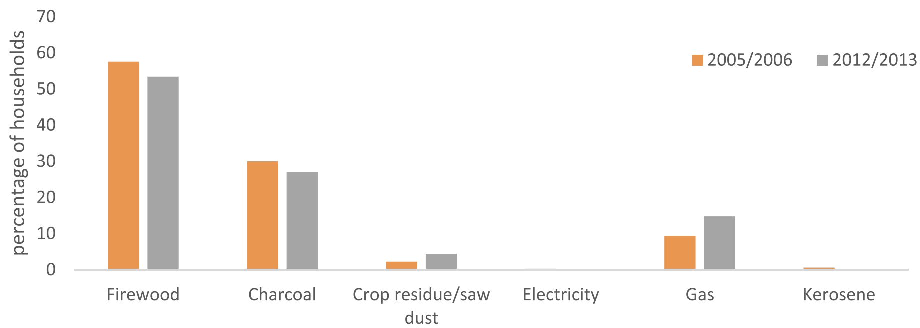

Fig. 2. Distribution of households by cooking energy source.
Source: Author's computation using GLSS V and GLSS VI.

The MEPI is computed by multiplying the headcount ratio (share of people identified as energy poor) and the average intensity of energy poverty. The headcount ratio H is defined as $H = {}^{q}/_{n}$ where q is the number of people that are energy poor, and n is the total number of people.[11] On the other hand, the average intensity of energy poverty, A, is defined as $A = \sum_{i=1}^{n} {}^{c_i(k)}/_{q}$. The MEPI has advantages compared with other energy poverty metrics. First, it can be decomposed into different sub-groups and dimensions because of its robust functional form. For instance, the MEPI can be calculated for households in the rural and urban areas or for high- and low-income households. The decomposability of the MEPI allows for a wide range of analyses that are not possible with other energy poverty metrics. Moreover, it focuses on the deprivation of energy services as opposed to extracting information indirectly through variables such as energy or electricity consumption [8]. More importantly, it can capture both the incidence and intensity of energy poverty.

Since the dataset is obtained from a survey, sampling weights are applied in the estimation of the MEPI to adjust for disproportionate sampling and non-response. This ensures that the MEPI estimates from the sample data are representative of the population.

5. Results

5.1. Cooking energy sources

Fig. 2 shows the distribution of households by each cooking energy source in 2005/2006 and 2012/2013. The figure shows that most households in Ghana use firewood for cooking followed by charcoal, gas, crop residue/sawdust, kerosene, and electricity. The results indicate a decline in the percentage of households that depend on firewood during the two periods (from 57.54% to 53.39%), electricity (from 0.28% to 0.23%), charcoal (from 30.02% to 27.07%), and kerosene (from 0.59% to 0.15%). On the other hand, there was an increase in the percentage of households that depend on gas (from 9.35% to 14.75%) and crop residue/sawdust (from 2.23% to 4.41%). The increase in the percentage of households depending on gas can be attributed to the implementation of the National LPG Programme, which has led to an increase in the National LPG penetration share from 6% in 2000 to 18% in 2010.

In summary, there was a slight decline in the percentage of households depending on traditional cooking energy sources (i.e., firewood, crop residue/sawdust, and charcoal) from 89.79% to 84.88% during the study period. This decline indicates some gains in government efforts to reduce dependence on traditional biomass. On the other hand, there was an increase in the percentage of households depending on modern cooking energy sources (i.e., kerosene, gas, and electricity) from 10.21% to 15.12%,[12] which indicates a gradual transition from the use of traditional cooking energy sources to modern sources.[13]

The distribution of household cooking energy sources is further decomposed by the locations of households in Table 2.[14] Over 80% of rural households use firewood as their main cooking fuel during the study period. Including charcoal and crop residue/sawdust, most rural households use traditional biomass as the main cooking fuel. In contrast, about half of the urban households use charcoal as their main cooking fuel. Including charcoal and crop residue/sawdust, urban households depend on traditional biomass as their main cooking fuel to a lesser extent than rural households. Moreover, urban households' dependence on traditional biomass decreased from 77% to 70% during the period. A significant number of urban households use gas as their main cooking fuel, with this share increasing from 22% to 30% in the same period.

There are marginal declines in the percentage of rural households using firewood (from 83.11% to 80.33%), electricity (from 0.08% to 0.05%), and kerosene (from 0.16% to 0.13%) between 2005/2006 and 2012/2013. On the other hand, there are increases in the percentage of rural households using charcoal (from 11.83% to 12.62%) and gas (from 1.12% to 3.72%). The biggest change is in rural households' use of gas, which saw an increase of 2.6% points during the study period. For urban households, there are slight declines in the percentages of households using firewood (from 19.35% to 17.61%), kerosene (from 1.23% to 0.17%), charcoal (from 57.19% to 46.30%), and electricity (from 0.57% to 0.47%). However, there are increases in the percentages of urban households using gas (from 21.63% to 29.38%) and crop residue/sawdust (from 0.03% to 6.08%). An interesting finding is that while firewood is the major cooking fuel for rural households, urban households mainly use charcoal.

In summary, the data show an increase in the use of modern cooking energy sources by urban households (from 23.43% to 30.02%) and rural households (from 1.30% to 3.90%). At the same time, there is a decrease in the use of traditional cooking energy sources by urban households (from 76.57% to 69.98%) and rural households (from 98.70% to 96.10%).[15] This indicates a wide disparity in the use of modern and traditional cooking energy sources between urban and rural households.

Table 3 shows the regional differences in the use of modern and traditional cooking energy sources. The table indicates a decline in the use of traditional cooking energy sources across all 10 regions from 2005/2006 to 2012/2013. Except for the Greater Accra region, at least

[11] The unit of analysis is the household. However, we include the number of persons per household in the computation of the headcount ratio and the average censored weighted deprivation.

[12] See Figure A in the Appendix section.

[13] Some households in Ghana use multiple cooking fuels (fuel stacking). The data used in this study, however, only collect information on the main cooking fuel. Thus, this study omits the complementary use of other cooking fuels.

[14] An "Urban area" is a locality with at least 5000 inhabitants; otherwise, it is a "rural area."

[15] See Table A in the Appendix section.

Table 2
Distribution of household cooking energy sources by area of residence (%).

	GLSS V (2005/2006)		GLSS VI (2012/2013)	
Main cooking fuel	Area of residence		Area of residence	
	Rural	Urban	Rural	Urban
Firewood	83.11	19.35	80.33	17.61
Crop residue/saw dust	3.70	0.03	3.15	6.08
Charcoal	11.83	57.19	12.62	46.30
Electricity	0.08	0.57	0.05	0.47
Gas	1.12	21.63	3.72	29.38
Kerosene	0.16	1.23	0.13	0.17
Total	100.00	100.00	100.00	100.00

Source: Author's computation using GLSS V and GLSS VI.

Table 3
Distribution of household cooking energy source types by region (%).

	GLSS V (2005/2006)		GLSS VI (2012/2013)	
Region	Modern	Traditional	Modern	Traditional
Western	7.81	92.19	22.47	77.53
Central	14.99	85.01	14.99	85.01
Greater Accra	38.04	61.96	44.10	55.90
Volta	4.92	95.08	9.36	90.64
Eastern	6.00	94.00	10.20	89.80
Ashanti	11.88	88.12	24.54	75.46
Brong Ahafo	3.63	96.37	9.47	90.53
Northern	1.04	98.96	2.33	97.67
Upper East	0.51	99.49	4.67	95.33
Upper West	1.80	98.20	4.24	95.76

Source: Author's computation using GLSS V and GLSS VI.

75% of the households in each region depend on traditional cooking energy sources for cooking. Households in the Northern, Upper East, and Upper West regions have the largest shares of households that depend on traditional energy sources compared with the other regions. This is not surprising because the monetary poverty rates in these three regions are the highest in Ghana. Monetary poverty rates in Northern, Upper East, and Upper West regions are far higher than the poverty rates in the other regions as estimated by Ref. [45] as 50.4%, 44.4%, and 70.7%, respectively.[16] The table also shows an increase in the use of modern cooking energy sources across all regions between the two periods. The Northern, Upper East, and Upper West regions have the lowest shares of households depending on modern cooking energy sources. The Western region had the largest decline in the use of traditional cooking energy sources and the largest increase in the use of modern cooking energy sources. This can be attributed to the decline in monetary poverty levels in the region. Western region had the largest drop in monetary poverty levels, from 59.6% in 1992 to 20.9% in 2013 [45].

5.2. Access to electricity

Fig. 3 shows the distribution of households with access to electricity. The figure indicates that access to electricity has improved over the study period. Specifically, the share of households with access to electricity increased from 44.68% to 59.20%. This can be attributed to investments in thermal and hydropower plants such as the Tema Thermal 1 and 2 power plants, the Sunon Asogli Thermal power plant, and the Bui Hydroelectric power plant. Access to electricity in rural areas improved by 16.59% points compared with 8.07% points for urban households during the study period. As expected, households in urban areas have a much higher electrification rate compared with rural households (Fig. 3). Access to electricity has improved in all regions (Fig. 4). While the Northern, Upper East, and Upper West regions continue to have the lowest share of households with access to electricity, there have been increases in the share of households with access to electricity in these three regions.

5.3. Construction of MEPI

Table 4 shows the percentage of people deprived of each energy service. The results indicate that the cooking dimension has the largest percentage of people deprived of the energy service. Specifically, more than 80% of people in Ghana are deprived of access to modern cooking fuel and modern cooking stoves. This figure declined marginally from 89.8% in 2005/2006 to 84.9% in 2012/2013. The decline between the two periods can also be observed for other indicators. The telecommunication indicator showed the largest improvement, with a drastic decline in deprivation from 81.1% to 25.6%. This can be attributed to the rapid increase in the mobile phone penetration rate in Ghana. According to the International Telecommunication Union (ITU) of the United Nations, mobile phone subscriptions in Ghana increased dramatically from 0.1 million in 2000 to 35 million in 2015 [46].

Table 5 also shows the overall energy poverty measure, headcount ratio, and the average intensity of energy poverty in Ghana in 2005/2006 and 2012/2013. The overall energy poverty rates in Ghana are 0.70 in 2005/2006 and 0.57 in 2012/2013. The results also indicate that the share of people who are energy poor was 88.4% in 2005/2006 and 82.5% in 2012/2013. Although there has been a statistically significant decline in the overall energy poverty in Ghana during these two periods, the incidence of energy poverty remains high.[17]

Energy poverty and headcount ratio are further decomposed by the area of residence (Table 6). As expected, the results indicate high energy poverty in rural areas compared with urban areas. Specifically, the share of rural people who are energy poor was 98.3% in 2005/2006 and 95.3% in 2012/2013. On the other hand, the proportion of energy poor urban people was 73.5% in 2005/2006 and 65.5% in 2012/2013. Thus, the results suggest greater improvement in the reduction of energy poverty among urban dwellers. Moreover, overall energy poverty rates in the rural areas were 0.838 and 0.706, whereas the overall energy poverty rates in the urban areas were 0.496 and 0.382 in 2005/2006 and 2012/2013, respectively. In other words, rural people are almost twice as energy poor as urban people.

Energy poverty can be further decomposed by region (Table 7). There has been reduction in energy poverty in all regions during the study period. The lowest incidence of energy poverty during the two periods is observed in the Greater Accra region, with 61.6% and 54.2% of people estimated as energy poor in 2005/2006 and 2012/2013, respectively. This is not surprising since this region has the highest percentage of households with access to electricity (Fig. 4) and the highest percentage of households depending on modern cooking energy sources (Table 2). At the same time, the Greater Accra region has had the lowest monetary poverty rates among the 10 regions since the year 1992, which could partly explain the region having the lowest energy poverty rates over these two periods [45]. Income has been pointed out as a key determinant for the choice of modern cooking fuel in Ghana [41,42]. The highest energy poverty rates during the two periods continue to be observed in the Northern, Upper East, and Upper West regions. Energy poverty was highest in the Upper West and Upper East regions in 2005/2006 and 2012/2013, respectively.

[16] The monetary poverty analysis is based on the consumption per adult equivalent using the standard Foster, Greer, and Thorbecke (FGT) poverty indices.

[17] A t-test was conducted to ascertain the statistical significance of the decrease in the overall energy poverty rates. A p-value of 0.003 led to the conclusion that the decrease is statistically significant at 5%.

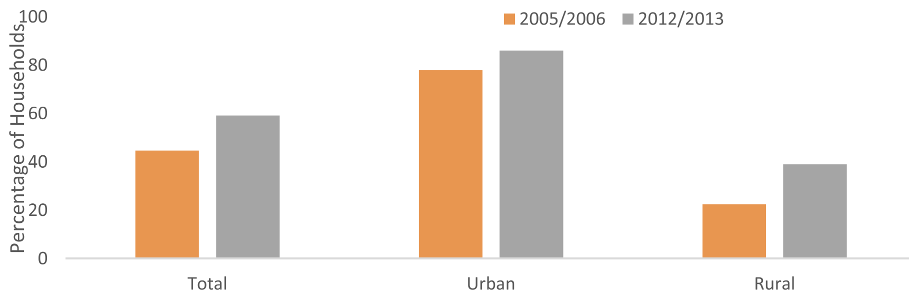

Fig. 3. Distribution of households with access to electricity, 2005 to 2013 (%).
Source: Author's computation using GLSS V and GLSS VI.

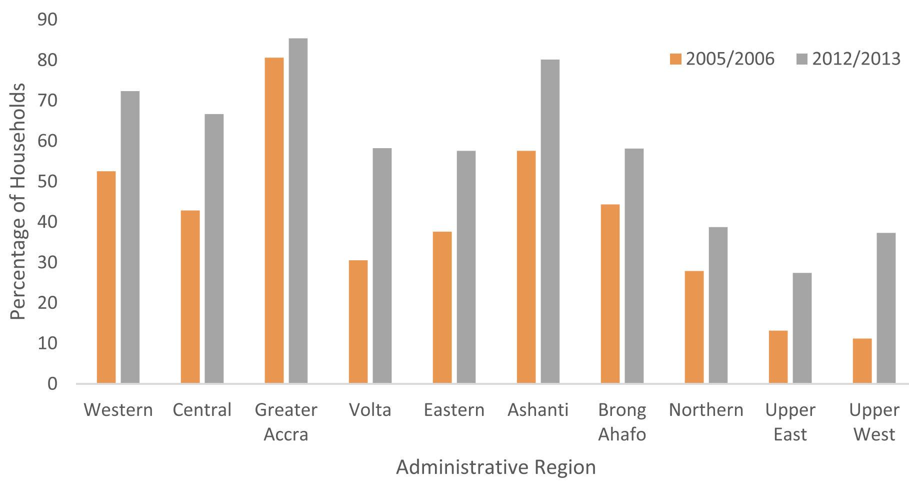

Fig. 4. Distribution of households with access to electricity by region, 2005 to 2013 (%).
Source: Author's computation using GLSS V and GLSS VI.

Table 4
Summary of deprivation indicators, 2005 to 2013.

			GLSS V (2005/2006)	GLSS VI (2012/2013)
Indicator	Type	Weight	Deprived (%)	Deprived (%)
Domain 1				
Modern cooking fuel	Binary	0.205	89.8	84.9
Indoor pollution	Binary	0.205	81.2	80.0
Domain 2				
Electricity access	Binary	0.20	55.3	40.8
Domain 3				
Household appliance ownership (fridge)	Binary	0.13	80.2	75.1
Domain 4				
Entertainment/education appliance ownership (radio or television)	Binary	0.13	31.9	25.0
Domain 5				
Telecommunication means (phone land line or mobile phone)	Binary	0.13	81.1	25.6

Source: Authors' estimation.

5.4. Sensitivity analysis

This paper conduct two different sensitivity analysis to test the robustness of the results. First, the MEPI results may be vulnerable to the cut-off set at 0.33. Following [8], the cut-off of multidimensional energy poverty, k, is varied to examine the impact on MEPI and H for all sub-groups (rural, urban, and the 10 administrative regions). To test the robustness, the cut-off, k, is varied using 0.20 and 0.40. The results are presented in Tables C, D, E, and F in the Appendix section. The results indicate that changes in the energy poverty cut-offs do not lead to significant changes in the values of MEPI and H (incidence of energy poverty). A key observation is that the values of MEPI and H begin to decrease when the cut-off increases from 0.2 to 0.33 and 0.40.

Also, the MEPI results may be sensitive to the weights assigned to the dimensions. Following [47], the rank sum method of assigning weights is used. Before assigning the weights, the appliance dimension, education/entertainment dimension and communication dimension are grouped into one main dimension called the “other measures.” Hence,

Table 5
Summary of MEPI measures, 2005 to 2013.

	GLSS V (2005/2006)		GLSS VI (2012/2013)	
Index	Estimate	Std. Error	Estimate	Std. Error
Main				
MEPI	0.701	0.0034	0.567	0.0026
Additional				
H (Headcount ratio)	0.884	0.0035	0.825	0.0031
A (Average intensity)	0.793	0.0021	0.687	0.0017

Source: Authors' estimation.

Table 6
Summary of MEPI measures by area of residence, 2005 to 2013.

	GLSS V (2005/2006)			GLSS VI (2012/2013)		
Index	Area of Residence Urban	Rural	Total	Area of Residence Urban	Rural	Total
Main						
MEPI	0.496	0.838	0.701	0.382	0.706	0.567
Additional						
H (Headcount ratio)	0.735	0.983	0.884	0.655	0.953	0.825
Population share (%)	40.1	59.9	100	42.9	57.1	100

Source: Authors' estimation.

Table 7
Summary of MEPI measures by region, 2005 to 2013.

	GLSS V (2005/2006)			GLSS VI (2012/2013)		
Region	H	MEPI	Population share	H	MEPI	Population share
Western	0.918	0.707	0.099	0.739	0.468	0.102
Central	0.909	0.723	0.081	0.845	0.563	0.097
Greater Accra	0.616	0.400	0.137	0.542	0.308	0.104
Volta	0.948	0.794	0.085	0.888	0.615	0.096
Eastern	0.923	0.737	0.106	0.854	0.585	0.108
Ashanti	0.840	0.624	0.174	0.705	0.425	0.116
Brong Ahafo	0.956	0.758	0.093	0.872	0.590	0.096
Northern	0.982	0.839	0.093	0.971	0.718	0.106
Upper East	0.990	0.862	0.071	0.946	0.737	0.089
Upper West	0.978	0.883	0.060	0.945	0.730	0.085
Total	0.884	0.701	1.000	0.825	0.567	1.000

Source: Authors' estimation.

the five dimensions have now been reduced to only three dimensions which are ordered based on the relative importance of the individual dimensions. To compute the weight using the rank sum method, the following formula is used.

$$w_{ti} = \frac{K - r_i + 1}{\sum_{j=1}^{K} K - r_i + 1}$$

where r_i is the rank of the ith objective, and K is the total number of objectives. Using the above formula, a weight of 0.50, 0.33 and 0.17 are calculated for the dimensions; cooking, lighting and other measures respectively. Following [47], two ordering schemes are used− the first, cooking, lighting and other measures: and the second, lighting, cooking and other measures. The weight is equally divided if a dimension has more than one indicator, similar to the assignment of weights in Table 3. The results are presented in Tables G, H, I and J in the Appendix section. The results indicate that changes in the weights of the dimensions do not also lead to significant changes in the values of MEPI and H (incidence of energy poverty). Thus, MEPI and H are robust to the weights and cut-offs used in the index construction.

6. Summary and conclusions

Energy plays a vital role in the development and transformation of every country. Access to modern energy services is a key to achieve the SDGs. Energy poverty is a measure that provides important information on household dependence on both traditional and modern energy services. Thus, it is helpful to measure the extent to which a country has made progress toward sustainable development.

In Ghana, as in many SSA countries, a high percentage of households depend on traditional biomass as their main source of energy for cooking. At the same time, about a quarter of the population of Ghana does not have access to electricity. Given this background, this study investigated the dynamics of energy poverty in Ghana using the MEPI as a measure of energy poverty. This study sought to ascertain whether there has been some significant transition from traditional biomass use to modern energy using two nationally representative cross-sectional datasets: the GLSS V in 2005/2006 and GLSS VI in 2012/2013.

The results of this study indicate a decline in the use of biomass as a cooking energy source by households between the two study periods. At the same time, there has been an increase in the percentage of households with access to electricity. However, the results show a wide disparity between urban and rural households in the use of traditional cooking energy sources as well as access to electricity. There is also a large gap between urban and rural energy poverty since rural people are almost twice as energy poor as urban people. In terms of regional decomposition, there has been a reduction in energy poverty in all regions between the two periods, although energy poverty is still high in the Upper West and Upper East regions. The study's conclusion is that there has been some progress in alleviating energy poverty in Ghana, but much more must be done in terms of policy interventions to reduce energy poverty.

The results of this study showed that cooking dimension had the largest percentage of people deprived of energy service. Also, the cooking dimension contributes more than 49% to energy poverty in Ghana (Table B in the Appendix section). This implies that addressing issues regarding cooking fuels could largely help in reducing energy poverty in Ghana. Ghana has implemented the Rural LPG program which supplies LPG cylinders and cookstoves to rural households with the aim of reducing deforestation and increasing the usage of modern cooking fuels. One of the major challenges of this program is the financial constraint faced by beneficiaries to sustain the use of LPG cylinders and stoves [41,48]. Therefore, this study recommends a mechanism to identify these group of beneficiaries with the goal of providing some form of financial incentives to help sustain their usage of LPG. Identification of potential beneficiaries would require establishing monitoring and evaluation systems to effectively obtain feedbacks from these beneficiaries. These monitoring and evaluation systems could also facilitate the scaling up of the rural LPG program. Another major challenge with regards to the usage of LPG is supply constraints particularly in the Northern, Upper East and Upper West regions of Ghana. Out of the 641 LPG filling stations in Ghana, only 33 (representing 5%) are located in these three regions [48]. Hence, there is the need to increase the number of LPG filling stations in these regions to help reduce supply difficulties, thereby reducing energy poverty in Ghana. These energy poverty reduction strategies should be incorporated into income poverty reduction strategies to improve not only access to modern energy but also in terms of affordability.

Declaration of interest statement

No potential conflict of interest was reported by the authors.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

We acknowledge helpful comments from participants at the East Asian Association of Environmental and Resource Economists (EAAERE) 2017 in Singapore. We also wish to acknowledge comments and suggestions from an anonymous reviewer and the editor.

Appendix

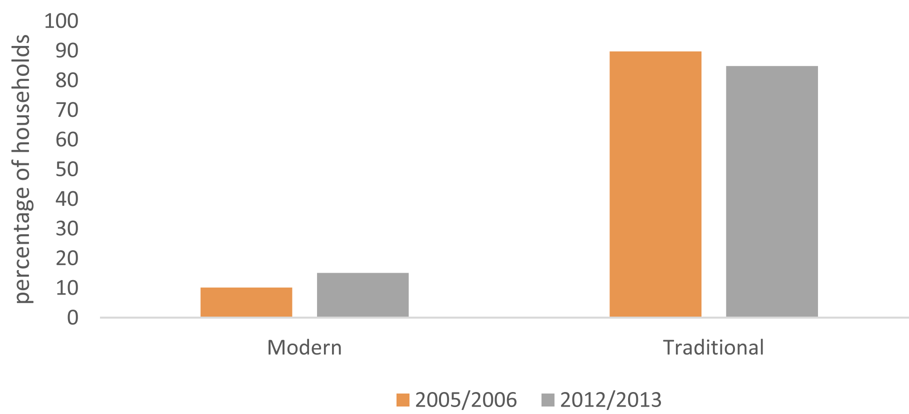

Fig. A. Distribution of households by type of cooking energy source.

Table A
Distribution of households' type of cooking energy source by area of residence

	GLSS V (2005/2006)		GLSS VI (2012/2013)	
Main cooking fuel	Area of residence		Area of residence	
	Rural (%)	Urban (%)	Rural (%)	Urban (%)
Modern	1.30	23.43	3.90	30.02
Traditional	98.70	76.57	96.10	69.98
Total (%)	100.00	100.00	100.00	100.00

Table B
Each indicator's contribution to MEPI

	GLSS V (2005/2006)	GLSS VI (2012/2013)
Indicator	MEPI	MEPI
Domain 1		
Modern cooking fuel	0.254	0.294
Indoor pollution	0.237	0.285
Domain 2		
Electricity access	0.157	0.143
Domain 3		
Household appliance ownership (fridge)	0.146	0.165
Domain 4		
Entertainment/education appliance ownership (radio or television)	0.059	0.056
Domain 5		
Telecommunication means (phone land line or mobile phone)	0.148	0.057
Total	**1**	**1**

Table C
Robustness results of MEPI measures, 2005 to 2013.

	GLSS V (2005/2006)		GLSS VI (2012/2013)	
k (cut-off)	H	MEPI	H	MEPI
0.20	0.942	0.713	0.883	0.579
0.33	0.884	0.701	0.825	0.567
0.40	0.844	0.681	0.795	0.557

Note: 0.33 is the baseline cut-off used in the main results.

Table D
Robustness results of MEPI measures by area of residence, 2005 to 2013.

k (cut-off)	GLSS V (2005/2006)				GLSS VI (2012/2013)			
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
	H	H	MEPI	MEPI	H	H	MEPI	MEPI
0.20	0.990	0.841	0.843	0.519	0.974	0.761	0.711	0.405
0.33	0.983	0.735	0.838	0.496	0.953	0.655	0.706	0.382
0.40	0.970	0.682	0.834	0.479	0.940	0.602	0.702	0.365

Note: 0.33 is the baseline cut-off used in the main results.

Table E
Robustness results of MEPI measures by region, 2005/2006

k (cut-off)	0.20		0.33		0.40	
	H	MEPI	H	MEPI	H	MEPI
Western	0.923	0.721	0.918	0.707	0.904	0.717
Central	0.931	0.734	0.909	0.723	0.909	0.726
Greater Accra	0.620	0.438	0.616	0.400	0.603	0.420
Volta	0.952	0.815	0.948	0.794	0.930	0.800
Eastern	0.943	0.754	0.923	0.737	0.929	0.747
Ashanti	0.852	0.703	0.840	0.624	0.836	0.644
Brong Ahafo	0.964	0.802	0.956	0.758	0.944	0.768
Northern	0.990	0.902	0.982	0.839	0.880	0.849
Upper East	0.993	0.932	0.990	0.862	0.890	0.872
Upper West	0.981	0.914	0.978	0.883	0.965	0.893

Note: 0.33 is the baseline cut-off used in the main results.

Table F
Robustness results of MEPI measures by region, 2012/2013.

k (cut-off)	0.20		0.33		0.40	
	H	MEPI	H	MEPI	H	MEPI
Western	0.812	0.484	0.739	0.468	0.709	0.458
Central	0.897	0.574	0.845	0.563	0.799	0.588
Greater Accra	0.664	0.335	0.542	0.308	0.478	0.478
Volta	0.923	0.623	0.888	0.615	0.865	0.608
Eastern	0.920	0.598	0.854	0.585	0.823	0.574
Ashanti	0.807	0.447	0.705	0.425	0.654	0.408
Brong Ahafo	0.927	0.602	0.872	0.590	0.850	0.583
Northern	0.982	0.720	0.971	0.718	0.969	0.717
Upper East	0.965	0.741	0.946	0.737	0.931	0.732
Upper West	0.967	0.735	0.945	0.730	0.936	0.727

Note: 0.33 is the baseline cut-off used in the main results.

Table G
MEPI measures based on rank sum weighted method (2005–2013)

	Energy Poverty (Baseline)		Energy Poverty (Rank Sum Weighted)-1		Energy Poverty (Rank Sum Weighted)-2	
	H	MEPI	H	MEPI	H	MEPI
GLSS V (2005/2006)	0.884	0.701	0.873	0.677	0.803	0.608
GLSS VI (2012/2013)	0.825	0.567	0.803	0.541	0.799	0.518

Note: Energy Poverty (Rank Sum Weighted)-1 is based on the cooking, lighting and other measures ordering of dimensions and Energy Poverty (Rank Sum Weighted)-2 is based on lighting, cooking and other measures.

Table H
MEPI measures based on rank sum weighted method by area of residence (2005–2013)

	Energy Poverty (Baseline)		Energy Poverty (Rank Sum Weighted)-1		Energy Poverty (Rank Sum Weighted)-2	
	H	MEPI	H	MEPI	H	MEPI
GLSS V (2005/2006)						
Rural	0.983	0.838	0.964	0.804	0.914	0.801
Urban	0.735	0.496	0.704	0.432	0.702	0.423
GLSS VI (2012/2013)						
Rural	0.953	0.706	0.904	0.714	0.900	0.704
Urban	0.655	0.382	0.592	0.340	0.584	0.324

Note: Energy Poverty (Rank Sum Weighted)-1 is based on the cooking, lighting and other measures ordering of dimensions and Energy Poverty (Rank Sum Weighted)-2 is based on lighting, cooking and other measures.

Table I
MEPI measures based on rank sum weighted method by region (2005/2006)

	Energy Poverty (Baseline)		Energy Poverty (Rank Sum Weighted)-1		Energy Poverty (Rank Sum Weighted)-2	
	H	MEPI	H	MEPI	H	MEPI
Western	0.918	0.707	0.898	0.698	0.754	0.700
Central	0.909	0.723	0.897	0.710	0.804	0.720
Greater Accra	0.616	0.400	0.605	0.396	0.500	0.404
Volta	0.948	0.794	0.931	0.790	0.875	0.782
Eastern	0.923	0.737	0.908	0.725	0.809	0.706
Ashanti	0.840	0.624	0.823	0.609	0.732	0.682
Brong Ahafo	0.956	0.758	0.949	0.708	0.890	0.725
Northern	0.982	0.839	0.973	0.824	0.965	0.806
Upper East	0.990	0.862	0.988	0.858	0.907	0.884
Upper West	0.978	0.883	0.963	0.879	0.924	0.859

Note: Energy Poverty (Rank Sum Weighted)-1 is based on the cooking, lighting and other measures ordering of dimensions and Energy Poverty (Rank Sum Weighted)-2 is based on lighting, cooking and other measures.

Table J
MEPI measures based on rank sum weighted method by region (2012/2013)

	Energy Poverty (Baseline)		Energy Poverty (Rank Sum Weighted)-1		Energy Poverty (Rank Sum Weighted)-2	
	H	MEPI	H	MEPI	H	MEPI
Western	0.739	0.468	0.709	0.461	0.717	0.444
Central	0.845	0.563	0.834	0.559	0.804	0.543
Greater Accra	0.542	0.308	0.534	0.300	0.502	0.298
Volta	0.888	0.615	0.876	0.609	0.818	0.606
Eastern	0.854	0.585	0.804	0.569	0.796	0.543
Ashanti	0.705	0.425	0.700	0.408	0.690	0.414
Brong Ahafo	0.872	0.590	0.868	0.576	0.846	0.531
Northern	0.971	0.718	0.970	0.711	0.954	0.704
Upper East	0.946	0.737	0.938	0.731	0.921	0.727
Upper West	0.945	0.730	0.941	0.728	0.923	0.711

Note: Energy Poverty (Rank Sum Weighted)-1 is based on the cooking, lighting and other measures ordering of dimensions and Energy Poverty (Rank Sum Weighted)-2 is based on lighting, cooking and other measures.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rser.2019.06.038.

References

[1] IEA. World energy outlook. Paris: International Energy Agency; 2015.
[2] Reddy AKN. Energy and social issues. In: Goldemberg J, Ba-N'daw S, Khatib H, Popescu A, Viray FL, editors. World energy assessment: energy and the challenges of sustainability. United Nations Development Programme; 2000. p. 39–58.
[3] Li K, Lloyd B, Liang XJ, Wei YM. Energy poor or fuel poor: what are the differences? Energy Policy 2014;68:476–81.
[4] Ismail Z, Khembo P. Determinants of energy poverty in South Africa. J Energy South Afr 2015;26:66–78.
[5] Ogwumike OF, Ozughalu UM. Analysis of energy poverty and its implications for sustainable development in Nigeria. Environ Dev Econ 2015;21:1–18.
[6] Barnes D, Khandker SR, Samad HA. Energy access, efficiency and poverty: how many households are energy poor in Bangladesh. World Bank Pol Res Working Paper 2010;5332:1–48.
[7] Foster V, Tre J, Wodon Q. Energy prices, energy efficiency and fuel poverty. 2000http://info.worldbank.org/etools/docs/voddocs/240/502/Gua_price.pdf, Accessed date: 10 January 2017.
[8] Nussbaumer P, Bazilian M, Modi V. Measuring energy poverty: focusing on what matters. Renew Sustain Energy Rev 2012;16:231–43.
[9] Pachauri S, Spreng D. Energy use and energy access in relation to poverty. Econ Pol Wkly 2004;39:271–8.
[10] Wang K, Ya-Xuan W, Kang L, Yi-Ming W. Energy poverty in China: an index based comprehensive evaluation. Renew Sustain Energy Rev 2015;47:308–23.
[11] WHO. Fuel for life: household energy and health. Ginebra: World Health Organization; 2006.
[12] Zhou Z, Dionisio KL, Arku RE, Quaye A, Hughes AF, Vallarino J, Ezzati M. Household and community poverty, biomass use, and air pollution in Accra, Ghana. Proc Natl Acad Sci Unit States Am 2011;108:11028–33.
[13] IEA. Focus on energy poverty. World energy outlook. Paris: International Energy Agency; 2007.
[14] WHO. Global health risk assessment. Geneva: World Health Organization; 2009.
[15] Chakravarty S, Ghosh SK, Suresh CP, Dey AN, Shukla G. Deforestation: causes, effects and control strategies. In: Akais CA, editor. Global perspectives on sustainable forest management. Rikeka: InTech Publishing Inc; 2012. p. 1–28.
[16] Food and Agriculture Organization (FAO). Global forests resources assessment main report. 2015.
[17] Gonzalez-Eguino M. Energy poverty: an overview. Renew Sustain Energy Rev 2015;47:377–85.
[18] Food and Agriculture Organization (FAO). Global forest resources assessment main report. 2007.
[19] Gyampoh B. Deforestation in Ghana: government's incentives and policies. 2011http://benjigyampoh.blogspot.jp/2011/10/deforestation-in-ghana-governments.html, Accessed date: 15 December 2016.
[20] Brew-Hammond A, Kemausuor F. Energy for all in Africa-to be or not to be? Curr Opin Environ Sustain 2009;1:83–8.
[21] Fan S, Jitsuchon S, Methakunnavut N. The importance of public investment for reducing rural poverty in middle-income countries: the case of Thailand. Int Food Pol Res Inst DSGD Discuss Pap 2004;7:1–54.
[22] Fedderke J, Bogetic Z. Infrastructure and growth in South Africa: direct and indirect productivity impacts of nineteen infrastructure measures. World Bank Pol Res Working Paper 2006;3989:1–48.
[23] Um NP, Straub S, Vellutini C. Infrastructure and economic growth in the Middle East and north Africa. World Bank Pol Res Working Paper 2009;5105:1–26.
[24] Ayogu M. Before prebendalism: a positive analysis of core infrastructure investment in a developing fiscal federalism. Afr Dev Rev 1999;11:169–98.
[25] Canning D, Pedroni P. The effect of infrastructure on long run economic growth Department of Economics, Williams College Working Paper 04. 2004. p. 1–29.
[26] Fan S, Zhang L, Zhang X. Growth, inequality, and poverty in rural China: the role of public investment. Int Food Pol Res Inst Res Rep 2002;125:1–72.
[27] Arnold JM, Mattoo A, Narciso G. Services inputs and firm productivity in sub-saharan Africa: evidence from firm-level data. J Afr Econ 2008;17:578–99.
[28] Goedhuys M, Sleuwaegen L. High-growth entrepreneurial firms in Africa: a quantile regression approach. Small Bus Econ 2010;34:31–51.
[29] Khandker RS, Samad HA, Ali R, Barnes DF. Who benefits most from rural electrification? Evidence in India. Energy J 2014;35:75–96.
[30] Ackah I. Policy interventions in renewable energy for sustainable development: is Ghana on the right path to achieve SDG 7? Africa center for energy policy working paper. 2016. p. 1–18.
[31] Mathrani S, Santley D, Hosier R, Bertholet F, Braud A, Dawson-Amoah G, Matthews B. Energizing economic growth in Ghana: making the power and petroleum sectors rise to the challenge. World Bank Energy Group 2013;79656:1–63.
[32] ISSER. Electricity insecurity and its impact on micro and small businesses in Ghana. 2015http://isser.edu.gh/index.php/news/92-workshop-on-electricity-insecurity-and-its-impact-on-the-economy-of-ghana, Accessed date: 20 February 2017.
[33] Sakah M, Amankwah DF, Katzenbach R, Gyamfi S. Towards a Sustainable Electrification in Ghana: a review of renewable energy deployment policies. Renew Sustain Energy Rev 2017;79:544–57.
[34] Kemausuor F, Obeng YG, Brew-Hammond A, Duker A. A review of trends, policies and plans for increasing energy access in Ghana. Renew Sustain Energy Rev 2011;15:5143–54.
[35] Pennise D, Brant S, Agbeve SM, Quaye W, Mengasha F, Tadele W, Wofchuck T. Indoor air quality impacts of an improved wood stove in Ghana and an ethanol stove in Ethiopia. Energy Sustain Dev 2009;14:71–6.
[36] Energy Commission of Ghana. National energy statistics 2000-2013. 2014http://energycom.gov.gh/files/National%20Energ%20Statistics_2014final.pdf, Accessed date: 10 February 2017.
[37] Energy Commission of Ghana. National energy (supply and demand) outlook for Ghana. 2015 2015 http://energycom.gov.gh/files/Energy%20Outlook%20for%20Ghana%20-%202015.pdf, Accessed date: 10 February 2017.
[38] Ghana Statistical Service. Ghana living standards survey round 6 (GLSS 6) main report. 2014http://www.statsghana.gov.gh/docfiles/glss6/GLSS6_Main%20Report.pdf, Accessed date: 15 November 2016.
[39] Akpalu W, Dasmani I, Aglobitse PB. Demand for cooking fuels in a developing country: to what extent do taste and preferences matter? Energy Policy 2011;39:6525–31.
[40] Karimu A. Cooking fuel preferences among Ghanaian Households: an empirical analysis. Energy Sustain Dev 2015;27:10–7.
[41] Karimu A, Mensah JT, Adu G. Who adopts LPG as the main cooking fuel and why? Empirical evidence on Ghana based on national survey. World Dev 2016;85:43–57.
[42] Mensah JT, Adu G. An empirical analysis of household energy choice in Ghana. Renew Sustain Energy Rev 2015;51:1402–11.
[43] Alkire S, Foster J. Counting and multidimensional poverty measures. J Public Econ 2011;95:476–87.
[44] Sen A. Development as freedom. first ed. New York: Oxford University Press; 1999.
[45] Cooke E, Hague S, McKay A. The Ghana poverty and inequality report. 2016https://www.unicef.org/ghana/Ghana_Poverty_and_Inequality_Analysis_FINAL_Match_2016(1).pdf, Accessed date: 12 November 2016.
[46] Itu. World telecommunication/ICT indicators database. http://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx; 2016http://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspxhttp://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx.
[47] Sadath CA, Acharya HR. Accessing the extent and intensity of energy poverty using Multidimensional Energy Poverty Index: empirical evidence from households in India. Energy Policy 2017;102:540–8.
[48] Asante KP, Afari-Asiedu S, Abdulai AM, Dalaba AM, Carrion D, Dickinson KL, Abeka AN, Sarpong K, Jack DW. Ghana's rural liquefied petroleum gas program scale up: a case study. Energy Sustain Dev 2018;46:94–102.