Ogundipe, Adeyemi A.; Akinyemi, Opeyemi; Ogundipe, Oluwatomisin M.

Article

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Energy Access: Pathway to Attaining Sustainable Development in Africa

Adeyemi A. Ogundipe*, Opeyemi Akinyemi, Oluwatomisin M. Ogundipe

Department of Economics and Development Studies, College of Business and Social Sciences, Covenant University, Ota, Nigeria. *Email: ade.ogundipe@covenantuniversity.edu.ng

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ABSTRACT

The study assesses the effect of energy use on social, economic and environmental sustainability in Africa. The energy sources considered in the study comprises four prominent sources in Africa, including: fossil fuel, solid fuel, electricity and natural gas consumption. The finding suggests that fossil fuel consumption and solid fuel constitute about 75% of energy use in the region and contributively worsen social and environmental conditions. The predominant consumption of these dirty energies has severely hampered child and adult survival and efficient delivery of services. Also, the time wasted in fetching biomass has constituted an impediment to learning capacities in children and women's mobility. In the same manner, frequent exposure to fumes from the dirty energy sources had resulted in severe indoor air pollution and rising incidence of pneumonia, lung cancer and chronic obstructive pulmonary diseases in women and children. On the other hand, the empirical and conceptual analysis shows that access to clean and reliable energy sources (such as electricity) reduce time poverty, enhance gender empowerment and reduce environmental degradation. The study recommends structural policy reforms and transformation towards decentralizing energy provisions and adopting off-grid power solution to rural areas. Furthermore, African governments need to develop a sustainable energy financing mechanism through an affordable pricing template; this can be achieved by increasing local contents in energy provision and increasing the share of abundant domestic resource in energy mix.

Keywords: Energy Access, Structural Transformation, Sustainable Development, Africa
JEL Classifications: Q43, K32, Q01

1. INTRODUCTION

Ensuring access to energy is arguably one of the major challenges the world faces today. For those living in extreme poverty, a lack of access to energy services dramatically affects and undermines health, limits opportunities for education and development, and can reduce a family's potential to rise up out of poverty. The problem of energy access for the poor has become even more acute because of increased vulnerability brought about by climate change, the global financial crisis and volatile energy prices (Legros et al., 2009). Some 1.4 billion people have no access to electricity and a billion more only have access to unreliable electricity networks. About 3 billion people rely on solid fuels (traditional biomass and coal) to meet their basic needs. Access to modern energy services for cooking and heating, lighting and communications, and mechanical power for productive uses is a vast area of unmet need. The energy access challenge is particularly acute in the least developed countries (LDCs), south Asia and Sub-Saharan Africa (SSA) (UNDP Report, 2010).

In the words of Davidson (2002), Sustainable energy is defined as providing affordable, accessible and reliable energy services that meet economic, social and environmental needs within the overall developmental context of the society for which the services are intended, while recognizing equitable distribution in meeting those needs. According to UNDP and and WHO Report (2009), energy deeply influences people's lives. It is central to practically all aspects of human welfare, including access to water, agricultural production, health care, education, job creation, climate change, and environmental sustainability. Yet, millions of households in developing countries still lack access to modern energy services that are affordable, clean, reliable, and safe, and pay high prices for poor quality substitutes.This situation entrenches poverty, damages health, constrains delivery of local services, increases vulnerability to climate change, limits expansion of opportunities, erodes environmental sustainability at the local, national and global levels and creates negative impacts on education and health.

There are 615 million people in developing Asia and nearly 600 million people in SSA who lack access to electricity. The population without access to electricity in SSA is now almost equal to that of developing Asia and, if current trends continue, will overtake it in the near future. Also, more than half of the population of developing Asia, over 1.8 billion people-around 80% of the people in SSA-nearly 700 million people live without clean cooking facilities. While the number of people relying on biomass is larger in developing Asia than in SSA, the share of the population is lower, 50% in developing Asia compared with 80% in SSA (WEO, 2013). LDCs and SSA have the lowest levels of access to modern energy services. In these regions, people relying on solid fuels-traditional biomass and coal for cooking are exposed to various pollutants that create a large burden of disease in the form of pneumonia, chronic obstructive pulmonary diseases and lung cancer.

Though there was no specific Millennium Development Goal (MDG) on energy, the global aspirations embodied in the Goals could not become a reality without massive increases in the quantity and quality of energy services. The wake of UN sustainable development goals (SDGs) identified as a major to enhancing human living conditions. In the words of Rao and Pachauri (2017) accelerating the pace of living standards especially in low income economies includes the provision of access to electricity, clean cooking energy, improved water and sanitation[1]. Unfortunately, the outlook for access to electricity and clean cooking shows that the world is not on track to meet the SDG 7 goal of achieving universal access to modern energy by 2030. This becomes apparent as the WEO 2016 new policies scenario, an energy access projection showed that more than 780 million people are projected to remain without access to electricity in 2030 and 540 million still remain without access in 2040. In the light of the foregoing, it is necessary to examine the consequence of different energy access currently accessible in developing Africa countries. This is necessary to provide the necessary leap for African governments, decision makers and international agencies in charting appropriate structural transformation arrangement in providing the minimum clean and efficient energy services for the rural and urban communities[2] in Africa.

The issue of energy poverty is highly detrimental to developing Africa because of its ripple effect on all aspects of wellbeing. In an attempt to salvage this critical problem in SSA, it is not enough to have access to energy but to a sustainable source of clean, reliable and affordable energy which has a profound impact on multiple aspects of human development. The quest to achieve sustainable energy informed the ıntegrated development approach initiated by UNDP, which helps developing countries to expand access to reliable and modern sources of energy in order to reduce poverty and to improve the health of their citizens while at the same time promoting economic growth and mitigating climate change (IEA, 2011). Also, improved household energy technologies for the very poor can prevent the almost 2 million deaths a year attributable to indoor air pollution from solid fuel use. It has been estimated that there are over 200–300 million people (a significant number of these people are in Africa) rely on coal for cooking and heating purposes, which causes air pollution and has serious potential health implications when used in traditional stoves.

As articulated in the SDGs document, by 2030 governments and other stakeholders envision a world where “human habitats are safe, resilient and sustainable and where there is universal access to affordable, reliable and sustainable energy” (UNEP, 2015). This will entail the adoption of policies that will improve access to affordable, reliable, sustainable and modern energy services. In this light, the future looks deem for African countries, while projections showed that developing Asian countries, Latin America and Middle East had significant achievement. However, progress is uneven as SSA[3] inhabits the reminder of the population without access to electricity by 2040 (Table 1 in appendix).

Going forward, the benefits of achieving universal access to modern energy services are transformational and can be linked to the achievement of SDGs, for instance by: Providing lighting for schools, functional health clinics, powering pumps for water and sanitation; empowering women by eliminating the time wasted in gathering biomass; ensuring cleaner indoor air; reducing deforestation and ensuring more environmental sustainability; facilitating speedy food processing and more income generating opportunities. In these ways and many others, energy access can culminate in innovative solutions which will be instrumental to overcome extreme poverty.

Specifically, the study answers the following questions:

a. What is the contribution of different types of energy sources (electricity, biomass and fossil) on social, environment and economic sustainability in SSA?
b. Do traditional energy sources contribute to trans-generational poverty in SSA?
c. What is the role of indigenous and global institutions in driving sustainable energy inclusion in SSA?
d. What is the contribution of traditional biomass usage on environmental degradation and climate change in SSA?

1 According Alkire and Santos (2010) and UNDP (2010), these amenities play a critical role in reducing deprivations known to constitute multidimensional poverty.

2 According to the International Energy Agency, the initial threshold level of electricity consumption for rural households is assumed to be 250 kilowatt-hours (kWh) per year and for urban household it is 500kw per year.

3 The region accounts for more than 90% of the global total without electricity access in 2040, up from just over half today. At present, per-capita electricity consumption in sub-Saharan Africa, excluding South Africa, is only 6% of the world’s average today and is projected to grow to only to 14% by 2040. Those without electricity become more and more concentrated in rural areas, with 95% of the total population without access in rural areas by 2040, from around 80% today.

2. CONCEPTUAL FRAMEWORK

According to the IEA Report (2010), with billions of people without access to electricity or clean cooking facilities, the ambitious goal to eradicate extreme poverty may never be fully realized. The report further emphasized that unless new and dedicated policies are put into place to ensure access to ensure access to modern energy services, conditions for lives of billions of people are not expected to improve. The World Energy Outlook addresses energy poverty using two indicators at the household level: (i) Lack of access to electricity and (ii) reliance on the traditional use of biomass for cooking. Also, poor energy access is typically linked to poor nations.

Specifically in SSA, the electrification rate is 31% and the number of people relying on traditional use of biomass is 80%. Globally, the number of people relying on traditional use of biomass is projected to rise from 2.7 billion to 2.8 billion in 2030. Linking the World Bank estimates to the World Energy Outlook projections of biomass use, the year 2010 estimates show that household air pollution from the use of biomass in inefficient stoves would lead to over 1.5 million premature deaths per year, over 4000 per day, in 2030, greater than estimates for premature deaths from malaria, tuberculosis or HIV/AIDS. However, the estimate ascends to 4.3 million premature deaths per year due to the inclusion of new diseases such as cardiovascular disease and lung cancer.

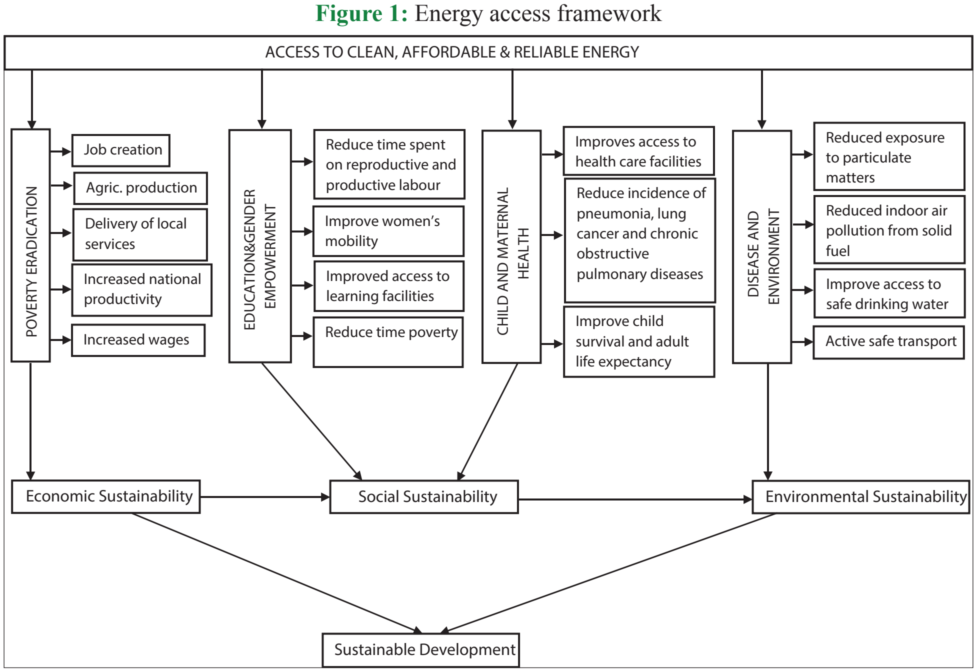
Lack of access to modern energy services is a serious hindrance to economic and social development and must be a priority if the SDGs are to be achieved. Access to modern forms of energy is essential for the provision of clean water, sanitation and health care. Also, increasing energy efficiency can contribute to improving water efficiency and contributes to increasing food production and food availability, which often improves farm income and enhances savings on energy cost.

Moreover, access to energy eliminates time poverty by reducing the time spent in gathering biomass by women and children, hereby creating time for productive engagement for women and learning time for children. In this light, women can together with men play a significant role as energy providers and engage in delivery of local services. Similarly, access to reliable and affordable modern energy services can significantly reduce the burden of disease related to household air pollution and plays a critical role in health care provisions. In the same manner, energy efficiency improvements in power generation, transport and buildings can yield a range of health benefits including reduction of urban air pollution. Invariably, Figure 1 shows that provisions of clean affordable and reliable energy provides great benefits for development via the provision of reliable lighting, heating, cooking, mechanical power, transport and telecommunication services.

While MDGs and SDGs are development enablers for developing economies, it is necessary to note that energy access is a critical enabler. Every advanced economy has required secure access to modern sources of energy to underpin its development and growing prosperity. Unfortunately, as Birol (2007) suggests, electricity access contributes positively to income level. As shown in Table 1, countries with large proportion of the population living on an income of less than US$2 per day tend to have low electrification rates and a high proportion of population relying on traditional biomass. Lack of access to modern energy sources has remained a development problem for SSA economies and dimmed the progress of the millennium development goals.

If appropriate caution is not exercised, the SDGs might achieve far less than what was attained in the implementation of the MDGs. For developing countries, who are mostly saddled with competing ends for their limited development resources, taking on the 17 SDGs without any priority focus is an inherent challenge. For the SSA region, affordable clean energy access is central to all the three pillars

Figure 1: Energy access framework



Source: Compiled by author

Table 1: Regression Result for Suspended Particulate Matters (PM10)

Variables	LNPM10	LNPM10	LNPM10	LNPM10	LNPM10	LNPM10
L.LNPM10	0.929***	0.977***	0.986***	0.969***	0.986***	0.982***
	(0.0133)	(0.0116)	(0.0136)	(0.0270)	(0.00992)	(0.00957)
Lngdpk	−0.101***	0.00110	0.0666***	−0.0741	0.00489	0.0276***
	(0.0204)	(0.00559)	(0.0140)	(0.0639)	(0.00422)	(0.00897)
Lndcps	0.0147	0.0349***	−0.0410***	0.0661**	0.0266***	−0.0284***
	(0.0117)	(0.0123)	(0.00607)	(0.0329)	(0.00692)	(0.00638)
Lnedu	−0.00943	−0.0146	−0.0890***	0.00449	0.0267	−0.0210
	(0.0278)	(0.0346)	(0.0209)	(0.203)	(0.0227)	(0.0187)
lninst2	−0.209***	−0.127***	−0.214***	−0.269	−0.118***	−0.242***
	(0.0492)	(0.0442)	(0.0245)	(0.188)	(0.0343)	(0.0204)
Lnffc	0.155***					
	(0.0254)					
Lntelc		0.00371				
		(0.00947)				
Lntcc			0.00267			
			(0.00169)			
Lnngc				0.0213		
				(0.0176)		
Lntpc					−0.00188	
					(0.00855)	
Lsldfuel						0.0183***
						(0.00189)
Constant	0.639***	0.148	0.346***	0.611	−0.0949	0.180*
	(0.185)	(0.218)	(0.127)	(0.855)	(0.149)	(0.0971)
Observations	341	669	251	207	709	279
Number of id	26	49	24	18	49	26
Year FE	YES	YES	YES	YES	YES	YES
F-test (Wald .^{2})	10682.1	33439.2	49065.3	18275.5	36203.9	519773.1
F-test (P-values)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan	0.3426	0.1820	0.6643	0.8697	0.1734	0.5599
AR (1)	0.0005	0.0001	0.0048	0.0022	0.0001	0.0034
AR (2)	0.9228	0.7999	0.5637	0.4210	0.7969	0.3083

of sustainable development - social, economic and environmental sustainability. This is because energy access is fundamental to reducing poverty and improving health, increasing productivity, enhancing competitiveness and promoting economic growth.

3. BRIEF LITERATURE OVERVIEW

Energy plays a critical role in enhancing income and alleviating poverty, this is in addition to other functions it supports that drive economic growth. For example, energy is important for improved healthcare delivery as it helps in refrigerating drugs, perform surgical operations, among others. It is also a key input in industrial production process. According to the global energy assessment (GEA) (2012) report, there are key areas through which energy access contributes to economic growth. They include enhancing food security, transformation of agriculture-based economics, employment generation, enhanced modern health services, better access to safe drinking water, improved availability and quality of educational services and gender parity. Therefore, providing access to energy had been a top policy priority for sustaining development in many countries. Adequate access to modern forms of energy is also important if the goal of overcoming poverty, generating employment and economic sustainability is to be attained. Alleviating poverty and achieving the SDGs will not be possible if billions of people still do not have access to clean, quality, efficient, affordable and reliable energy (GEA, 2012).

Access to energy especially modern sources is crucial to the success of any development initiative (Adam et al., 2013). Expanding access to modern energy services had been an enormous challenge for developing countries, especially in the poorest countries (Legros et al., 2009). Part of the challenge to expanding energy access in SSA as argued by Ganda and Ngwakwe (2014) is the continued employment of fossil fuel subsidies and high transaction costs. Other associated problems include presence of monopoly structures in the energy sectors, large capital required to fund sustainable schemes, regulatory and macroeconomic risks in sustainable energy schemes, low carbon risk and negative social impacts. They, however, recognised that these challenges can be alleviated if some solutions can be adopted. Such solutions ranges from the phase out of monopoly power to countries employing renewable energy targets, integrate clean development mechanisms, seek external assistance, introduce tax incentives, increase independent power producers and expand rural electrification programmes.

Technically, defining the concept of access follows different manner in empirical literature. This varying definition depends on who the targeted beneficiary cover (e.g., villages, households), the types of energy supply that are included (e.g., grid-connected or off-grid electricity) and the characteristics of service that makes the service accessible (e.g., affordability, reliability, quality and adequacy) (Pachauri et al., 2012). Despite this varying definition, a simple definition of universal access implies the physical availability of modern energy carriers and improved end-use devices such as cookstoves which are provided at affordable prices.

Relating to the hypothetical relationship between energy access and economic sustainability, there is a growing evidence of the influence that energy access has on GDP and income growth (Pachauri et al., 2012). This evidence suggests that access to modern forms of energy contributes essentially to job creation and economic growth. This was evident from the plot graph of the energy development ındex against the human development ındex and GDP per capita which represents income. Adam et al. (2013) confirms the hypothesis that access to modern forms of energy increases as income levels increases for Ghana. Their result indicated that the relationship depends on the type of energy. For example, there was only a positive relationship for households using electricity for lighting while it was a negative relationship for households using kerosene. In the same vein, Kabir et al. (2013) and Alege et al., (2016) assessed this relationship for Nigeria and found evidence of a strong positive relation that flows from energy consumption to national income. The study by Pachauri et al. (2012) also found a bi-directional relationship between energy access and income, implying that increased energy access strengthens growth of income and use of energy tends to rise with income levels.

The important role of energy access and reliable energy supply for economic sustainability is underscored by GDP loses from electricity supply interruptions, particularly for SSA. According to Pachauri et al. (2012), the cumulative average interruptions cause businesses to lose 6% of their production. Studies such as that of Foster and Briceno-Garmendia (2010) estimated up to 7% of GDP to be the economy-wide cost of interruptions. Also, the Economic Consulting Associates (2014) report extensively analysed a number of literature that explored the relationship between electricity access/availability and economic growth. Their findings indicated that a strong causal relationship between the two variables exists; however, there was no consensus about the direction of causality. There is also a growing consensus in the literature that ensuring access to modern, less polluting and affordable energy options is essential in alleviating poverty (GEA, 2012; Pachauri et al., 2012; Akinyemi et al., 2014,2015,2017). Energy poverty restricts productivity and generation of livelihoods, leaving low-income earners with minimal surplus cash. This in turn constrains their ability to purchase access to energy services that could alleviate their condition (Pachauri et al., 2012). They are often trapped in this vicious cycle.

4. METHODOLOGY

This study primarily investigates the effect of different types of energy sources (electricity, biomass and fossil) on social, environmental and economic sustainability in SSA using panel data analysis for the period 2000 through 2015.

Table 2: Regression Result for Carbon dioxide Emissions (CO2)

Varıables	LNCO2K	LNCO2K	LNCO2K	LNCO2K	LNCO2K	LNCO2K
L.lnco2k	0.211***	0.605***	0.894***	0.189***	0.575***	0.858***
	(0.0144)	(0.0224)	(0.0170)	(0.0536)	(0.0201)	(0.0130)
Lngdpk	0.461***	0.524***	0.105***	0.266*	0.586***	0.144***
	(0.0328)	(0.0350)	(0.0217)	(0.137)	(0.0291)	(0.0229)
Lndcps	−0.0364***	−0.143***	−0.0123***	−0.161**	−0.183***	−0.0278***
	(0.00727)	(0.0233)	(0.00465)	(0.0758)	(0.0220)	(0.00672)
Lnedu	0.217***	0.188***	0.140***	0.436	0.174***	0.219***
	(0.0673)	(0.0614)	(0.0217)	(0.277)	(0.0562)	(0.0248)
lninst2	0.693***	−0.232*	0.0847*	0.269	−0.0956	−0.152***
	(0.115)	(0.125)	(0.0460)	(0.520)	(0.127)	(0.0214)
Lnffc	0.367***					
	(0.0529)					
Lntelc		0.0142				
		(0.0188)				
Lntcc			0.0144***			
			(0.00261)			
Lnngc				0.195***		
				(0.0455)		
Lntpc					0.0876***	
					(0.0125)	
Lsldfuel						0.0432***
						(0.00185)
Constant	−6.582***	−4.238***	−1.632***	−4.639**	−4.889***	−2.203***
	(0.240)	(0.379)	(0.232)	(2.108)	(0.355)	(0.223)
Observations	348	710	257	211	759	294
Number of id	26	51	24	18	51	26
Year FE	YES	YES	YES	YES	YES	YES
F-test (Wald χ^2)	13216.3	5152.04	217186.8	66.31	5193.19	452666.1
F-test (P-values)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan	0.6395	0.8771	0.9123	0.9938	0.7815	0.0728
AR (1)	0.2853	0.1707	0.0011	0.3098	0.1769	0.0728
AR (2)	0.2486	0.2544	0.7022	0.0802	0.2944	0.3280

Other explanatory variables in the model includes: GDP per capita, domestic credit to private sector, literacy rate (education) and institutional quality. The energy sources to be considered will be based on the definition of energy poverty by World Energy Outlook and this includes: Electricity access, fossil fuel consumption and reliance on traditional biomass use. Environmental sustainability is captured using the rate of CO_2 emissions and suspended particulate matters (PM), social sustainability is addressed using three indicators: Under-five mortality, infant mortality, life expectancy; and economic sustainability is addressed using per capita income. (Table 3 and 4). The model for the general objective to be estimated is structured thus:

Environmental sustainability model:

$$CO_{2it} = \beta_0 + \beta_1 GDPK_{it} + \beta_2 GDPK_{it}^2 + \beta_3 DCPS_{it} + \beta_4 EDU_{it} + \beta_5 INST_{it} + \beta_6 ELC_{it} + \beta_7 BIOM_{it} + \beta_8 FFC_{it} + U_t$$

Social sustainability model:

$$SPM_{it} = \alpha_0 + \alpha_1 GDPK_{it} + \alpha_2 GDPK_{it}^2 + \alpha_3 DCPS_{it} + \alpha_4 EDU_{it} + \alpha_5 INST_{it} + \alpha_6 ELC_{it} + \alpha_7 BIOM_{it} + \alpha_8 FFC_{it} + U_t$$

$$U5MR_{it}=\gamma_0+\gamma_1 GDPK_{it}+\gamma_2 INTV_{it}+\gamma_3 DCPS_{it}+\gamma_4 MEDU_{it}+_{\gamma 5}INST_{it}+\gamma_6 ELC_{it}+\gamma_7 BIOM_{it}+\gamma_8 FFC_{it}+U_t$$

$$LFE_{it}=\omega_0+\omega_1 GDPK_{it}+\omega_3 DCPS_{it}+\omega_4 EDU_{it}+\omega_5 INST_{it}+\omega_6 ELC_{it}+\omega_7 BIOM_{it}+\omega_8 FFC_{it}+U_t$$

Economic sustainability model:

$$GDPK_{it}=\varphi_0+\varphi_1 GDPKt\text{-}1_{it}+\varphi_3 KAP_{it}+\varphi_4 LAB_{it}+\varphi_5 DCPS_{it}+\varphi_6 MEDU_{it}+\varphi_7 INST_{it}+\varphi_8 ELC_{it}+\varphi_8 BIOMit+\varphi_9 FFC_{it}+U_t$$

The models will be estimated using the system GMM. The choice of the technique is hindered on its ability to overcome the problem of endogeneity inherent in most macro data studies. On the other hand, a major challenge usually encounter using this technique is the likely proliferation of instruments. This study will overcome that using the Roodman (2006) specification (xtabond2) specification for the two-step options. The idea here is drawn from the strength of the two-step GMM estimates since in the presence of heteroskedascity and serial correlation, the two-step system GMM uses a consistent estimator of the weighting matrix. In two-step estimation, the standard covariance matrix is already robust in theory but typically yields standard errors that are downward biased. Thus, though the two-step GMM estimates may be asymptotically more efficient; extreme caution must be exercised since this option presents standard errors that tend to be severely downward biased. Roodman (2006) suggests that it is possible to solve the problem using the finite sample correlation to the two-step covariance matrix derived by Windmeijer (2005), which interestingly can make the two-step robust GMM estimates

Table 3: Regression Result for Under-Five Mortality Rate (U5MR)

VARIABLES	LNU5MR	LNU5MR	LNU5MR	LNU5MR	LNU5MR	LNU5MR
L.lnu5mr	1.096***	1.057***	1.044***	1.045***	1.032***	1.007***
	(0.0126)	(0.0111)	(0.00806)	(0.0177)	(0.00985)	(0.00812)
Lngdpk	0.0276***	0.0750***	0.101***	0.0241***	0.0726***	0.100***
	(0.00772)	(0.00856)	(0.00543)	(0.00867)	(0.00724)	(0.00393)
Lndcps	0.0147***	0.00407***	−0.0200***	0.0125***	0.00467***	−0.00605***
	(0.00350)	(0.00138)	(0.00182)	(0.00469)	(0.00145)	(0.00102)
Lnedu	0.0340***	7.64e-05	−0.0285***	−0.0222	−0.0178***	−0.0793***
	(0.00602)	(0.00365)	(0.00877)	(0.0284)	(0.00315)	(0.0116)
lninst2	−0.168***	−0.0101	−0.202***	−0.0629	−0.0272***	−0.164***
	(0.0230)	(0.00833)	(0.0309)	(0.0428)	(0.00942)	(0.0286)
Lnffc	−0.00778*					
	(0.00425)					
Lntelc		−0.00513**				
		(0.00237)				
Lntcc			−0.00846***			
			(0.000706)			
Lnngc				−0.000382		
				(0.00146)		
Lntpc					−0.0102***	
					(0.00246)	
Lsldfuel						−0.00440***
						(0.000310)
Constant	−0.660***	−0.799***	−0.454***	−0.267	−0.541***	−0.132
	(0.100)	(0.114)	(0.0628)	(0.219)	(0.101)	(0.0994)
Observations	348	710	257	211	759	294
Number of id	26	51	24	18	51	26
Year FE	YES	YES	YES	YES	YES	YES
F-test (Wald $.^2$)	30760.6	50557.4	59166.4	70962.9	77627.2	65903.7
F-test (P-values)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan	0.7406	0.7870	0.8964	0.9904	0.6271	0.5218
AR (1)	0.2510	0.0329	0.0604	0.1223	0.0716	0.0824
AR (2)	0.2665	0.3276	0.1003	0.4066	0.3528	0.0624

Table 4: Regression Result for Infant Mortality Rate (INFMT)

Variables	LNINFMT	LNINFMT	LNINFMT	LNINFMT	LNINFMT	LNINFMT
L.lninfmt	1.076***	1.034***	1.019***	1.031***	1.016***	1.013***
	(0.0108)	(0.0110)	(0.00660)	(0.0151)	(0.00982)	(0.00755)
Lngdpk	0.0270***	0.0476***	0.0670***	0.0101**	0.0482***	0.0558***
	(0.00553)	(0.00639)	(0.00605)	(0.00426)	(0.00546)	(0.00468)
Lndcps	0.0119***	0.00553***	−0.0102***	0.00880**	0.00582***	−0.00150
	(0.00398)	(0.00163)	(0.00204)	(0.00435)	(0.00211)	(0.00111)
Lnedu	0.0193***	−0.00702*	−0.0174***	0.00669	−0.0166***	−0.00962
	(0.00626)	(0.00403)	(0.00568)	(0.00562)	(0.00391)	(0.0119)
lninst2	−0.147***	−0.0491***	−0.172***	−0.106***	−0.0887***	−0.188***
	(0.0298)	(0.0117)	(0.0135)	(0.0201)	(0.0120)	(0.0128)
Lnffc	−0.00542					
	(0.00412)					
Lntelc		−0.00676***				
		(0.00234)				
Lntcc			−0.00645***			
			(0.000541)			
Lnngc				−0.00166		
				(0.00125)		
Lntpc					−0.0107***	
					(0.00192)	
Lsldfuel						−0.000171
						(0.000733)
Constant	−0.483***	−0.420***	−0.223***	−0.179*	−0.234***	−0.209***
	(0.0805)	(0.0872)	(0.0466)	(0.0972)	(0.0771)	(0.0700)
Observations	348	710	257	211	759	294
Number of id	26	51	24	18	51	26
Year FE	YES	YES	YES	YES	YES	YES
F-test (Wald $.^2$)	79786.9	36183.4	57426.4	181146.3	44848.8	250255.9
F-test (p-values)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan	0.7923	0.7202	0.8041	0.9949	0.4628	0.8263
AR (1)	0.6146	0.6617	0.8813	0.2995	0.2134	0.2046
AR (2)	0.2111	0.3468	0.1140	0.4061	0.3336	0.0822

more efficient than the one-step robust ones in system-GMM.

The data to be used for the study in addressing the general and the specific questions will be sourced from IEA/WEO energy data base (2016), World Development Indicators (2016) and World governance ındicators. The findings of the study led credence to policy analysts and African governments in understanding consequences of the predominant use of traditional biomass and how to adequately address the energy poverty situation via appropriate channeling of resources to this priority area towards accelerating human development in Africa.

5. DISCUSSION OF RESULTS

The study empirically examines the determinants of different energy consumed on sustainable development in Africa. The empirical result results available in Table 1 shows the regression results of the effect of energy use on environmental sustainability in Africa. The study adopted two measures of environmental sustainability namely: Suspended PM10 and the CO_2 emissions. The available evidence from the empirical analysis shows that fossil fuel consumption exerts the largest influence on suspended atmospheric particles (PM10) and carbon emissions (CO_2) in the region. This implies that emission from fossil fuel consumption represents the largest contributor to environmental pollution in Africa. It suggests that a unit increase in fossil fuel consumption increases environmental pollution by 15.5%. Also, solid fuel consumption contributes about 1.83% to environmental pollution in the region. This is followed by total electricity consumption and natural gas consumption contributing 0.37% and 2.13% respectively. The evidence shows that energy sources such as fossil fuel and biomass (solid fuel) are the major stimulants of environmental pollution in the region. This reflects predominant concentration on fossil fuel for provision of energy in virtually all sectors of the economy due to the gross inadequate supply of clean energy sources. Energy provision in the construction, transportation, industries and manufacturing are propelled by fossil fuel while the households heavily depend on solid fuel (such as traditional biomass, sawdust) for their cooking, heating and lighting purpose. This corroborates evidence from IEA Report 2017 which states that the number of people using traditional solid fuels for cooking purposes climbed slightly to 3.04 billion indicating that developmental effort towards ensuring sustainable energy for all[4] (SE4All) has not matched population growth.

Also, per capita income, education and institutions significantly influence environmental pollution in Africa. The evidence reveals

4 This is a United Nation initiative intended to attract global attention and public-private commitments to meeting three objectives by 2030; this include: Universal access to electricity and clean cooking, doubling the global rate of improvement in energy efficiency and doubling the share of renewable energy in the global mix by 2030.

Table 5: Regression Result for Life Expectancy (LE)

VARIABLES	LNLE	LNLE	LNLE	LNLE	LNLE	LNLE
L.lnle	1.040***	0.893***	1.052***	0.988***	0.906***	0.998***
	(0.0146)	(0.0198)	(0.0137)	(0.0239)	(0.0129)	(0.0127)
Lngdpk	−0.00644*	−0.00558	−0.0152***	−0.00200	−0.0105***	−0.0124***
	(0.00352)	(0.00348)	(0.00120)	(0.00186)	(0.00260)	(0.00103)
Lndcps	0.0121***	0.0109***	0.0139***	0.00141*	0.00634***	0.0120***
	(0.00113)	(0.00124)	(0.000816)	(0.000739)	(0.00105)	(0.000989)
Lnedu	−0.00708***	0.00770***	−0.00800***	−0.00151	0.00708***	−0.00557***
	(0.00190)	(0.00271)	(0.00245)	(0.00195)	(0.00202)	(0.00187)
lninst2	−0.0261***	−0.0749***	−0.0601***	−0.0428***	−0.0774***	−0.0510***
	(0.00511)	(0.0116)	(0.00527)	(0.0132)	(0.00674)	(0.00507)
Lnffc	−0.0164***					
	(0.00221)					
Lntelc		−0.00225*				
		(0.00135)				
Lntcc			−0.00293***			
			(0.000332)			
Lnngc				0.000208		
				(0.000724)		
Lntpc					−0.00386***	
					(0.000958)	
Lsldfuel						−0.00415***
						(0.000586)
Constant	−0.0298	0.486***	−0.0187	0.114	0.493***	0.175***
	(0.0380)	(0.0627)	(0.0517)	(0.0961)	(0.0440)	(0.0492)
Observations	348	707	257	211	755	294
Number of id	26	51	24	18	51	26
Year FE	YES	YES	YES	YES	YES	YES
F-test (Wald .^{2})	44215.3	7193.8	106632.9	28884.0	8814.5	8818.5
F-test (P-values)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan	0.6945	0.6330	0.6415	0.9978	0.1524	0.6905
AR (1)	0.0290	0.8410	0.0141	0.2215	0.8980	0.0085
AR (2)	0.0141	0.0054	0.0056	0.1636	0.0039	0.0099

that environmental quality was more responsive to institutional framework and per capita income. It suggests that a 100% change in income, education and institution yield a less proportionate change of 10.1%, 0.9% and 20.9% change in environmental quality. This corroborates existing evidences suggesting that average income has not grown to secure sustainable environment or abatement of the existing environment. In the same manner, institutions have been generally weak making enforcement of environmental regulations restraining industrial and household environmental abuses complicated. The Table 2 shows the empirical relationship between carbon emissions (CO_2) and energy access in Africa. The evidences obtained were similar to the abovementioned, clean energy access such as electricity consumption does not significantly contribute to carbon emissions. On the other hand, fossil fuel and natural gas consumption were the most important stimulants of carbon emissions in Africa. The result portrays fossil fuel as the largest contributor to environmental degradation, exerting about 36.7% pollutant emissions, followed by natural gas consumption with 19.5%, total petroleum consumption with 8.76%, solid fuel with 4.32% and total coal consumption with 1.44%. The varying degree of emissions generated by these energy sources reflects their different levels of usage in the region.

As previously specified, the study also attempts an empirical assessment of the relationship between social sustainability and energy sources. The regression result in Table 5 also reveals that fossil fuel consumption impacts more on life expectancy than other energy sources. It suggests that fossil fuel consumption causes life expectancy short by about 0.4% in the region. The dangerous gaseous emissions from industrial and household power generating plants, acidic fumes from transport services and production equipments has posed life threatening ailments in the region. In the same manner, frequent exposure to flames from biomass has led to respiratory problems in women and children in the rural African communities. Regression Results for School Enrollment (SE) are presented in Table 6.

Furthermore, the study analyzed empirically the effect of different energy sources on economic sustainability. The economic sustainability was captured using an indicator of green growth; this is achieved by using the share of services export in total exports. This is premised on the reality that the service export is entirely non emissive unlike the extractive, manufacturing and industrial exports. Also, the emergence of the service sector suggests transition to the advanced stage of economic development; this is further espoused by the Rostow stages of growth model. The evidence available in Table 7 reflects that economic sustainability is largely propelled by the consumption of clean energy sources (total electricity consumption and natural gas consumption). These two sources of energy are the only significant energy sources that influence economic sustainability in Africa. The total electricity

Table 6: Regression Result for School Enrollment (SE)

VARIABLES	LNSE	LNSE	LNSE	LNSE	LNSE	LNSE
L.lnse	0.968***	0.556***	0.685***	0.431***	0.611***	0.865***
	(0.0393)	(0.0264)	(0.0481)	(0.154)	(0.0326)	(0.0217)
lngdpk	0.0928	−0.0237	0.0230	−0.342	0.172***	0.229**
	(0.0604)	(0.0584)	(0.0738)	(0.529)	(0.0473)	(0.101)
lndcps	−0.146***	−0.0210	0.300***	0.150	0.0760**	0.0511
	(0.0276)	(0.0355)	(0.0511)	(0.114)	(0.0325)	(0.0683)
lnedu	0.255***	0.107	−0.806***	1.409**	0.101*	−0.322**
	(0.0824)	(0.0708)	(0.145)	(0.714)	(0.0565)	(0.147)
lninst2	1.063***	0.888**	−0.589**	2.389*	−0.103	−0.741**
	(0.194)	(0.397)	(0.245)	(1.370)	(0.373)	(0.300)
lnffc	−0.0186					
	(0.0893)					
lntelc		0.252***				
		(0.0431)				
lntcc			0.0114			
			(0.0227)			
lnngc				−0.0292		
				(0.0543)		
lntpc					0.0606*	
					(0.0337)	
lsldfuel						0.0645
						(0.0419)
Constant	−1.899**	7.497***	10.19***	4.556	5.775***	3.104***
	(0.823)	(0.723)	(1.365)	(4.985)	(0.747)	(0.850)
Observations	315	604	227	191	642	261
Number of id	24	44	21	17	44	23
Year FE	YES	YES	YES	YES	YES	YES
F-test (Wald .^{2})	16291.3	979.0	2531.5	1437.5	1208.1	33059.6
F-test (P-values)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan	0.4964	0.0929	0.7239	0.7195	0.1374	0.8315
AR (1)	0.0483	0.0018	0.0125	0.1478	0.0014	0.0126
AR (2)	0.9528	0.2724	0.7469	0.2019	0.4531	0.5588

Table 7: Regression Result for High Tech Export (HTEXP)

Variables	LNHTEXP	LNHTEXP	LNHTEXP	LNHTEXP	LNHTEXP	LNHTEXP
L.lnhtexp	0.383***	0.521***	0.370***	0.663***	0.479***	0.208***
	(0.0417)	(0.0304)	(0.0347)	(0.189)	(0.0278)	(0.0256)
Lngdpk	1.241***	0.565***	0.00484	0.390	−0.198	−0.265***
	(0.176)	(0.204)	(0.193)	(0.870)	(0.126)	(0.0565)
Lndcps	0.568***	0.376***	0.0925	0.450	0.570***	0.546***
	(0.175)	(0.127)	(0.102)	(0.707)	(0.111)	(0.137)
Lnedu	−3.050**	−0.977***	−0.240	−1.111	−0.378***	0.114
	(1.486)	(0.298)	(0.554)	(4.186)	(0.110)	(0.236)
lninst2	−1.202	1.317*	2.860***	4.093	0.523	1.837***
	(0.944)	(0.705)	(0.445)	(4.474)	(0.701)	(0.668)
Lnffc	−0.720**					
	(0.328)					
Lntelc		−0.368***				
		(0.0652)				
Lntcc			−0.0313			
			(0.0378)			
Lnngc				0.0497		
				(0.210)		
Lntpc					−0.120**	
					(0.0570)	
lsldfuel						−0.119***
						(0.0233)
Constant	9.265	−1.035	−1.827	−2.933	1.679***	−1.268*
	(7.201)	(2.007)	(1.982)	(12.33)	(0.595)	(0.667)
Observations	298	594	240	163	635	274
Number of id	23	44	21	14	44	23
Year FE	YES	YES	YES	YES	YES	YES

(Contd...)

Table 7: ***(Continued)***

Variables	LNHTEXP	LNHTEXP	LNHTEXP	LNHTEXP	LNHTEXP	LNHTEXP
F-test (wald .^{2})	2704.2	321.9	819.7	423.2	467.8	28156.5
F-test (P-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan	0.9353	0.5345	0.8923	0.9970	0.5425	0.8910
AR (1)	0.0022	0.0090	0.0052	0.0261	0.0201	0.1559
AR (2)	0.8203	0.2122	0.1232	0.3330	0.6418	0.0982

consumption and natural gas consumption stimulates economic sustainability by 25.2% and 6.06% respectively. This hence implies that provision of clean, efficient and affordable energy sources is necessary for attaining economic sustainability and ultimately sustainable development in Africa.

6. CONCLUSION AND POLICY RECOMMENDATIONS

Since the subject of energy access was neglected in the MDGs, it should take priority place in the first three years of implementing the SDGs. Given the above background and framework on the importance of energy access to economic, social as well as environmental sustainability in the SSA region, this paper proposes an orientation towards giving the SDG Goal 7 'to ensure access to affordable, reliable, sustainable and modern energy for all' priority concern in the drive towards achieving the other elements of the SDGs. The particular attention given to consequence of energy sources on human development (especially electricity and solid-fuel types) in our analysis will go a long way to influence policy and strengthen efforts by the international community and national governments in addressing the challenge of energy poverty in SSA.

The study assesses the effect of energy use on social, economic and environmental sustainability in Africa. The energy sources considered in the study comprises four prominent sources in Africa, including: fossil fuel, solid fuel, electricity and natural gas consumption. The finding suggests that fossil fuel consumption and solid fuel constitute about 75% of energy use in the region and contributively worsen social and environmental conditions. The predominant consumption of these dirty energies has severely hampered child and adult survival and efficient delivery of services. Also, the time wasted in fetching biomass has constituted an impediment to learning capacities in children and women's mobility. In the same manner, frequent exposure to fumes from the dirty energy sources had resulted in severe indoor air pollution and rising incidence of pneumonia, lung cancer and chronic obstructive pulmonary diseases in women and children. On the other hand, the empirical and conceptual analysis shows that access to clean and reliable energy sources (such as electricity) reduce time poverty, enhance gender empowerment and reduce environmental degradation.

In view of the fact that 63% of the population of SSA reside in rural areas, with poor living conditions and energy infrastructure, the study proposes a rural development paradigm towards reaching the SDG Goal 7. Consequent to this, acknowledging the intricate linkage that access to modern energy has to rural development, findings of this study provide policies for rural development countries in the SSA region as well as resettlement programmes targeted at curbing the rural-urban drift. Amongst several things, domestic energy utilization can be made sustainable by improving rural access to technologies which use modern fuels or use traditional fuels in cleaner, safer and more environmentally sustainable ways. This can help to balance out the urban bias that has hitherto trailed development policy implementation in many SSA countries.

The quest to overcoming energy poverty in Africa will require structural policy reforms and transformation towards decentralizing energy provisions and adopting off-grid power solution to rural areas. Furthermore, African governments need to develop a sustainable energy financing mechanism through an affordable pricing template; this can be achieved by increasing local contents in energy provision and increasing the share of abundant domestic resource in energy mix.

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APPENDIX

Table 1: Number of people and projection of people without access to electricity (million people)

Regions	Without access to electricity				Without access to clean cooking facilities			
	2011	2014	2030	2040	2011	2014	2030	2040
Developing countries	1257		969		2642		2524	
Africa	600	634	619	489	696	793	823	708
SSA	599	633	619	489	695	792	823	708
Developing Asia	615	512	166	166	1869	1875	1458	1081
China	3	0	0	0	446	453	244	175
India	306	244	56	0	818	819	675	450
Latin America	24	22	0	0	68	65	56	52
Middle East	19	18	0	0	9	8	8	7
World	1258	1186	969	536	2642	2742	2345	1849

Source: Compiled from IEA and World Health Organization) database, SSA: Sub-Saharan Africa