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EXAMINING HOUSEHOLDS INCOME-ENERGY CHOICE NEXUS: A MICRO-LEVEL EVIDENCE FROM GHANA

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Abstract

This paper aimed at analysing factors affecting the smooth uptake of clean energy transition in low-income economies such as Ghana. The results show that 72.14% of Ghanaians derived their main source of electricity from the national grid system, while 24.95% had no electricity access, of which 3.63% and 21.31% respectively lived in urban and rural communities. with the majority living in the three northern regions, (Northern, Upper East, and Upper West Regions). Furthermore, 85.27% of Ghanaians used a flashlight as their main lighting fuel. About 46.48% of Ghanaians used firewood, 28.16% used charcoal, 18.37% used gas, 0.21% used electricity, and 0.06% used kerosene for cooking services. Almost 2% of Ghanaians used crop residue, sawdust, animal waste, or other forms of energy resources for cooking. Woody biomass constitutes about (charcoal and firewood) 74.64% of the Ghanaian households cooking energy fuel mix. The study confirms the "energy ladder hypothesis" in the Ghanaian households' context: household heads' choice of relatively clean energy commodities increased with rising income levels, all things being equal. Concerning households' main source of lighting, the results show that access to electricity was an increasing function of income level, with variations in rural-urban and north-south geographical divides. Similarly, charcoal and gas were revealed as fuel commodities whose choice increase with rising income, especially in the Greater Accra Region. Contrary, the usage of firewood showed a decreasing trend with increasing income levels. The study suggests an integrated geographical information system-based household energy data collection for comprehensive sustainable energy access policy targeting.

Keywords: Ghana, environmental sustainability, household energy access, energy ladder, income quintiles

INTRODUCTION

Recent decades have witnessed a growing notion of energy-growth-development-environmental sustainability at national and global levels of research, development, and practices. Undoubtedly, energy remains the epicenter and the heart (Khan et al., 2022) of the United Nations' Sustainable Development Goals (SDGs) and the Paris Agreement (PA), which were all endorsed by the international community in 2015 as post-Millennium Development Goals (MDGs) agenda. The well-known textbook definition of energy as the "*ability to do work*" (Costanza et al., 2015; Ehrlich & Geller, 2017), implies that our social-technical systems, which are made of exosomatic organs – such as cars, railways systems, airplanes, automobile, machinery, will be become stalled when the energy systems of any economy failed. Thus, modern society is a function of available, accessible, reliable, and useful energy resources. Henry Louie (2018) summaries the above in the following terms:

Energy in its many forms underwrites all human [endeavors]. Our most basic needs—growing and harvesting food, accessing potable water, and transporting goods and people—and our most complex undertakings, from robotics to space exploration, require access to inexpensive and abundant energy sources (Louie, 2018, p. 5).

If human development is viewed in modern terms as a multidimensional phenomenon, as measured by multi development indicators such as good health, education, capability and functions, access to useful information, democracy and participation, etc.; then we have both theoretical and practical reasons to believe that energy infrastructure services are indispensable, giving other equally important factors. Based on Amartya Sen's analysis, therefore, energy services constitute an "e*ntitlement*" (Sen, 1982). An agent's *entitlement* is thus, an "*a collection of alternative bundles of goods and services from which the person in question is free to choose*"[1]. In line with this reasoning and thinking, the lack of modern energy infrastructure services, known in the literature as *energy poverty* (Lan et al., 2022; Sule et al., 2022; Sy & Mokaddem, 2022; Ugembe et al., 2022) constitutes an 'entitlement failure' among the population affected, particularly in both economically developed and less developed economies. Although energy-growth-development has always been a co-evolutionary phenomenon with human civilizations, over the past three decades or so have seen a growing national and international policy and research interests in the complexities of energy and development issues. Thus, international development and donor agencies have made strategic investments aimed at realizing the confluence of energy and development, particularly, in developing regions of the world (Nalule, 2019). Aside from the observed strong interconnection between energy services and social-economic development, there is also a strong link between

[1] Accessed from https://www.britannica.com/science/famine/Entitlement-failure (2022-04-18).

energy supply value chains – generation, transmission, and consumption and ecological systems' health degradation (Urbina, 2022), notably, the role of anthropogenic greenhouse gas emissions (especially, carbon dioxide) (Chun-sheng et al., 2012; Han & Wei, 2021), which are blamed for climate change and global warming.

Accordingly, access to modern energy infrastructure services in a manner that is environmentally benign has become a critical component of development policy programming, international environmental treaties, and conventions such as the Paris Agreement and the SDGs. Energy resources and technologies are considered 'modern' if they demonstrate such characteristics as a comparatively high degree of energy density and high efficiency of combustion, and consequently, low environmental health impact [1 Cite Here]. Based on existing knowledge and technologies, non-solid energy fuels such as LPG (Liquefied Petroleum Gas), and kerosene is probably the closest examples. Based on the UNDP (United Nations Development Programme), WHO (World Health Organization (WHO), and IEA (International Energy Agency), the notion of "*modern fuels*" collocates with electricity, liquid fuels (e.g.; paraffin/kerosene), and energy of gaseous state such as LPG (liquefied petroleum gas) and NG (natural gas), except solid biomass and coal energy resources.

By way of borrowing from Colombo et al. (2013) for this paper, there are two main ways in which human development and access to energy services present an interlocking phenomenon:

- The availability of [exosomatic] energy allowed human beings to extend their life and increase its quality, by saving time for activities other than subsistence; and;
- The consequent sociocultural development allowed the discovery of new
- energy sources, processes, and technologies for more efficient use of [exosomatic] energy (Colombo et al., 2013, p. 4).

Additionally, the use of any energy resource that is not social-ecological systems health compatible -- imposes risks on ecological well-being, social well-being, and economic well-being of agents. In the nutshell, lack of access to modern energy infrastructure services amounts to a critical "*entitlement failure*" which can affect health and the health of the earth's social-ecological systems, and consequently, undermines opportunities, creating or widening the development gap between the rich and poor within and across nations, *all other relevant factors remaining constan*t. Particularly in the sub-Saharan regions where more than half of the world's energy-poor reside (IEA, 2021), some scholars, noting the human rights implications of lack of access to modern energy services have provided legal arguments to address the problem of energy poverty from social, economic and environmental-justice frameworks grounded on "*three philosophical notions, namely distributive justice, procedural justice, and recognition justice"*(Mostert & Niekerk, 2018*)*. Such a social-legal and jurisprudence approach to society-energy-environment systems discourses gives us reasons to look at energy systems beyond the dominant socio-technical approach, particularly at household units of analysis. For instance, we are piqued to quiz: '*what does it mean in the context of the right to development and a healthy environment if international statistics continue to show that indoor and outdoor air pollution together is a major leading cause of premature deaths in low- and middle-income economies*?[2]. One possible implication is household energy access and the right to a healthy environment (Giorgetta, 2002; Greene & Sangokoya, 2021; Kaime, 2019).

Low-income economies vary in terms of their access to modern energy technologies and fuels. However, access is substantially limited in sub-Saharan African regions and developing economies in Asia generally, and also across urban and rural communities (*Africa energy outlook 2019: World Energy Outlook special report*, 2019; IEA, 2021; Newell et al., 2019). For instance, Table 1 shows the proportion of the population with access to clean cooking fuel and technologies in selected globally and selected regions between 2000 and 2018. In 2000 and 2018, only 23% and 30% of the population in Africa respectively have access to clean cooking and technologies as against the global average of 50% and 65% in the same period at a global level. However, the sub-Saharan African regions have only 9% and 17% of the population with access to clean cooking fuel and technologies in 2000 and 2018 respectively. This is way below the continual average in the same period. However, the economies in North Africa have access to clean cooking fuel and facilities that were above both the African region and global average between 2000 and 2018 (89% and >95% respectively).

Table 1: Proportion of households with access to clean cooking

Region	***2000***	***2005***	***2010***	***2015***	***2018***
WORLD	**50**	**53**	**57**	**62**	**65**
Africa	**23**	**25**	**27**	**28**	**30**
North Africa	89	>95	>95	>95	>95
Sub-Saharan Africa	9	11	13	15	17
Developing Asia	**30**	**35**	**43**	**53**	**62**
China	43	47	54	60	66
India	22	29	35	49	65
Indonesia	6	14	42	68	82
Other Southeast Asia	34	42	48	54	59
Other Developing Asia	19	22	27	33	39
Central and South America	**80**	**83**	**86**	**88**	**89**
Middle East	**88**	**92**	**93**	**94**	**94**

Source: Author's compilation based on data from SDG7 Database, IEA, 2022.

[2] See for instance https://yaleclimateconnections.org/2022/01/household-air-pollution-contributes-to-almost-4-million-premature-deaths-a-year/

Out of the 23% of the Ghanaian population with access to clean cooking fuel and facilities in 2019, 36% and 8% were living in rural and urban areas respectively. An environmental health consequence of the above sharp inequality of access to clean cooking energy fuel is evidenced by about 14,000 premature deaths annually in Ghana, which affects mostly women and children under five (Crentsil et al., 2020). In addition, it implies the majority of the population relies on woody biomass fuels—charcoal and firewood whose unsustainable extraction could potentially lead to deforestation, and greenhouse gas emissions and undermines climate change mitigation policy efforts.

This implies that the majority of energy-poor who rely on solid biomass such as firewood, charcoal, agriculture waste, and animal dung (Diouf et al., 2020), are located in sub-Saharan African regions, just seconded by the developing regions of Southeast Asia countries. While solid biomass fuel provides cooking services for more than 2.6 billion people daily globally (*Tracking SDG7: The Energy Progress Report 2021*, 2021), significant epidemiological literature has reported severe environmental health impacts owing to household indoor air pollution (HAP), the main cause of over 4 million premature deaths globally[3]. In Ghana, households with access to clean cooking energy fuel and technologies increased from 6% in 2000 to 23% in 2019. Whereas Ghana's access rate of 23% is above the sub-Saharan region of 16% in 2019, it was below the global average of 66% in 2019 (https://trackingsdg7.esmap.org/time).

Table 2 shows a summary of the proportion of the population with access to electricity between 2000 and 2020. At a glance, Table 2 reveals that global electricity services access is not only a physical infrastructure problem, the phenomenon also skirts around inequities across nations, and within nations (rural-urban access inequities, for instance). Between 2000 and 2020, the world's electricity access rate increased by 17% (from 73 to 82%).

Table 2: Proportion of electricity access by region (2000-2020*)*

Region			***National***			***Urban***	***Rural***
	2000	**2005**	**2010**	**2015**	**2020**	**2020**	**2020**
WORLD	**73**	**77**	**80**	**85**	**90**	**97**	**82**
Africa	**36**	**40**	**43**	**50**	**56**	**83**	**36**
North Africa	91	97	>99	>99	>99	>99	>99
Sub-Saharan Africa	24	28	33	40	49	79%	28
Developing Asia	**67**	**74**	**79**	**87**	**97**	**99**	**95**
China	99	>99	>99	>99	>99	>99	>99
India	43	58	68	79	>99	>99	>99
Indonesia	53	56	67	88	>99	>99	>99
Other South-East Asia	65	75	79	85	92	98	86

[3] See recent report: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

Other Developing Asia	38	46	58	73	82	90	77
Central and South America	**88**	**91**	**94**	**96**	**97**	**>99**	**86**
Middle East	**91**	**90**	**91**	**92**	**92**	**98**	**77**

Table 2…

Source: Author's compilation based on data from SDG7 Database, IEA, 2022.

However, this increase was not evenly distributed globally as 97% of urban as against 82% of the rural population had access to electricity in 2020. It is important to mention that these observed access rates improvement is masked by other factors, such as reliability and affordability. For instance, Subarna and Buluswar (2015) state that "*Access to electricity changes lives but only when people can afford electricity-powered services to meet their basic needs, and this is more than just two light bulbs and a fan*" (Mitra & Buluswar, 2015).

Developing regions differ widely concerning access to modern fuels, but access is more limited in the least developed regions.

The literature establishes a comprehensive interconnection between multiple human development indicators and energy consumption, economic growth, social-economic development, and multidimensional poverty (Acheampong et al., 2021; Sasmaz et al., 2020). Whereas the direction of causality remains contentious, general literature fairly agrees that monetary poverty turns to influence the types of energy fuel households consumed. The types of energy resources used by households, in turn, have multiple effects on households, especially women's and girls' rights to a healthy environment, education and learning progress, participation in democratic processes, access to information through information and communication technology, and sustainable income-earning opportunities. Thus, within a unique context of the sub-Saharan region, the modern energy access goal of the Sustainable Development Goals (SDG 7) as an independent goal, is also critical to achieving other SDGs such as poverty, hunger (food insecurity) eradication, promotion, health and well-being, quality and equitable education, clean water and sanitation, decent economic growth, gender equity, environmental protection (Singh & Ru, 2022; Tucho & Kumsa, 2020), etc.; *giving other equally important factors*.

Woody biomass energy commodities (largely, charcoal and firewood) remain the largest source of energy fuel for many Ghanaian poor households. According to the 2020 Multidimensional Poverty Index Report – Ghana (GMPI), 31.5% and 19.5% of Ghanaians were deprived of cooking fuel and electricity dimensions. Whereas the energy dimension of the MPI is moderate, compared to deprivations in sanitation (86.6%) and health insurance (64.6%), modern energy fuel and clean cooking technologies have a positive feedback effect, given their centrality to subjective well-being production. Also, several scholars have hypothesized that access to modern energy services is directly linked (Gebreegziabher et al., 2012; Ma et al., 2022). This study establishes the relationship between households' income status and access to relatively clean types of energy based on national survey data in Ghana.

Ghana National Welfare Quintile Levels

Like many low-income economies, the income of households in Ghana is a metric usually applied by the GSS (Ghana Statistical Service) as a measurement of households' income. Probably, following legal provisions, each household income is estimated relative to the legally acceptable source(s) of income of each legal resident who is 18 years and above in the country. According to the Ghana Living Standard Survey Round 7 (GLSS 7) 2016/17, the sources of households' income include agricultural and non-farming activities, employment, rent, remittances, and others considered legally appropriate. In addition, the GLSS 7 provides a piece of comprehensive information for analyzing and monitoring the Ghana households living conditions (*Ghana Living Standards Survey Seven*, 2017).

Table 3: Household gross annual and per capita income by quintile

National Quintile	Gross Annual per Capita Income (GH¢)	Gross Annual Income (GH¢)
Q1	1194.702 (2931.779)	7462.354 (18853.97)
Q2	3480.323 (16582.67)	19632.85 (157295.9)
Q3	6016.678 (29190.28)	26769.16 (117312.7)
Q4	8290.514 (24497.96)	30866.44 (118487.9)
Q5	23,500.96 (139096.3)	50,422.89 (244457.4)
Ghana (Total)	**9,084.091 (70753.98)**	**27,576.84(154988.8)**

Note: Q means national welfare quintile, the standard deviation in the blackest "().

Table 3 is a summary of gross annual household income and per capita annual income measured in Ghana Cedis (GH¢) during the national survey in 2016/17. Table 3 shows that the average gross household income in Ghana was approximate GH¢27,577with a standard deviation of about standard GH¢1549,889, while the per capita annual income was about GHC9,084 with a standard deviation of GH¢70,754. In low-income economies, energy transition is among other things, a function of social-economic class (income status of households). In this lens, variations in the income levels of households (residential) as one of the critical energy end-users are important for policy concerns. Using simple computation of the coefficient of variation (CV) is defined as the ratio of a distribution's standard to its mean (deviation (S) to its x̄, i.e. CV = S/ x̄). From Table 3, the CV of a household's gross income during 2016/17 was 5.620 or approximately 562% of the mean gross annual income, while the CV of the annual per capita income was 7.789 or approximately 778.9% of the mean per capita income. Compared to the annual household income, there is much variation in the distribution of per capita income in Ghana as explained by the CV computations.

Table 4: Mean household gross annual and per capita income by regions

Region	Mean of gross annual income (in Ghana Cedi)	Mean of gross annual per income (in Ghana Cedi)
Western	25,015.42	8,125.05
Central	28,848.14	10,356.78
Greater Accra	56,141.3	19,793.57
Volta	27,674.44	6,759.99
Eastern	20,822.4	6,946.52
Ashanti	27,762.56	11,868.14
Brong Ahafo	34,035.87	15,167.86
Northern	21,282.83	5,158.23
Upper East	14,537.83	3,086.9
Upper West	11,559.46	3,005.93
Ghana	**26,799.14**	**9,084.091**

Source: Author's illustration using data from GLSS 7 (2016/17).

Table above shows that the highest and lowest quintiles had about GH¢50,423 (with a standard deviation of GH¢244,457) and GH¢7,462 (with a standard deviation of GH¢18,854) of gross annual income respectively. In terms of households per capita income, the highest and lowest households reportedly had GH¢235,001 (with a standard deviation of GH¢13,9096) and GH¢1,195 (with a standard deviation of GH¢2932) respectively during the survey period.

Sustainable energy policy implications are that a household in the upper quintile reported both gross annual and income per capita that is almost seven times as much as that of a representative household in the lowest quintile. This observed inequality is further confirmed in the Ghana Multidimensional Poverty Index Report (2020). According to the GMPI (2020), Ghana has made substantive progress in economic development, "*Yet, inequality is on the rise and large parts of the population are at risk of being left behind*". Again, the annual household per capita income of about GH¢9,084 suggests that at the mean point, a representative Ghanaian household must live under GH¢24.90 during the survey period.

Table 5: Ghana welfare quintile levels by region

	National welfare Quintile					
REGION	**1**	**2**	**3**	**4**	**5**	**Total**
Western	160	283	290	315	283	1331
	(5.10)	(11.18)	(12.18)	(12.08)	(8.45)	(9.50)
Central	110	226	295	301	386	1318
	(3.51)	(8.93)	(12.39)	(11.54)	(11.52)	(9.41)
Greater Accra	13	51	132	352	850	1398
	(0.41)	(2.01)	(5.54)	(13.50)	(25.37)	(9.98)
Volta	305	342	284	252	184	1367
	(9.72)	(13.51)	(11.93)	(9.66)	(5.49)	(9.76)
Eastern	120	258	315	325	377	1395
	(3.83)	(10.19)	(13.23)	(12.46)	(11.25)	(9.96)
Ashanti	94	210	314	438	679	1735
	(3.00)	(8.29	(13.19)	(16.79)	(20.26)	(12.38)
Brong Ahafo	214	268	275	285	276	1318
	(6.82)	(10.58)	(11.55)	(10.93)	(8.24)	(9.41)
Northern	654	301	178	141	135	1409
	(20.85)	(11.89)	(7.48)	(5.41)	(4.03)	(10.06)
Upper East	659	324	180	103	105	1371
	(21.01)	(12.80)	(7.56)	(3.95)	(3.13)	(9.79)
Upper West	808	269	118	96	76	1367
	(25.76)	(10.62)	(4.96)	(3.68)	(2.27)	(9.76)
Total (Ghana)	**3137**	**2532**	**2381**	**2608**	**3351**	**14009**
	100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: Author's compilation based on GLSS 7 (2016/17) data.

From the regional administrative level, Table 4 shows that at the mean point, Greater Accra Region had the highest mean annual and per capita incomes, about GH¢56,143 and GH¢19,194 respectively in 2016/17, followed by Brong Ahafo, Central Region, etc. Fifty percent of the regions in Ghana (Ashanti, Brong Ahafo, Central, Greater Accra, and Volta Regions) had a mean gross income above the national average of about GH¢26,799. Two regions, the Upper East and Upper West reported an annual average income that was almost twice the national average (Table 4). In terms of household per capita gross income, Greater Accra Region reported the highest value of about GH¢19,793.6, which was almost twice the national average. However, sixty percent of the regions in Ghana recorded per capita income below the national average, with the lowest recorded in the three northern regions (Northern, Upper East, and Upper West Regions). Table 5 shows that the highest number of households in the lowest income quintile was located in the Northern, Upper East, and Upper West Regions. On the other hand, the Northern, Upper East, and Upper West Regions had the lowest number of households in the upper quintile income levels.

Households' main cooking energy fuel

The pattern of energy household unit fuel use in Ghana was observed to be akin to other low and emerging economies in the world. Woody biomass energy commodities mainly charcoal and firewood constitute the bulk of energy services to meet households cooking needs, proceeded by liquefied petroleum gas (LPG). Based on the GLSS datasets for 2016/17, of the 14,009 households surveyed, 5.5% (constituting 774 household heads) did not cook (Table 6). For household heads who reported that they cooked, firewood was the most preferred energy fuel, about 46.5% followed by charcoal (28.2%).

Table 6: Sources of household main cooking fuel

Household main cooking fuel	Freq.	Percent	Cum.
No Cooking	774	5.53	5.53
Wood	6511	46.48	52.00
Charcoal	3945	28.16	80.16
Gas	2573	18.37	98.53
Electricity	30	0.21	98.74
Kerosene	9	0.06	98.81
Crop residue	134	0.96	99.76
Sawdust	2	0.01	99.78
Animal waste	21	0.15	99.93
Other	10	0.07	100.00
Total	14009	100.00	

Source: Author's own based on GLSS 7 (2016/17) data.

Together, woody biomass energy resources constitute about 74.6% of the Ghanaian cooking energy fuel mix (Figure 1 and Table 6). Only 18.4% of the respondents reported that they used LPG. All other energy resources, for instance, animal dung/waste, agriculture residue, sawdust, kerosene, electricity, and other types of fuels for cooking constituted approximately 7%.

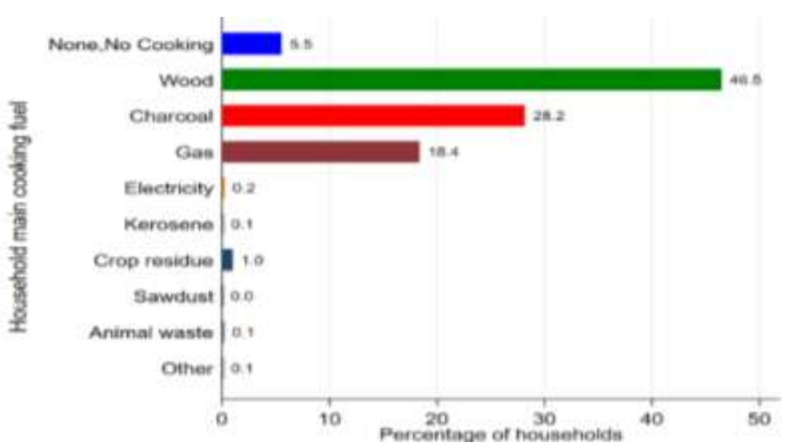

Figure 1: Percentage distribution of households' main cooking fuels in Ghana (2016/17).

Source: Author's construction based on GLSS 7 (2016/17).

Furthermore, about 12.6% of urban dwellers as against 72% of rural folks used firewood as their primary source of cooking, and about 44.2% and 16.1% used charcoal as their cooking fuel respectively in urban and rural Ghana (Table 7). The relationship between rural and urban settlement and the associated dominant cooking fuels in Ghana is consistent with the literature in low and emerging economies (Desalu et al., 2012; Rahut et al., 2017; Win et al., 2018). Table 8 shows that for the 18.4% (2573 households) who used gas cooking, about 35% and 6% were located in urban and rural communities respectively. Table 7 indicates that the choice of firewood as the most preferred cooking fuel is a rural phenomenon probably because rural folks, compared to urban dwellers have limited fuel resources to make choices from, so they turn to rely on a single source of cooking (wood) whose supply is less susceptible to intermittent shocks and price hikes.

Table 7: Distribution of numbers and proportion of household's main cooking fuel (urban vs rural)

Household main cooking fuel	**Location**		
	Urban	**Rural**	**Total**
No Cooking	476 (7.91)	298 (3.73)	774 (5.53)
Wood	755 (12.55)	5756 (72.03)	6511 (46.48)
Charcoal	2661 (44.22)	1284 (16.07)	3945 (28.16)
Gas	2097 (34.85)	476 (5.96)	2573 (18.37)
Electricity	14 (0.23)	16 (0.20)	30 (0.21)
Kerosene	7 (0.12)	2 (0.03)	9 (0.06)
Crop residue	3 (0.05)	131 (1.64)	134 (0.96)
Sawdust	2 (0.03)	0 (0.00)	2 (0.01)
Animal waste	0 (0.00)	21 (0.26)	21 (0.15)
Other	3 (0.05)	7 (0.09)	10 (0.07)
Total	**6018 100.00**	**7991 100.00**	**14009 100.00**

Source: Author's illustration using data from GLSS 2016/17.

Note: Percentages in the parentheses, "()".

The dominance of charcoal in the cooking fuel mix in urban areas also reflects how urban areas remain important selling destinations for charcoal producers. However, in general, households engage in "fuel technology stacking behavior" by using multiple energy resources and technologies as security against the high cost of LPG and intermittent shortages (Yadav et al., 2021). In addition, Table 7 shows that household heads in urban areas in comparison with rural folks were less likely to cook as indicated in the column "No cooking".

Table 8 is a crosstabulation of household head's choice of cooking fuels and national quintile levels. The earlier literature review in this paper hypothesized based on the energy ladder hypothesis that a representative household head's decision to climb the energy ladder from the traditional solid fuels to relatively safe sources of energy such as LPG and electricity is influenced by the agent's "income class", which is proxied mostly by income and consumption quintiles. If there are enough theoretical, empirical, and practical reasons to accept the energy ladder hypothesis, then, we have reason to anticipate that the global call to transit into a low-carbon economy and reduce poverty, particularly in low-income and emerging economies in the residential sector of energy consumption will be determined by agents' income level, *ceteris paribus*. Our analysis agreed with scholarships on household energy economics research presented in the introduction section of this paper. An attempt to establish this hypothesis in the Ghanaian context is evidenced in Tables 8, 9, and Figure 2.

Table 8: Distribution of household's energy choice by national quintile levels

Household main cooking fuel	**National welfare quintile levels**					
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Total**
No Cooking	52 (1.66)	74 (2.92)	108 (4.54)	197 (7.55)	343 (10.24)	774 (5.53)
Wood	2710 (86.39)	1628 (64.30)	1057 (44.39)	709 (27.19)	407 (12.15)	6511 (46.48))
Charcoal	253 (8.07)	682 (26.94)	917 (38.51)	1054 (40.41)	1039 (31.01)	3945 (28.16)
Gas	18 (0.57)	101 (3.99)	284 (11.93)	635 (24.35)	1535 (45.81)	2573 (18.37)
Electricity	0 (0.00)	2 (0.08)	1 (0.04)	7 (0.27)	20 (0.60)	30 (0.21)
Kerosene	0 (0.00)	1 (0.04)	2 (0.08)	3 (0.12)	3 (0.09)	9 (0.06)
Crop residue	84 (2.68)	37 (1.46)	10 (0.42)	3 (0.12)	0 (0.00)	134 (0.96)
Sawdust	1 (0.03)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.03)	2 (0.01)
Animal waste	16 (0.51)	4 (0.16)	1 (0.04)	0 (0.00)	0 (0.00)	21 (0.15)
Other	3 (0.10)	3 (0.12)	1 (0.04)	0 (0.00)	3 (0.09	10 (0.07)
Total	**3137** **100.00**	**2532** **100.00**	**2381** **100.00**	**2608** **100.00**	**3351** **100.00**	**14009** **100.00**

Source: Author's own illustration-based GLSS 2016/17 data.
Note: Q denotes national quintile levels, percentages in "()".

Our analysis agreed with scholarships about household energy economics research presented in the introduction section of this paper. An attempt to establish this hypothesis in the Ghanaian context is evidenced in the Tables 9, 10, and Figure 2. Table 9 reveals that as a household head climbs the higher income ladder, the choice to not cook increases.

While there is not a straightforward interpretation for this observed household behavior, the "*theory of household production*" provides a theoretical foundation to speculate a descriptive explanation generally, and in the Ghanaian context. A few studies have observed factors that affect a household's decision to engage in eating "food-away-from-home" (FAFH) behavior (Keng & Lin, 2005; Kinsey, 1983; LaFrance, 2001; Stewart, 2011; Yen, 1993). FAFH is conceptualized to include food from restaurants and other foods cooked/provided by other forms of facilities for immediate consumption (Stewart, 2011). For instance, Keng and Lin (2005) using data from Taiwan households concluded that "*as women's [labor] market earnings increase, their household's demand for food away from home increases*". Given the socio-cultural practices in terms of gender roles in household units, non-labor market products such as cooking activities are usually performed by women. In this context, the relationship between the household head's income class and the choice of meeting food needs at FAFH markets can be fairly linked to Keng and Lin's findings, *all things being equal*. Further analysis that integrates sociocultural variables is needed to understand this relationship to inform energy policy, especially, in the context of low-income economies like Ghana.

Table 9 shows that in a lower income-consumption quintile, firewood dominates the household's energy cooking fuel mix, with LPG and kerosene constituting little in the agent's cooking fuel baskets. As a representative household head's increases, we observed in Table 9, the proportion of charcoal and LPG energy commodities are more preferred fuel mix. This positive relationship confirms a direct relationship between increasing income levels and household heads' preference for charcoal and LPG. Our analysis further shows an inverse relationship between increasing households' income and the adoption of firewood for cooking in Ghana. Whereas this relationship is simple to understand and inform energy-development policy, it could be more complex, as households in developing regions hardly rely on a single source of energy resources to meet their subjective well-being.

Table 9: Distribution of household's energy choice by poverty status

Household main cooking fuel	Household head's poverty status			
	Very poor	**Poor**	**Non-poor**	**Total**
No Cooking	20	43	711	774
	1.31	2.09	6.82	5.53
Wood	1386	1657	3468	6511
	91.06	80.44	33.26	46.48
Charcoal	56	278	3611	3945
	3.68	13.50	34.63	28.16
Gas	3	19	2551	2573
	0.20	0.92	24.47	18.37
Electricity	0	0	30	30
	0.00	0.00	0.29	0.21
Kerosene	0	0	9	9
	0.00	0.00	0.09	0.06
Crop residue	51	47	36	134
	3.35	2.28	0.35	0.96
Sawdust	0	1	1	2
	0.00	0.05	0.01	0.01
Animal waste	6	12	3	21
	0.39	0.58	0.03	0.15
Other	0	3	7	10
	0.00	0.15	0.07	0.07
Total	**1522**	**2060**	**10427**	**14009**
	100.00	**100.00**	**100.00**	**100.00**

Stata output: Pearson chi2(18) = 3.4e+03 Pr = 0.000

Source: Author's compilation based on GLSS 7 (2016/17) data.

For counterfactual or sensitivity analysis to establish a household-income-energy choice relationship, a crosstabulation was made between household "poverty status" and choice of cooking fuel. The GLSS 7 (2016/17) provided ordinal data that ranked households' poverty status: from being "*poor", "very poor"* to *"non-poor*". This ordinal ranking provides an opportunity to examine the relationship between the respondents' reported poverty status and choice of energy sources for cooking as a sensitivity analysis for a better appreciation of the earlier results based on the quintiles. Based on the literature, we formulate the following null hypotheses:

H0: "*There is no association between household poverty status and choice cooking fuel*

H1: *The relationship between household poverty status and choice energy for cooking is different from zero*", see for instance Anderson (2015) for general details. Using Stata's command, *tabulate,* with the option *chi* for the test significance of the relationship,

Table 10 reports the relationship between Ghanaians' cooking fuel commodities choice and their reported poverty status. Once again, it was confirmed that the poor household heads were more likely to cooking as reported in the column, "No cooking". In addition, out of the 6511 household heads who used wood to meet their cooking services, approximately 91% (1,386 households) and 80% (1,657 households) and 33% (3,468 households) respectively. Following (George & Mallery, 2019; Gorard, 2021), the Pearson chi-square informs us whether the outcomes of the cross-tabulation of households' poverty status and their choice of cooking fuel was statistically significant or not. The results in Table 10 reaffirm the relationship between the national quintile levels and household heads' choice of cooking choices in Ghana.

Furthermore, Figure 2 illustrates the distribution of household head's main cooking fuel choices and the national quintiles of Ghana. Like other developing regions in the world, households' energy fuel for cooking transit largely from wood to charcoal, then to gas as they climb the higher income ladder. For example, at the lowest quintile (Q1), the share of households using wood was about 88% against 51% at the highest quintile level. However, households may not necessarily quit the use of woody biomass as income increases, as other cultural elements and preferences could still play a role in the choice of cooking fuel (Giri & Goswami, 2018; Hassan et al., 2013; Necefer et al., 2020).

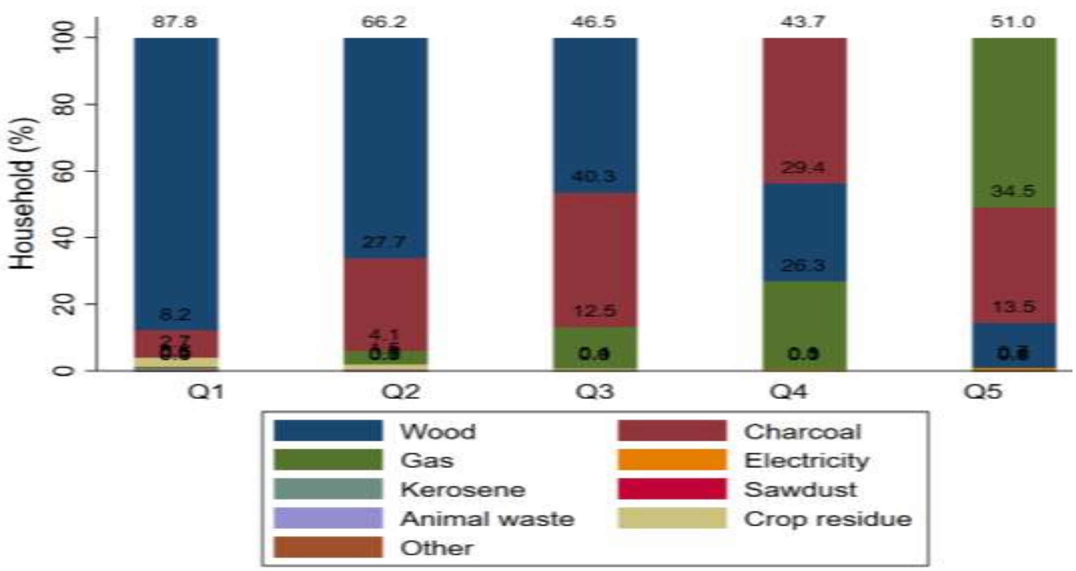

Figure 2: Income quintiles and distribution of main cooking fuel in Ghana

Source: Author's illustration using data from GLSS 7 (2016/17).

Next, the study results show household heads' energy choice behavior across the ten main administrative regions of Ghana[4].

[4] Note: Until 2018, Ghana has 10 regions. Currently, there are 16 regions following the creation of 6 new regions during the 2018 referendum. However, the creation of the new regions does not change any fundamental socio-economic conditions of the country, so thus the findings in the paper.

Table 10: Percentages and share of the number of households' cooking fuel by regions in Ghana

REGION	Main cooking energy fuel										
	No Cooking	**Wood**	**Charcoal**	**Gas**	**Electricity**	**Kerosene**	**Crop residue**	**Sawdust**	**Animal waste**	**Other**	**Total**
Western	50	599	362	314	5	1	0	0	0	0	1331
	6.46	9.20	9.18	12.20	16.67	11.11	0.00	0.00	0.00	0.00	9.50
Central	48	471	502	291	3	0	0	0	0	3	1318
	6.20	7.23	12.72	11.31	10.00	0.00	0.00	0.00	0.00	30.00	9.41
Greater Accra	101	21	536	730	5	3	0	0	0	2	1398
	13.05	0.32	13.59	28.37	16.67	33.33	0.00	0.00	0.00	20.00	9.98
Volta	30	733	371	232	0	1	0	0	0	0	1367
	3.88	11.26	9.40	9.02	0.00	11.11	0.00	0.00	0.00	0.00	9.76
Eastern	52	632	475	230	4	2	0	0	0	0	1395
	6.72	9.71	12.04	8.94	13.33	22.22	0.00	0.00	0.00	0.00	9.96
Ashanti	236	411	657	424	5	1	0	0	0	1	1735
	30.49	6.31	16.65	16.48	16.67	11.11	0.00	0.00	0.00	10.00	12.38
Brong Ahafo	101	701	365	145	4	1	0	1	0	0	1318
	13.05	10.77	9.25	5.64	13.33	11.11	0.00	50.00	0.00	0.00	9.41
Northern	81	1010	269	44	3	0	0	0	1	1	1409
	10.47	15.51	6.82	1.71	10.00	0.00	0.00	0.00	4.76	10.00	10.06
Upper East	34	905	188	88	0	0	134	0	20	2	1371
	4.39	13.90	4.77	3.42	0.00	0.00	100.00	0.00	95.24	20.00	9.79
Upper West	41	1028	220	75	1	0	0	1	0	1	1367
	5.30	15.79	5.58	2.91	3.33	0.00	0.00	50.00	0.00	10.00	9.76
Total	**774**	**6511**	**3945**	**2573**	**30**	**9**	**134**	**2**	**21**	**10**	**14009**
	100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.0**	**100.0**

Source: Author's compilation based GLSS 7 (2016/2017) data.

Table 11 shows that households' wood energy fuel use depicts the general trend of the country. The use of crop residue, animal dung/waste, sawdust, kerosene, and electricity generally were insignificant across all the regions in Ghana except the Upper West Region where 134 households reported using crop residue. Again, Table 10 and Figure 3 visually show that the three most socio-economically deprived regions in Ghana, Northern, Upper East, and Upper West Regions (*National Human Development Report 2018: Northern Ghana*, 2018) reported the highest number of households who used wood as cooking fuel as 2,943 out of the total 6,522 households nationwide who used wood for cooking during the survey period to reside in these regions. The three northern regions constitute about 45.2% of households who used wood for cooking in 2016/17. If we accept the simple definition of energy poverty from developing regions' perspective as "over-reliance on traditional biomass fuel" as the literature suggests (Churchill & Marisetty, 2020; Kasoga & Tegambwage, 2022), then Table 10 shows that about 45.2% of the energy-poor are located in the three northern regions in Ghana. However, further analysis is needed to appreciate whether these households used modern cooking technologies such as clean and efficient cooking stoves that reduce the environmental health of using wood fuel for cooking to inform policy. Already, existing evidence suggests that over-reliance on wood for fuel is one of the major reasons why deforestation is high in these regions of Ghana (*National Human Development Report 2018: Northern Ghana*, 2018), creating wood scarcity and forcing folks to use cow dung and guinea corn stalks as close substitutes of woody biomass.

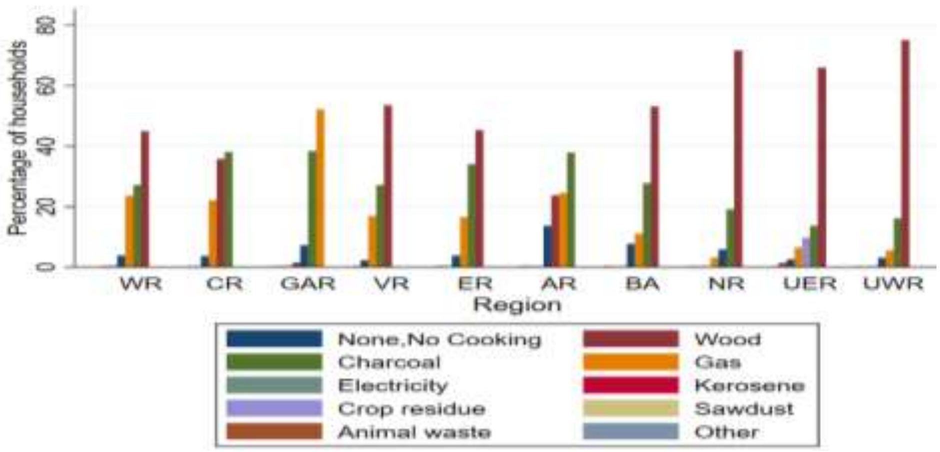

Figure 3: Distribution of household cooking fuel by regions in Ghana.

Note: WR = Western Region, CR = Central Region, CAR = Greater Accra Region, VR = Volta Region, AR = Ashanti Region, BA = Brong Ahafo Region, NR = Northern Region, UER = Upper East Region and UWR = Upper West Region.

Source: Author's illustration using GLSS 7 (2016/17) data.

Wood consumption is displayed in Figure 4. Generally, there is a negative relationship between household income and consumption of firewood in Ghana. The relationship is, however, much more pictorially clearer among the households in the Greater Accra Region than in others.

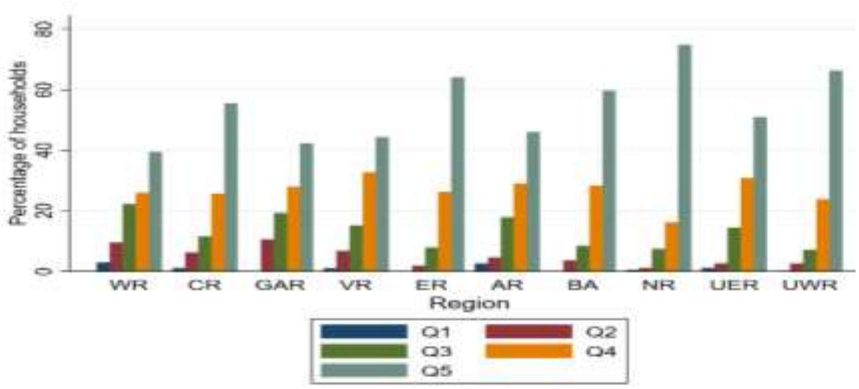

Figure 4: Percentage of households using firewood for cooking for regions and quintile levels

Source: Author's illustration based on GLSS 7 (2016/17) data.

Again, the use of charcoal as the main source of cooking fuel among the Ghanaian households is shown in Figure 5. charcoal, shown in Figure 5. The relationship between household heads income class which is proxied by income quintiles across the ten regions in Ghana is not a uniform phenomenon. For instance, except for the Greater Accra Region, it appears representative household head's decision to adopt charcoal as cooking fuel was an increasing function of income class, *ceteris paribus*.

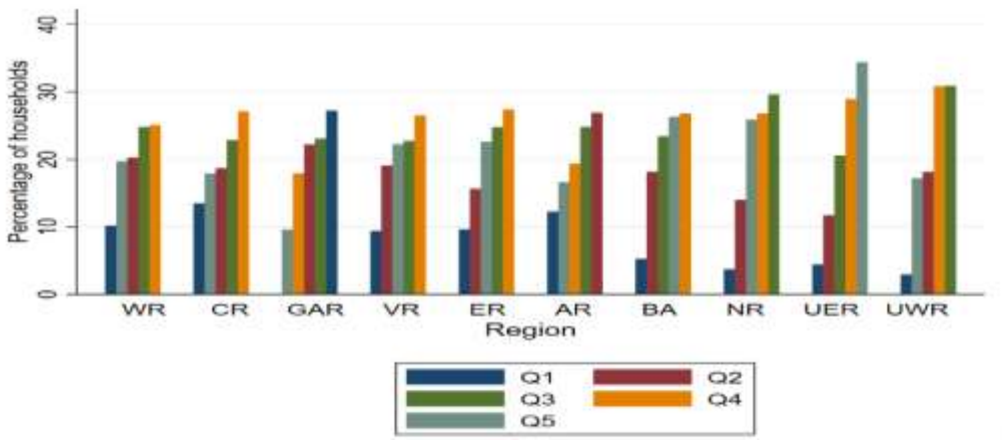

Figure 5: Distribution of charcoal as the main cooking fuel by income quintiles by region in Ghana. *Source*: Own illustration using data from GLSS 7 (2016/2017).

The households in the lowest income class (Q1) were comparatively less likely to use charcoal as their cooking fuel in Brong Ahafo, Upper East, and Upper West Regions of Ghana, while in the Greater Accra Region, households in the lowest income class showed higher use of charcoal for cooking. This complexity invokes an energy policy that takes into account the influence of households' income levels and cooking fuel choice behaviors, a uniform policy may fail to yield the intended social, economic or environmental well-being outcome.

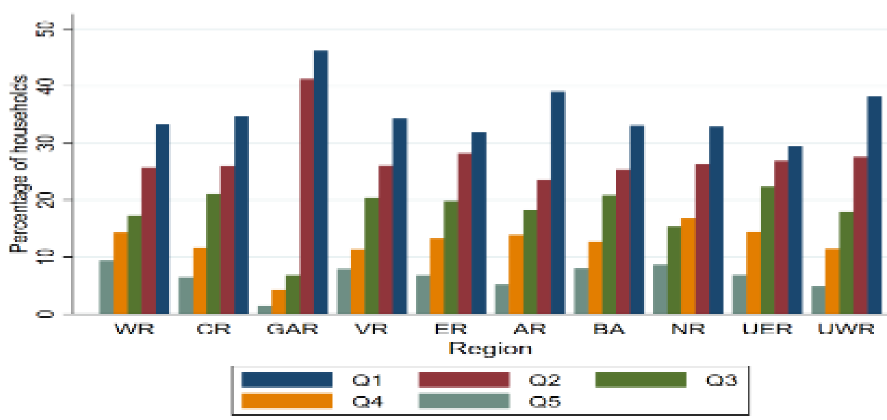

Figure 6: % of households using LPG as the main cooking fuel for quintiles across regions in Ghana. *Source*: Author's compilation using data from GLSS 7 (2016/17).

As displayed in Figure 6, household heads' choice of gas as cooking fuel is highly correlated with the income class across all the ten regions in Ghana during the survey period. We can fairly claim that, as far as policies that remove access constraints such as availability of gas stations, intermittent supply shortages, and affordability gaps, LPG is likely to dominate households cooking energy fuel mix in all the ten regions in Ghana. This impact may reduce pressure on the rate of fuelwood-based forest depletion and environmental degradation, while also addressing climate change and indoor air pollution from inefficient burning of solid biomass that prematurely kills about 14,000 Ghanaians annually (Crentsil et al., 2020). Whereas firewood was the most preferred cooking fuel among the households in the three social-economically deprived regions in Ghana, our results revealed, that the upper-income class households largely used charcoal to meet their cooking services in the Ghanaian economy.

Households' Main Source of Lighting Fuel and Electricity

The GLSS 7 compiled comprehensive information about the main source of fuel for lighting for their dwellings and electricity. Whereas the source of households lighting fuel and the main source of electricity may be closely related, the latter provides comprehensive information for understanding key national modern energy access policies such as geographical equity of access, environmental sustainability, and security, particularly, under the framework of Sustainable Development Goal Seven (SDG 7) in developing regions context.

Table 11: Households' main source of lighting energy fuel in Ghana (2016/17).

Main households' lighting fuel	Freq.	Percent	Cum.
Kerosene Lamp	119	3.40	3.40
Gas Lamp	3	0.09	3.49
Candle	34	0.97	4.46
Flash Light	2989	85.52	89.99
Firewood	53	1.52	91.50
Crop Residue	13	0.37	91.87
Other	284	8.13	100.00
Total	**3495**	**100.00**	

Source: Author's illustration based on GLSS 7 (2016/17) data.

Based on the research question: "*What is the main source of lighting for your dwelling*", For the 3,495 household heads who responded, about 85.5% (2,989 households) indicated they used a flashlight as their main source of lighting fuel. Almost 79% of households in urban areas have electricity for lighting as against 23 % of households in rural areas, 66 used solid biomass (firewood and crop residue) representing 1.9%, 119 (3.4%), 3 (0.09%), and 34 (1.0%) respectively used kerosene, gas lamps and candles as their main source of lighting, while 284

(8.1%) used other fuels to meet their lighting needs. Most households preferred a flashlight as their main source of lighting, probably due to the affordability of batteries and relatively cheap access to flashlight devices from China. However, the high patronage of a flashlight as the main source of lighting among the Ghanaian households piqued further investigations to understand the main social-economic drivers for purpose programming.

Table 12: Number of households and percentage of households' main source of lighting fuel by the national quintiles.

	Quintile Levels					
Households' main lighting fuel	**1**	**2**	**3**	**4**	**5**	**Total**
Kerosene Lamp	32	32	27	19	9	119
	2.02	3.94	5.23	5.28	4.13	3.40
Gas Lamp	2	1	0	0	0	3
	0.13	0.12	0.00	0.00	0.00	0.09
Candle	8	8	5	7	6	34
	0.50	0.98	0.97	1.94	2.75	0.97
Flash Light	1312	728	456	309	184	2989
	82.62	89.54	88.37	85.83	84.40	85.52
Firewood	37	8	6	1	1	53
	2.33	0.98	1.16	0.28	0.46	1.52
Crop Residue	12	1	0	0	0	13
	0.76	0.12	0.00	0.00	0.00	0.37
Other	185	35	22	24	18	284
	11.65	4.31	4.26	6.67	8.26	8.13
Total	**1588**	**813**	**516**	**360**	**218**	**3495**
	100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: Author's own based on GLSS 7 (2016/17) data.

The study further establishes the relationship between households' main lighting fuel source and their reported income class proxied by the national quintile levels. The results are presented in Table 12 and Figure 7, we can pictorially "visualize" a strong relationship between households' income class and the use of a flashlight as a main source of lighting in Ghana during the survey period. In particular, there was a strong negative relationship between the choice of flashlights and households' income class, i.e., an increasing income level was a decreasing function of a flashlight, *all things being equal*. Table 13 and Figure 7 confirmed, at least, pictorially that income level (class) is a major determinant of the household's decision to adopt a flashing light as the main lighting fuel. In a study conducted using the Kenyan national households survey data, the researchers concluded that "… *a household lives in a modern style house, the probability of choosing kerosene and battery*[5] *are reduced by 12.4 and 5.9%, respectively, compared to a household living in a traditional style house*" (Baek et al., 2020). "A

[5] Battery touch light is synonymous with "flashlight".

modern-style house" as used by these researchers could be associated with higher income class households. Given social-economic similarities between Kenya and Ghana's economies, there is a reason to speculate similar covariates of households' fighting fuel choice and income classes. Kerosene, candle, crop residue, firewood, and other sources, though insignificant, also revealed a negative relationship with households' income levels in Ghana (Table 12 and Figure 7).

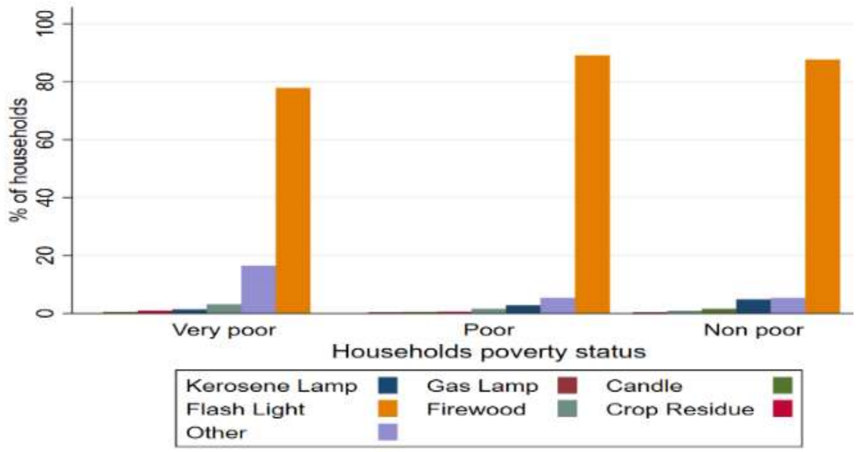

Figure 7: Percentages of households' main source of lighting fuel by income class in Ghana
Source: Author's own based on GLSS 7 data (2016/17).

The results, however, showed a complex relationship between the ordinal ranking of households, poverty status, and source of main lighting fuel. As shown in Figure 8, the households classified as being "poor", "very poor" and "non-poor", largely used flashlights as their main lighting fuel in Ghana, including but an insignificant proportion of firewood, crop residue, candle, and other sources. The use of gas lamps though insignificant appeared to increase as the household moved from being poor.

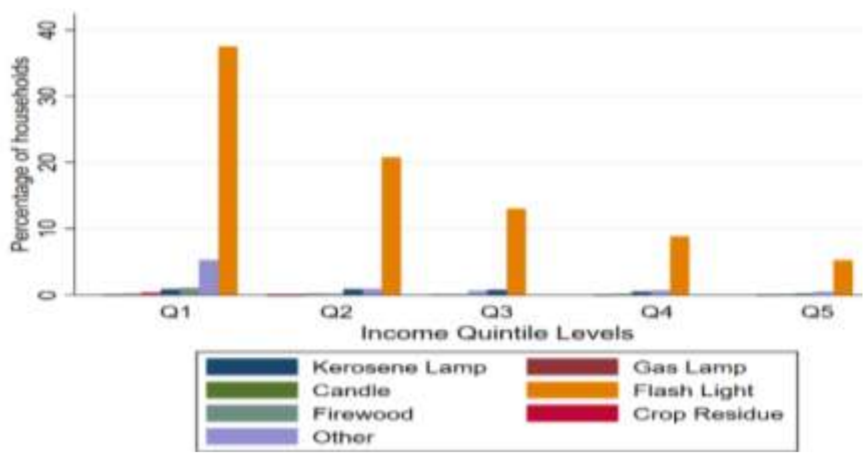

Figure 8: Percentage of the household's main source of lighting for the poverty status in Ghana.
Source: Author's illustration based on GLSS 7 (2016/17).

This suggests that the use of a gas lamp was a luxury good to the poor class in Ghana. Again, the poor and non-poor Ghanaian households largely used flashlights probably due to the unprecedented electricity supply instability from 2013 to 2016, coupled with rising electricity tariffs. Both households in rural and urban areas largely used a flashlight as their main source of lighting fuel (Table 13).

Table 13: Percentage of households' main lighting-urban-rural correlation

Household main source of lighting fuel	**Settlement**		
	Urban	**Rural**	**Total**
Kerosene Lamp	37	82	119
	7.27	2.75	3.40
Gas Lamp	0	3	3
	0.00	0.10	0.09
Candle	15	19	34
	2.95	0.64	0.97
Flash Light	434	2555	2989
	(85.27)	85.57	85.52
Firewood	1	52	53
	0.20	1.74	1.52
Crop Residue	0	13	13
	0.00	0.44	0.37
Other	22	262	284
	4.32	8.77	8.13
Total	**509**	**2986**	**3495**
	100.00	**100.00**	**100.00**

Source: Author's illustration-based GLSS 7 (2016/17).

Table 14 illustrates households' main lighting fuel source in the administrative regions of Ghana. Across the ten regions of Ghana, the flashlight was the main source of lighting fuel among the households surveyed in 2016/2017. However, the three poorest regions in Ghana, the Northern, Upper East, and Upper West regions had the highest number of households who used a flashlight as their main source of lighting fuel.

Table 15 displays the household's main *source of electricity* tabulation in Ghana, 2016/17. The table revealed that electricity supply from the National Grid (the mains) remains a predominant source of households' electricity supply in Ghana. It constituted about 72% of the source of households' electricity, followed by rechargeable batteries and solar lanterns. In line with the national renewable energy policies, local mini-grid and home solar systems are expected to drive decentralization of the energy systems, climate change mitigation, and reduce energy poverty, especially, in the rural communities.

Table 14: Share of number and percentages of main lighting fuels by regions in Ghana

REGION	Household main source of lighting							
	Kerosene Lamp	**Gas Lamp**	**Candle**	**Flash Light**	**Firewood**	**Crop Residue**	**Other**	**Total**
Western	12	0	2	208	3	0	14	239
	10.08	0.00	5.88	6.96	5.66	0.00	4.93	6.84
Central	23	0	5	150	0	0	8	186
	19.33	0.00	14.71	5.02	0.00	0.00	2.82	5.32
Greater Accra	7	0	9	67	0	0	3	86
	5.88	0.00	26.47	2.24	0.00	0.00	1.06	2.46
Volta	49	1	7	255	4	0	18	334
	41.18	33.33	20.59	8.53	7.55	0.00	6.34	9.56
Eastern	14	0	4	361	4	0	23	406
	11.76	0.00	11.76	12.08	7.55	0.00	8.10	11.62
Ashanti	5	1	2	157	1	0	30	196
	4.20	33.33	5.88	5.25	1.89	0.00	10.56	5.61
Brong Ahafo	1	0	0	363	1	0	13	378
	0.84	0.00	0.00	12.14	1.89	0.00	4.58	10.82
Northern	4	0	2	476	8	0	33	523
	3.36	0.00	5.88	15.93	15.09	0.00	11.62	14.96
Upper East	3	0	1	559	5	12	8	588
	2.52	0.00	2.94	18.70	9.43	92.31	2.82	16.82
Upper West	1	1	2	393	27	1	134	559
	0.84	33.33	5.88	13.15	50.94	7.69	47.18	15.99
Total	119	3	34	2989	53	13	284	3495
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Author's illustration based on GLSS 7 (2016/17).

However, Table 15 showed that these energy mixes were quite low, in the framework of sustainability thinking. Again, 3,495 households were not connected to any form of the electricity grid (which had no access to electricity). If we interpret the condition of these 3,495 households within the context of “the right to development” and the role that electricity infrastructure services play thereof, then these households were the “*left behind*" as they lacked fair access to all the perks that come with affordable and reliable access to electricity energy services, see for example (Omorogbe, 2018; Stojilovska, 2021).

Table 16 shows households' main source of electricity in the administrative regions of Ghana. Grid electricity is the most important household source of electricity in the Greater Accra and Ashanti Regions, 13% and 15% respectively, and comparatively low in the three northern regions – Northern (8.3%), Upper East (6%), and Upper West (7.8%) regions. In terms of local mini-grids, only 29 households were connected, Easter Region 34.5% (10 households), Brong Ahafo 27.6% (8 households), and Upper West Region 37.9% (11 households).

Table 15: Main source of electricity supply to households in Ghana

Households' most-used electricity source	Freq.	Percent	Cum.
National Grid Connection	10106	72.14	72.14
Local Mini-Grid	29	0.21	72.35
Private Generator	14	0.10	72.45
Solar Home System	32	0.23	72.67
Solar Lantern/Lighting System	131	0.94	73.61
Rechargeable Battery	150	1.07	74.68
Other (specify)	52	0.37	75.05
No Electric Power	3495	24.95	100.00
Total	14009	100.00	

Source: Author's illustration based on GLSS 7 (2016/17) data.

Households in the rest of the seven regions were not connected to any form of mini-grid system. Meanwhile, Ghana has ratified the "Mini-Grid Electrification Policy" in 2016, a state-led investment policy through the Volta River Authority, Electricity Company of Ghana, and Northern Electricity Distribution Company to generate and distribute electricity in the rural and underserved communities. The effectiveness of this policy needed to be revisited as comprehensive data becomes available.

Electricity generation from privately owned generators and home solar systems constituted insignificant sources for households in Ghana during the survey period. Table 17 showed households' main electricity sources in rural and urban locations in Ghana. The results show that about 39.1% and 33.1% respectively lived in urban and rural communities.

These results can be understood from what some geography and development scholars have termed as "*urban bias development*" (Lipton, 1977), and as argued by critical infrastructure access across rural and urban divides in African economies (Odusola, 2021). Among households who derived their source of electricity from the local mini-grids, 0.21% (29 households) as against zero in the urban areas.

Table 16: Households' main source of electricity by regions in Ghana

	Household's main electricity source								
REGION	**National Grid Connection**	**Local Mini-Grid**	**Private Generator**	**Solar Home System**	**Solar Lantern/ Lighting System**	**Rechargeable Battery**	**Other (specify)**	**No Electric Power**	**Total**
Western	1063	0	2	3	10	7	7	239	1331
	10.52	0.00	14.29	9.38	7.63	4.67	13.46	6.84	9.50
Central	1109	0	1	2	10	10	0	186	1318
	10.97	0.00	7.14	6.25	7.63	6.67	0.00	5.32	9.41
Greater Accra	1304	0	0	1	1	5	1	86	1398
	12.90	0.00	0.00	3.13	0.76	3.33	1.92	2.46	9.98
Volta	1010	0	1	1	12	2	7	334	1367
	9.99	0.00	7.14	3.13	9.16	1.33	13.46	9.56	9.76

Tab. 16...

Eastern	953	10	4	4	11	4	3	406	1395
	9.43	34.48	28.57	12.50	8.40	2.67	5.77	11.62	9.96
Ashanti	1516	0	1	0	4	8	10	196	1735
	15.00	0.00	7.14	0.00	3.05	5.33	19.23	5.61	12.38
Brong Ahafo	919	8	1	2	3	5	2	378	1318
	9.09	27.59	7.14	6.25	2.29	3.33	3.85	10.82	9.41
Northern	839	0	3	7	6	26	5	523	1409
	8.30	0.00	21.43	21.88	4.58	17.33	9.62	14.96	10.06
Upper East	606	0	1	8	72	79	17	588	1371
	6.00	0.00	7.14	25.00	54.96	52.67	32.69	16.82	9.79
Upper West	787	11	0	4	2	4	0	559	1367
	7.79	37.93	0.00	12.50	1.53	2.67	0.00	15.99	9.76
Total	**10106**	**29**	**14**	**32**	**131**	**150**	**52**	**3495**	**14009**
	100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: Author's illustration based on GLSS 7 (2016/17) data.

Table 17: Households' main electricity source by rural-urban locations in Ghana

Household main source of electricity	**Location**		
	Urban	**Rural**	**Total**
National Grid Connection	5470	4636	10106
	(39.05)	(33.09)	72.14
Local Mini-Grid	0	29	29
	(0.00)	(0.21)	0.21
Private Generator	0	14	14
	(0.00)	(0.10)	0.10
Solar Home System	2	30	32
	(0.01)	(0.21)	0.23
Solar Lantern/Lighting System	6	125	131
	(0.04)	(0.89)	0.94
Rechargeable Battery	22	128	150
	(0.16)	(0.91)	1.07
Other (specify)	9	43	52
	(0.06)	(0.31)	0.37
No Electric Power	509	2986	3495
	(3.63)	(21.31)	24.95
Total	**6018**	**7991**	**14009**
	42.96	**57.04**	**100.00**

Source: Author’s own based GLSS 7 (2016/17) data.

This is probably due to the rural policy-focused nature of the 2016 Mini-Grids Electricity Policy. Again, households in the rural communities were comparatively likely to rely on private generators, rechargeable batteries, and solar lanterns than the urban folks. For households who were not connected to any form of the electricity grid, 3.6% and 31.3% respectively lived in urban and rural communities.

Table 18: Households' main source of electricity
and poverty status in Ghana

Household main source of electricity	Household poverty			
	Very poor	Poor	Non-poor	Total
National Grid Connection	547	1107	8452	10106
	3.90	7.90	60.33	72.14
Local Mini-Grid	5	1	23	29
	0.04	0.01	0.16	0.21
Private Generator	0	1	13	14
	0.00	0.01	0.09	0.10
Solar Home System	4	4	24	32
	0.03	0.03	0.17	0.23
Solar Lantern/Lighting System	11	41	79	131
	0.08	0.29	0.56	0.94
Rechargeable Battery	49	37	64	150
	0.35	0.26	0.46	1.07
Other (specify)	17	8	27	52
	0.12	0.06	0.19	0.37
No Electric Power	889	861	1745	3495
	6.35	6.15	12.46	24.95
Total	1522	2060	10427	14009
	10.86	14.70	74.43	100.00

Source: Author's own using data from GLSS 7 (2016/17).

Again, this distribution shows rural-urban inequality in terms of the connection electricity as a critical infrastructure network service. If Ghana has to meet the "universal to modern energy" as expressed in the Sustainable Energy for All initiative (SE4ALL) and SDG 7 target 1 (provision of universal access to modern energy services) by 2030, then such an access gap between the rural-urban gaps needed to be addressed. Table 19 indicates the number and percentage of households' main source of electricity by the national quintile levels.

At the national level, the main grid electricity connection appeared as an increasing function of households' quintile levels, that is, those who used national grid-based electricity turned to be higher as they climb the higher income class proxied by the quintiles. Again, the results show a strong correlation between households without electric power energy and the national quintile levels. For instance, for households who reported that they were not connected to electricity, 11.3%, 5.8%, 3.7%, 2.6%, and 1.6% were in the first, second, third, fourth, and fifth quintile respectively. However, further and more comprehensive investigations are imperative to appreciate the directions of association and likely simultaneity for optimal policy targeting.

Table 19: The number and percentage of household main electricity sources by quintiles in Ghana

	National welfare quintile					
Household's main source of electricity	1	2	3	4	5	Total
National Grid Connection	1381	1616	1813	2212	3084	10106
	9.86	11.54	12.94	15.79	22.01	72.14
Local Mini-Grid	6	3	4	4	12	29
	0.04	0.02	0.03	0.03	0.09	0.21
Private Generator	1	3	2	1	7	14
	0.01	0.02	0.01	0.01	0.05	0.10
Solar Home System	8	14	7	2	1	32
	0.06	0.10	0.05	0.01	0.01	0.23
Solar Lantern/Lighting System	44	47	15	14	11	131
	0.31	0.34	0.11	0.10	0.08	0.94
Rechargeable Battery	85	28	17	10	10	150
	0.61	0.20	0.12	0.07	0.07	1.07
Other (specify)	24	8	7	5	8	52
	0.17	0.06	0.05	0.04	0.06	0.37
No Electric Power	1588	813	516	360	218	3495
	11.34	5.80	3.68	2.57	1.56	24.95
Total	3137	2532	2381	2608	3351	14009
	22.39	18.07	17.00	18.62	23.92	100.00

Source: Author's own based on GLSS 7 (2016/17).

CONCLUSIONS AND IMPLICATIONS

This study points to a connection between income levels and households' energy consumption in Ghana. The study was grounded on the "**Energy Ladder Hypothesis**" in the energy economics literature. Accordingly, the primary guiding hypothesis was to establish whether the Ghanaian household income class has a direct relationship with the adoption of modern energy fuels to satisfy two main energy services: cooking and lighting, *ceteris paribus*. Our analyses reveal that woody biomass (mainly charcoal and firewood) and gas remain the three energy fuel commodities mostly used for cooking services in Ghana, with fuelwood revealed as the most preferred energy fuel among rural folks in Ghana. The use of charcoal and LPG are predominantly utilized among households in the urban communities in Ghana. Our counterfactual analysis shows that compared to the "non-poor" households, the "poor" and "very poor" are more likely to predominantly rely on firewood. In the same way, the results show that the main source of lighting fuel in the country is a flashlight. However, the degree of reliance on flashlights for lighting turns to decrease with an increasing income quintile level in Ghana. Furthermore, the national grid system is the main source of electricity for the Ghanaian households, however, access is unevenly distributed across rural-urban and north-south geographical divides. About 25% of Ghanaian households lacked access to electricity in 2016/17. The study confirmed that the majority of the Ghanaian households who lacked access to electricity were generally rural folks, and predominantly in the three northern regions.

Compared to the "non-poor" Ghanaian households, "the poor" and "very poor" households are less likely to be connected to grid system electricity. This implies that monetary poverty and energy poverty must be mutually inclusive, and hence needed to be addressed simultaneously.
The results clearly show a direct relationship between households' income class and the adoption of modern energy services. That is, all things being equal, as a representative agent climbs a higher income ladder, demand for modern forms of energy services turns to increase. In particular, the use of charcoal, LPG, and access to national electricity grid infrastructure show similar trends in Ghana. However, households' choice of animal dung, crop residue, and wood for cooking appeared as a decreasing function with an increasing household income level, these observations show a nationwide trend.

To achieve the energy goal (SDG 7) and its interlocking relationships with other Sustainable Development Goals (SDGs), the Government of Ghana will do well by rolling out households' energy transition programmes that take into consideration the existing rural-urban and north-south inequalities, ecological zones their affiliated energy vulnerability and opportunities, and gender-responsive policy instruments. The results further offer ample reasons to suggest that the sustainability transformations value principle of "***Leaving No One Behind***" (Kharas et al., 2019) in the energy sector cannot be achieved without addressing spatial factors, giving other equally important conditions. For instance, the analyses show that the three northern (Northern, Upper East, and Upper West) regions still have the largest number of households using fuelwood. These regions are also the most vulnerable to the impact of high deforestation rates and climate change spells (*Ghana's Fourth Communication to the United NationsFramework Convention on Climate Change*, 2020; Klutse et al., 2020). It is therefore important for the Government of Ghana and development partners to scale up the **Ghana Rural LPG Promotion Program**. For instance, by making LPG infrastructure services accessible and affordable through the operations of the Atuabo Gas Plant to reduce over-reliance on woody biomass. With about 25% of the Ghanaian households still lacking access to electricity, employment-generation-integrated solar projects should be undertaken, especially in the rural communities to alleviate the access gaps, while also creating job opportunities for the teeming youth. From a human rights perspective, models laws about the right to clean energy fuel and technologies for lighting and cooking to deal with the unmet needs and affordability gaps should be enacted to assist the marginalized populations/households (Gonzalez, 2018). Finally, future research involving micro-econometric modeling is needed to provide further empirical evidence to inform households' energy access policies in the country. Thus, policymakers, as well as individual researchers, are highly encouraged to detail the geographic and income context of households' energy use profiles in Ghana by integrating modern tools such as geographic information systems (GIS) for a comprehensive spatial understanding of households' energy access and affiliated environmental problems for optimal policy targeting. In particular, researchers in the field of energy, poverty, and sustainable development-related disciplines are highly recommended to conduct household units energy consumption survey to close the existential household levels energy profiles data paucity in Ghana for sustainable development, subject to resources availability and accessibility.

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