Title
Household Lighting and Cooking Energy Transitions from Fuels to Grid Based Electricity in The Gambia

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Household Lighting and Cooking Energy Transitions from Fuels to Grid Based Electricity in The Gambia

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Abstract

The Gambia, like other Sub-Saharan African nations, has seen a slow transition from traditional, dirty fuels to cleaner ones. Although measurement of energy access for lighting and cooking purposes has been performed in other Sub-Saharan African countries, no similar analysis has been published for The Gambia. Using data from the 2010 and 2015 Gambian Integrated Household Surveys, this study derives lighting and cooking fuel access levels and factors driving energy fuel transitions. Generalized linear modeling is used to determine the driving factors of lighting and cooking fuel choice among Gambian households over time. Results indicate that household's primary lighting fuel shows an overall decline in fuel use and rise in decentralized energy sources, instead of grid electricity. Further, grid electricity is concentrated in urban areas compared to rural. Household primary cooking fuel has shown little change over time and remains to be mostly firewood. Access to charcoal, a slightly cleaner fuel, is concentrated in urban areas.

Introduction

Energy Access Worldwide

In 2021, 43% of the Sub-Saharan Africa population did not have access to electricity (IEA, 2022). Electricity access is a key factor in economic, social, and human development, and many studies have found positive correlations between electricity access and higher levels of education, health, well-being, and productivity (Ahmad et al., 2014; Gafa & Egbendewe, 2021; Rao, 2013). Lighting and cooking are the most essential activities that require energy, either from electricity, fuels, or solar. Traditional bio-mass based fuels such as firewood, charcoal, and biogas serve as the primary source of lighting fuel for many households in developing countries, especially among lower income households, and more among rural communities. These solid fuels are often inefficient, pose health risks, and contribute to carbon emissions (Muller & Yan, 2018; Kebede et al., 2010). Adequate electricity supply quality and affordability are also major challenges that many developing countries face, with rural communities often experiencing unexpected outages, fluctuating voltages, and lack of maintenance and safety (Rosenthal et al., 2018). The measurement of energy access for lighting and cooking purposes has gained significant interests from governments and development agencies over the past decade. However, accessibility and affordability of electricity remains a major challenge in many developing communities worldwide.

The United Nations' Sustainable Development Goal (SDG) 7 calls for "universal access to affordable, reliable, sustainable, and modern energy services" by 2030, targeting access to energy, renewable energy resources, and energy efficiency (United Nations, 2015). Indicators of this goal include measuring the proportion of the population with access to electricity and proportion with primary reliance on clean fuels. In September 2020, the United Nations High-Level Political Forum published guidelines to help governments remain committed to the advancement of SDG 7 in light of the COVID-19 crisis (United Nations, 2020). Specifically for African nations, the brief recommends that governments focus on obtaining private sector investments for strengthening grid systems, increasing the adoption of microgrids and localized technology in rural areas, and decreasing an over reliance on biomass. Lighting and cooking fuel energy transitions from dirty to cleaner sources are an important driver in advancement toward achieving SDG 7.

The Gambia Overview

The Gambia is a small country in West Africa with a population of 2.4 million as of 2021 (World Bank, 2021). In 2020, over one third of the country did not have access to electricity. Almost half of the population is considered rural, of which only 35% have access to electricity (IEA, 2021). Like other Sub-Saharan African nations, The Gambia has seen a slow transition from dirty to cleaner lighting and cooking fuels. While limited information is available publicly on The Gambia's total electricity generation, the National Water and Electric Company (NAWEC) reported 232 GWh of electricity generated in 2011, and 291 GWh generated in 2016, a 5% growth rate per year (IRENA, 2013; NAWEC, 2012). The country also relies heavily on petroleum products, using mostly diesel and heavy fuel oil for electricity generation. By 2013, biomass sources accounted for nearly 65% of The Gambia's energy supply, and more than 90% of household energy consumption (IRENA, 2013).

In 2021, NAWEC published The Gambia's Electricity Sector: Strategic Roadmap 2021-2040, which details plans for universal access targets by 2025 (MoPE, 2019). The roadmap serves as a planning guide to reach the country's access targets and provide more reliable and affordable electricity by expanding grid extension areas and solar PV sites. However, with only one third of the population with access so far, the 2025 goal seems difficult to reach. Additionally, the COVID-19 pandemic had slowing, and even reversing, effects on energy access progress in many Sub-Saharan African countries. The IEA's 2021 World Energy Outlook found that the number of people lacking energy access increased by 2% (13 million people) from 2019 to 2020. The crisis also pushed 6% (30 million people) of the connected population back to energy poverty (IEA, 2021). One of the primary causes of these shifts was the lack of financial resources available to governments, private industry, and individual households, as many were forced to focus on emergency health measures instead of electricity infrastructure (IEA, 2021).

Specific insights on the country's lighting and cooking energy needs in rural areas remain largely unknown. This research explores Gambian household survey data for 2010 and 2015, and determines electricity access levels and the socio-economic factors driving lighting and cooking fuel transitions in the country. Given the limited assessment currently available on The Gambia's rural electricity access, this analysis aims to be among the first to provide insights on electricity access and fuel transitions in the country.

Background

Energy Use and Fuel Patterns

Understanding energy sources and fuel use in developing and rural regions is key to studying energy access and transitions. Fuel use patterns vary with region, urban/rural sprawl, income levels, education, gender and other household demographics (Ramji, 2012). Current energy use beyond electricity comes in various forms, each presenting unique benefits, challenges, and risks. When electricity is unavailable, unreliable, or unaffordable, many developing and rural regions turn to traditional fuel alternatives for lighting such as kerosene and firewood, or other resources like candles, battery powered devices, and solar lamps. In many cases, these resources are easier to obtain and could be considered more reliable when electricity infrastructure is lacking, but often not by choice.

A multiyear study in India revealed firewood and liquified petroleum gas (LPG) for cooking; and, kerosene and electricity for lighting, as the main fuels among rural households. From 2000 to 2010, firewood consumption increased by 7.5%, electricity access increased by 30%, and LPG use remained relatively constant. The study notes that kerosene consumption declined over time, which is attributed to the increase in access to electricity and LPG (Ramji, 2012). A similar study performed in Kenya found that kerosene was the dominant fuel among both rural and urban households for lighting, cooking, and water heating. The next most common sources for lighting include electricity and candles, and for cooking, biomass, and LPG (Karkezi et al., 2008).

Fuel costs must also be considered when studying lighting energy transitions, as lower income households often spend a higher percentage on energy than higher income households. Market research from SolarAid and Lighting Africa reveals that sub-Saharan African households spend an average of 4 USD per month on lighting alone, and 5 and 9 USD per month on energy (Harrison & Adams, 2017). The research found that the lowest income class quintile among Kenyan households spends 10% of total expenditure on energy. Choumert-Nkolo et al. (2019) found that kerosene prices in Tanzania are highly correlated with likelihood of using cleaner lighting fuels. The study concluded that a "10% increase in the kerosene price results in a 0.9% decrease in the likelihood of using lamp oil as a fuel source for lighting and an almost equivalent 0.9% increase in the likelihood of using modern fuels."

Approaches to Measuring Energy Access

Several methods to assess energy access have been employed by researchers around the world. Traditional methods often approach data in a single dimension, using only income, expenditure, or demand to determine access levels (Nassbaumer et al., 2012). Recent studies have revealed the benefits of using multidimensional approaches that include multiple variables such as physical access, affordability, health, safety, and convenience, taking a much more holistic approach (Gafa & Egbendewe, 2021; Nassbaumer et al., 2012).

The energy ladder hypothesis is another common approach to measuring energy access, theorizing that fuel transitions from traditional to cleaner energy sources occur as income and socioeconomic status increases (Leach, 1992; Choumert-Nkolo et al., 2019; Rahut et al., 2017). The energy ladder ranks fuel/energy sources by cleanliness and efficiency with income level. The bottom of the ladder includes solid fuels, in the order of crop waste, wood, charcoal, and coal. Gas and kerosene make up the middle, with electricity at the top, indicating that it is the cleanest energy source and dominant amongst the highest income levels (Van der Kroon et al., 2013). A lighting energy transition study spanning several sub-Saharan African countries confirms the energy ladder hypothesis by using ordered probit models to find higher income households are more likely to use cleaner sources of energy (electricity, solar, batteries) (Rahut et al., 2017). A similar study in Tanzania uses the energy ladder approach but instead emphasizes fuel stacking, where households use multiple fuels at the same time and are likely to choose different fuels for different uses. The study concludes that households stack "up the ladder," using "more modern" (cleaner) cooking and lighting fuels as per capital equivalent expenditure increases (Choumert-Nkolo et al., 2019).

The Energy Sector Management Assistance Program's (ESMAP) Multi-Tier Framework (MTF), launched by The World Bank and Sustainable Energy for All (SE4ALL), measures energy access on a 5-tier basis on dimensions such as affordability, capacity, voltage stability, reliability, legality, and safety (ESMAP). This method goes beyond using grid connection as a proxy for access and assigns a tier to each household for each of the dimensions. A study across 6 of the most populated states in India successfully employed the multi-tier framework to determine that 69% of rural households are electrified, of which nearly half experience frequent supply quality and duration issues, placing them in the lowest tier of access (Jain et al., 2016).

Socio-economic Drivers of Energy Access and Well-being

Many studies have investigated how electricity access affects various attributes of human well-being. Ahmad et al. (2014) finds that human well-being is notably better in electrified households than in non-electrified households in India. They find a positive association between electricity access and school enrollment, and a negative relationship between access and absenteeism and morbidity, concluding that greater access appears to be a contributor to improving education attainment in rural households (Ahmad et al., 2014). A study performed in Senegal and Togo also concluded that electricity access is positively associated with well-being, specifically with education and health advancements (Gafa & Egbendewe, 2021). Various studies also indicate a relationship between access to electricity and household income. Rao (2013) finds that electricity access in India increases average expected household income by about 43%. Rao (2013) concludes that higher incomes open up more opportunities for rural households, including greater access to household amenities in the form of electricity appliances such as electric lamps, space heaters, fans, and cooking devices. These types of appliances often lead to a higher quality of living and other well-being benefits such as healthier living due to increased productivity and education because of greater hours with lighting resources and healthier living due to more efficient cooking (Rao, 2013; Burns & Samad, 2018).

Generalized linear modeling is a common way to test the association between a response variable and a set of regressor or predictor variables (Kimutai et al., 2020). Using this method, Kemmler concludes that community electrification levels, education of household members, and employment type are much more relevant for assessing household electrification than household expenditure (Kemmler, 2007). Rahut et al. (2017) also use multinomial logit methods to study factors that influence household use of clean energy sources for lighting purposes, finding that the use of electricity for lighting increases as income increases. Rahut et al. (2017) conclude that as education levels increase, the number of households dependent on electricity increases, and use of batteries and kerosene decreases for those households. Finally, gender also affects lighting fuel choice, with female-headed households typically using cleaner energy sources compared to male headed households (Rahut et al., 2017). Additionally, Alkin et al. (2016) use multi logit regression to examine the relationships between the quality of electricity supply in rural India and household satisfaction with its electricity situation, on the basis of duration, reliability, and voltage stability. Results indicate that the number of hours of electricity per day is the strongest determinant in overall household satisfaction. Reliability and voltage stability also have positive impacts on satisfaction, but to a lesser extent than duration. A study across seven African countries identified the top factors influencing cooking fuel type as wealth index, electricity access, household size, education level, and type of residence (Makonese et al., 2017). Wealthier households with more educated household heads were more likely to use cleaner fuels for cooking than less educated ones. Rahut et al. (2016) achieved very similar conclusions in Bhutan, with the addition of age and gender as important drivers of fuel choice. Furthermore, access to electricity makes a household less likely to use other fuels.

Literature also reveals that gender plays a key role in fuel choice and household decisions. In developing countries, women are the main users of energy and are responsible for cooking and other fuel management (Gafa & Egbendewe, 2021). Women are often disproportionately affected by the burdens of low energy access as they are directly impacted by the amount of labor needed to maintain household activities, air pollutants from cooking fuels, and time spent collecting fuel for energy (Mazorra et al., 2020). Gafa and Egbendew (2021) find that the gender dimension of energy use is correlated to energy poverty levels, fuel choice, income, and distance traveled for fuel collection. A strong case can be made for the increased empowerment of women through access to clean energy and clean cooking methods and the need to open up more opportunities for women. A study conducted on rural electrification in Nicaragua shows that greater electricity access is associated with a higher probability (23% increase) of women engaging in salaried work. Data indicated that having electricity was associated with an average increase of 4 extra hours of salaried work for both men and women. Additionally, in electrified households, women spent much less time cooking and collecting firewood than in non-electrified households, positively impacting the health and well-being of families (Grogan & Sadanand, 2012; Ramji, 2012).

While electrification receives the most attention for improved energy access in developing countries, electricity is rarely used for cooking (Makonese et al., 2017; Ekholm et al., 2010) When households do have access to electricity, they often prioritize lighting or other electric appliances before cooking (Kanagawa & Nakata, 2008). Following the energy ladder methodology, it is sufficient to first focus on transitioning households to a cleaner fuel first, then electricity, if it is available. For example, moving a household from firewood to charcoal for cooking would be the first step in a transition. Electric cooking is considered the cleanest type of cooking, but is often not feasible in many developing regions. Literature also finds that many households use multiple energy sources at once, known as fuel stacking, where cleaner fuels tend to compliment traditional fuels instead of replacing (Makonese et al., 2017). Common alternatives to traditional bio cooking fuels include charcoal (or other biochar) and liquefied petroleum gas (LPG).

Health Impacts of Energy Transitions

The smoke and particulate matter released from cooking with firewood and other solid biofuels caused exposure to household air pollution (HAP) and increases the risk of respiratory diseases and other health issues (Kilabuko et al., 2007). Children are especially at risk from HAP which can stunt growth and cause premature death. The World Health Organization reports that 45% of acute respiratory infection (ARI) deaths in children under five is traceable to HAP associated with burning biomass fuels (Woolley et al., 2021). Common ARI symptoms include of shortness of breath, cough, or fever, and can escalate to pneumonia or similar illness (Simoes et al., 2006; Thomas & Bomar, 2023). A study across 30 developing countries observed more cases of ARI in children living in households that cooking with firewood compared to households that cook with charcoal. The study also concluded that outdoor cooking resulted in less risk of ARI symptoms (Woolley et al., 2021).

The health impacts of HAP can also cause economic burden for households. Health costs are influenced by medical examination fees, the cost of travel to a hospital, the cost of medication, and the cost of the loss of productivity in those who are affected by ARIs. A study in rural Nepal, found that the annual health cost per household due to burning dung-briquettes was 61% higher than the cost of biogas (16.94 USD vs 10.38 USD) (Pant, 2012).

Multiple studies have found that lack of access to clean cooking fuels disproportionally affects women and children (Mondal, 2020; Karanja & Gasparatos, 2019). Women often take on the primary household management, cooking, and childcare, and are often exposure to HAP while cooking (Mazorra et al., 2020). A study conducted in Ethiopia and Uganda measured particulate matter exposure in households and concluded that adult women had far more exposure than adult men in the same age group due to particulate matter from cooking. Children also had high rates of harmful exposure due to the amount of time spent around mothers during cooking or caregiving time (Okello et. al, 2018).

Many traditional cookstoves, especially in rural areas, use an open flame to burn firewood. This method is often very inefficient and the smoke/fumes are a major cause of HAP and respiratory diseases (Urmee & Gyanfi, 2016). Several studies have identified the benefits of using improved cookstoves and cleaner fuels. Higher efficiency of stoves reduces the amount of fuel needed to achieve the same thermal result. Biogas stoves also help reduce or eliminate the need to collect and burn firewood at all. Better technology also reduces the ramifications of indoor air pollution and other safety hazards (burns or fires). A study in Kenya found that using improved biomass over traditional three stone fires reduced particulate matter (PM 2.5) and carbon monoxide (CO) by up to 42 and 34%, respectively (Pilishvili et al., 2016). Another analysis synthesized literature on over 40 studies on solid fuel stoves, concluding that personal exposure to PM 2.5 and CO can be reduced by an average of 50% for each (Pope et al., 2017) Similar to using cleaner fuels for lighting, clean cooking can also offer opportunities for increased income, employment, and education due to the additional time available that is freed from firewood collecting and cooking (Karanja & Gasparatos, 2019).

Clean Lighting and Cooking Initiatives in Sub-Saharan Africa

Governments and organizations across Africa have worked to implement clean lighting and cooking technology to help increase energy access, improve efficiency, and reduce health risks. Many lighting programs focus on off-grid solar lighting or battery powered LED products. Large improvements in these technologies along with decreasing production costs globally have made these technologies a go to option for developing regions (Bensch et al., 2017). Programs such as The World Bank's *Lighting Africa*, USAID's *Power Africa,* and *Akon Lighting Africa (ALA)* have been leaders in implementing lighting specific projects in various African countries. Since 2009, *Lighting Africa* has helped over 32 million people meet their basic lighting needs with a variety of different solar lighting products (Lighting Global, 2023). In Kenya alone, *Lighting Africa* shifted the solar lantern market from 29,000 lamps in 2009 to 680,000 lamps in 2013, an increase of 23 times (Ockwell, 2021). Within the first 3 years of operation in 2017, *ALA* had installed over 3,000 solar powered microgrids and 100,000 households solar lighting kits across ten African countries (Ahmed et al., 2014). The organization's work has launched job opportunities in many countries and established a solar education training program. The World Bank recently announced a new initiative to accelerate electrification in sub-Saharan Africa by implementing mini grids and off grid solar (World Bank, 2022).

Many cooking initiatives focus on improving cookstove technology with greater thermal efficiency and cleaner fuel use. Programs range from government or organization subsidies on stoves or fuel, or appliances provided at low or no cost to households. Organizations such as The Clean Cooking Alliance, United Nations, Ripple Africa, USAID, and the World Bank continue to run clean cookstove programs across the continent. In 2020, the Ghana Ministry of Energy launched a program to distribute 500,000 improved charcoal cooking stoves in the country, funded by private partners (Afful, 2020). African nations that may not have external financing for such programs have taken a policy driven route. For example, the Kenyan government has passed multiple regulations and over the past decade to promote clean domestic cooking (Karanja & Gasparatos, 2019).

Affordability of such technology still remains a major challenge for many areas in sub-Saharan Africa. Energy access organizations have attempted to address this with business models for such as "pay-as-you-go" or rented lighting and cooking appliances. These business models can open up opportunities for low-income households to access clean lighting or cooking appliances or fuels, without high up-front costs. Pay-as-you-go models allow households to pay for technology such as lanterns or cookstoves in small increments over time, enabling access to clean energy with flexible, more affordable options (Lighting Global, 2023; Solarun, 2023). Other models, like The Lighting a Billion Lives initiative in India, operate a fee-for-service model, where solar lanterns are rented to households for a daily fee (Baruah, 2015).

Despite these initiatives, programs have had difficulty with adoption of the new lighting and cooking technology and implementation beyond the initial set up. Barriers to new technology and clean fuel adoption include financial constraints, cultural preferences, and household characteristics (Kapfudzaruwa, 2017). A study in Ghana observed mixed results with the implementation of improved cookstoves in a rural community, with continued reliance and preference for traditional three-stone fires for cooking (Piedrahita et al., 2016). A 2018 review of the Africa Biogas Partnership (ABPP) in eastern Africa revealed some success in promoting biogas cooking, such as reduced fuelwood consumption and respiratory systems when using improved stoves. However, several challenges were still present during the program, such as continued fuel stacking, high upfront costs, and lack of maintenance, which led to high abandonment rates (Clemens et al., 2018).

While many clean lighting and cooking initiatives exist around the globe, country and region-specific programs are often necessary to meet different needs. The measurement of energy access and fuel transitions also varies by region, country, and urban/rural areas. Therefore, this research studies lighting and cooking fuel transitions specific to The Gambia in 2010 and 2015 in both urban and rural households.

Methodology

Data Sources

The 2010 and 2015 rounds of the Integrated Household Survey (IHS) were obtained from the Gambian Bureau of Statistics and used as a basis for this analysis. The HIS measures poverty and household conditions (expenditure, income, status, living conditions, etc.) and covers demographics, education, health, employment, child nutrition, household head characteristics, household amenities, and household perception of well-being. The 2010 IHS recorded responses from 4913 households and the 2015 IHS recorded 10,026 households.

Data Preparation and Analysis

The IHS survey data were obtained in Stata file format (.dta) for each individual section of each survey. Key demographic, lighting and cooking fuel variables were extracted from the raw survey data and combined to create custom data sets. The data sets were cleaned to remove inconsistencies and responses with missing data. Income classes were created using deciles of household expenditure, with 1 being the lowest and 10 being the highest. Household expenditure was used as a proxy for household income because it is possible that survey bias may exist for income reporting. For example, in the 2010 IHS data set, about 60% of observations of income were less than total expenditure of the same household. While this could indicate that a household is in debt, given the significant number of observations, total expenditure was chosen as the proxy for income in the study. These variables were used to represent changes in fuel shares by income class over time and in the subsequent regression to understand the driving factors of lighting and cooking fuel choices among households.

Two types of generalized linear models were used to determine the driving factors of fuel choices and electricity access. Both a binary and multinomial model are used in this analysis. In this case, the impact of chosen explanatory variables are modeled in predicting primary lighting and cooking fuel choices. A follow up discussion is also included with inferences from the analysis results. Figure 1 represents the data preparation and analysis methodology steps in order.

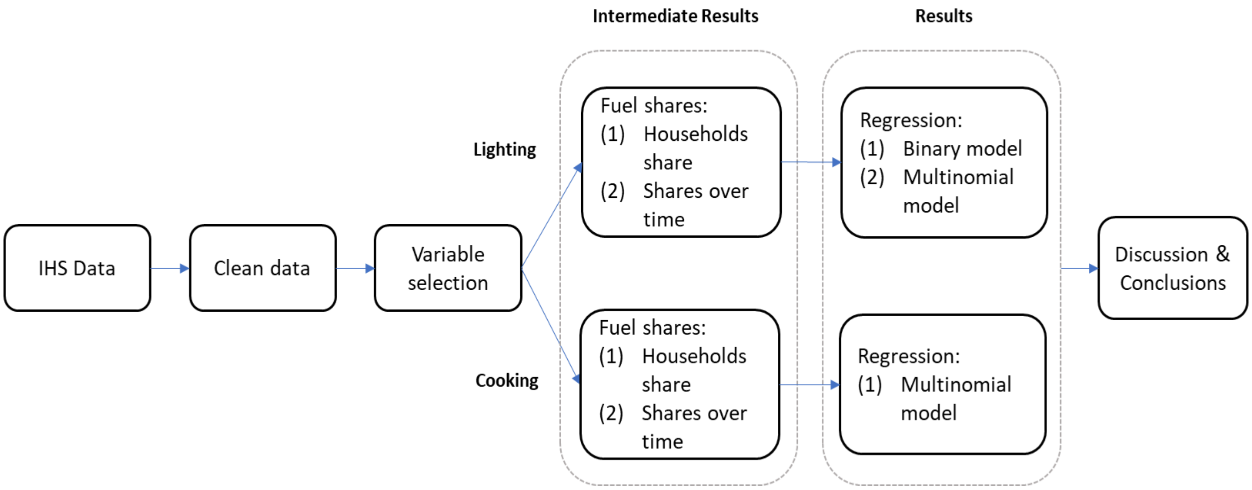

Figure 1: Data preparation and analysis methodology steps

Intermediate Results: Lighting Fuel Changes Over Time

In this section, I analyze both the 2010 and 2015 data to understand the various lighting fuels used by households and their access to electricity across demographics, including urban and rural. In this analysis, "Grid electricity" refers to electricity supply from the national utility company, NAWEC. The term "Fuel" includes private generator, kerosene, and candles. Private generators have been included in the fuel category for two reasons: (1) the primary input fuel is diesel, and, (2) the share of generators in final end use lighting energy account for less than 3% of the national lighting fuel in 2010 and less than 1% in 2015. The category "decentralized energy" includes improvised torches (battery operated lights) and household scale solar energy.

The data presented are based on the primary lighting fuel reported by the household. Results indicate an overall decline in fuel use and rise in decentralized energy sources, with little growth in electricity. Further, grid electricity is concentrated in urban areas compared to rural. Policy implications of these observations are discussed later.

In 2010, at the national level (Figure 2), grid electricity as the primary lighting source increased with income class, with a decrease in decentralized energy. About 20% of low-income households reported grid electricity as the primary source, followed by 35% among middle income households and 62% among high income households. The share of fuel for the low- and middle-income classes were nearly equal (44%), indicating that electricity likely substituted for decentralized energy among middle income households. For high income, electricity replaced both fuel and decentralized energy sources. Fuels including kerosene and private generators still remain a key primary lighting source for households given the lack of access to grid electricity.

In 2015, while the share of households reporting grid electricity as a primary lighting source still increased with income class, it is important to note that a lower proportion of middle-income (25%) and high-income (35%) households were reporting grid electricity as a primary source. Further, it can be observed that there is a significant growth in households reporting decentralized energy as the primary lighting source across all income classes, i.e., about 2/3 of the households in low- and middle-income households and about 55% among high income households. Fuel use for lighting significantly decreased across all income classes. A unique characteristic revealed in The Gambia is the high use of candles as a lighting source. At the national level in 2010, candles were the number one primary lighting fuel reported (35%), followed closely by electricity (32%). Candles make up about 90% of the fuel share category. In urban households, electricity (55%) outweighs candles (32%), but the opposite is true for rural households, with candles at 47%. The 2015 results reveal a significant decrease in the use of candles as a primary lighting source, with both urban and rural households shifting toward battery powered lights.

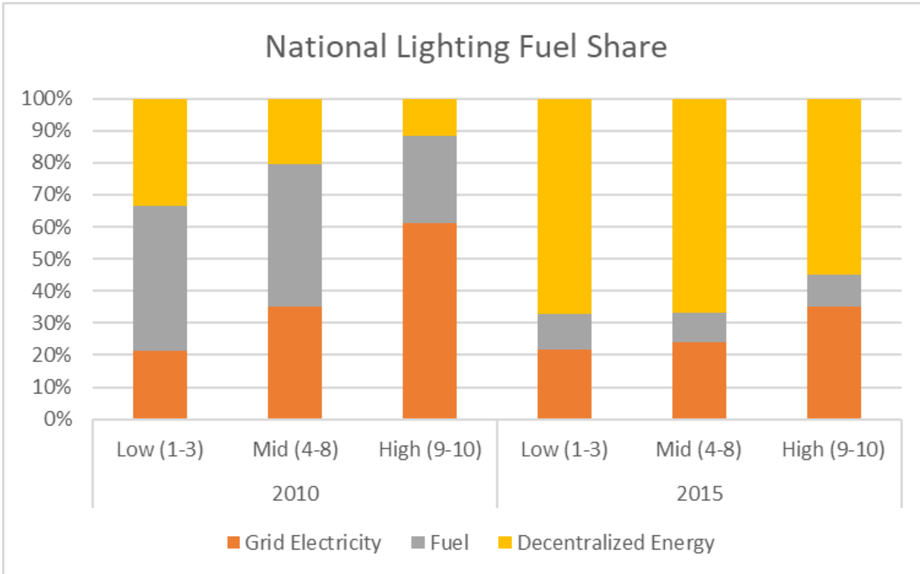

Figure 2: National lighting fuel share by income class category (low, medium, and high) of Gambian households in 2010 and 2015 (IHS data)

At an urban level in 2010, grid electricity as a primary lighting source increased with income class, making up 35% of the fuel share for low-income and 75% for high-income (Figure 3). Electricity substituted for both fuel and decentralized energy in the middle- and high-income classes. In 2015, the number of households reporting grid electricity as the primary lighting source increased across both low- and middle-income households, rising to 65% for each. While decentralized energy increased across income groups in 2015 as a primary lighting source, it was primarily driven by a shift to battery powered lights.

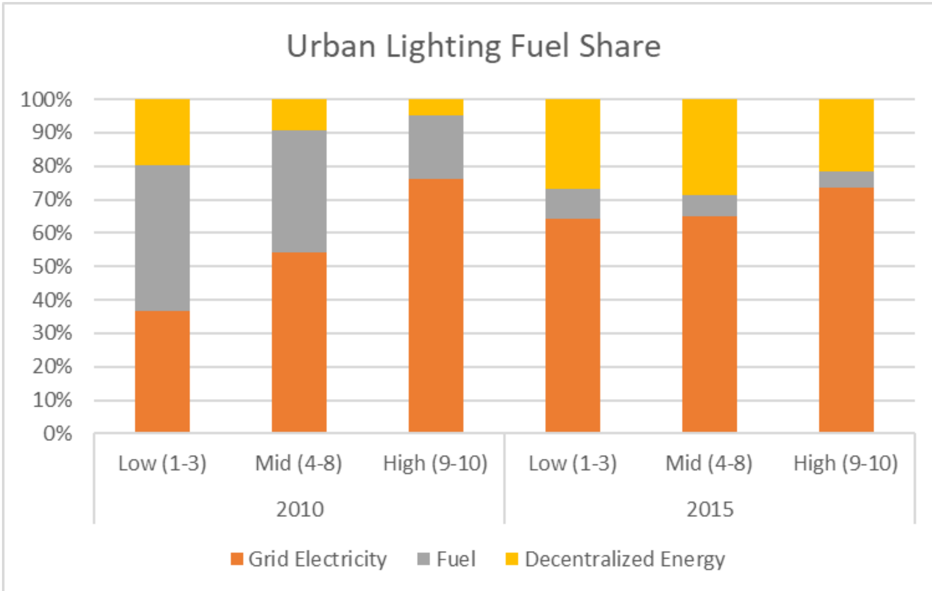

Figure 3: Urban Lighting Fuel Share by income class category (low, medium, and high) of Gambian households in 2010 and 2015 (IHS data)

Among rural households, the share of households reporting grid electricity as the primary lighting source was much lower compared to urban across all income groups, with the low-income share at only 5% and high-income at 15% (Figure 4). In 2010, the dominant primary energy sources for lighting were both fuel and decentralized energy. In 2015, decentralized energy rose to account for nearly 80% of low- and middle-income lighting fuel use, largely replacing fuel.

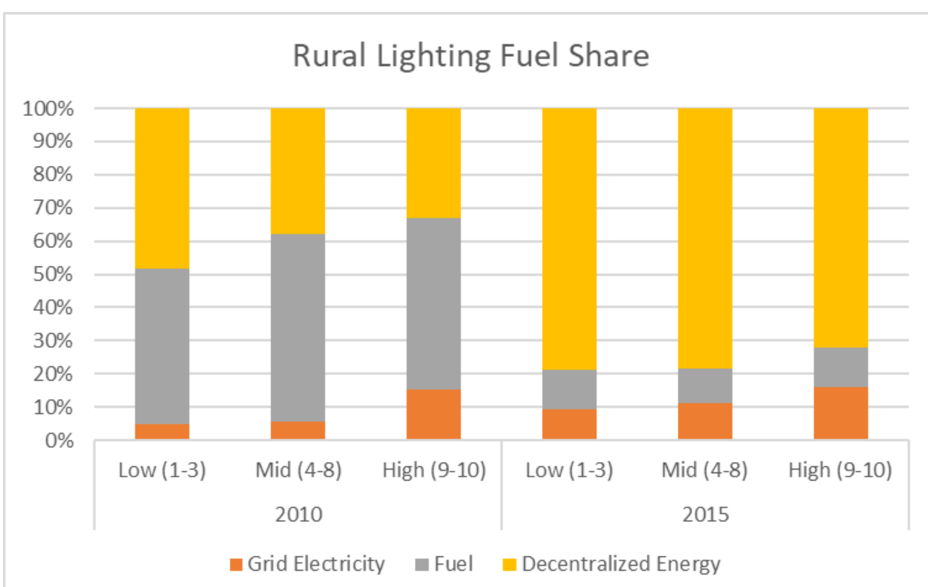

Figure 4: Rural Lighting Fuel Share by income class category (low, medium, and high) of Gambian households in 2010 and 2015 (IHS data)

The following figures (Figures 5-7) provide a better understanding of the transition in primary lighting sources over time among households by income classes, across urban and rural. At a national level in 2010, fuel is the dominant lighting source for lower income groups (40-50%) and electricity dominates for higher income (50-70%), with the inflection point at income class 7 (at 40%). Decentralized energy is the second most dominant for lower income groups, with an inflection point at class 4 with electricity, slowly decreasing as income rises. In 2015, the share of electricity for lighting fuel actually decreased compared to 2010. Decentralized energy dramatically increases, up 30-40% from 2010 across all groups.

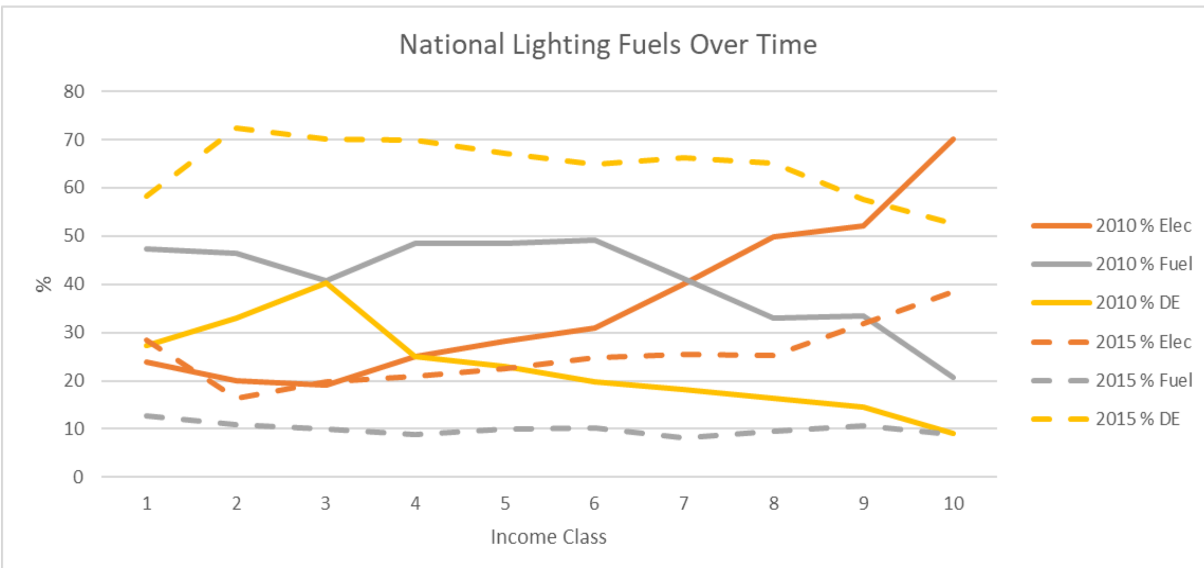

Figure 5: National lighting fuels over time by income class of Gambian households in 2010 and 2015 (IHS data)

At an urban level, electricity use for lighting increased slightly for lower income classes between 2010 and 2015, rising 15-20% (Figure 7). Fuel use for lighting decreased across all income groups, replaced mostly with decentralized energy sources.

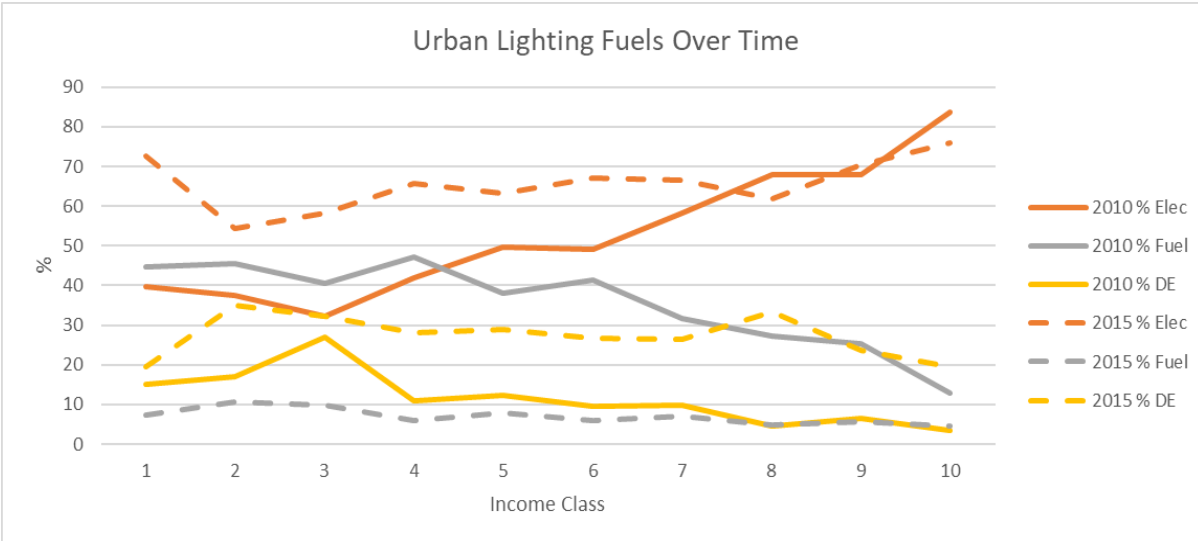

Figure 6: Urban lighting fuels over time by income class of Gambian households in 2010 and 2015 (IHS data)

At a rural level, the percentage of electricity use for lighting remained largely unchanged between 2010 and 2015, indicating that rural transitions remain a challenge in the country (Figure 8). Fuel use decreased, replaced exclusively with decentralized energy sources, making up 70-80% by 2015.

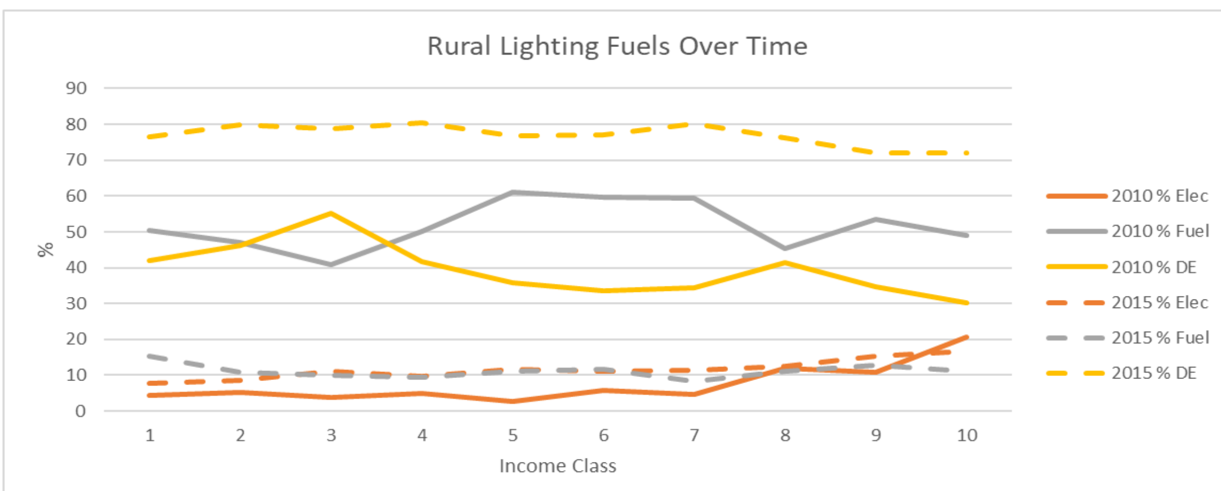

Figure 7: Rural lighting fuels over time by income class of Gambian households in 2010 and 2015 (IHS data)

Intermediate Results: Cooking Fuel Changes Over Time

In this section, I analyze both the 2010 and 2015 data to understand the various cooking fuels used by households across demographics, including urban and rural. The data presented are based on the primary cooking fuel reported by each household. In this analysis, "gas" refers to liquified petroleum gas (LPG) used for cooking. In most cases, households use small canisters of LPG to cook with. Results indicate continued reliance on firewood and a little movement towards clean cooking fuel alternatives. Charcoal and improved cookstoves are concentrated in urban areas, highlighting the disproportionate distribution of access to clean energy.

In 2010, at a national level (Figure 8), firewood is the dominant cooking fuel across income classes, with, followed by charcoal. About 80% of low-income households report firewood as the primary source, followed by 15% charcoal. The share of firewood decreases with income class and is replaced mostly by charcoal. In 2015, firewood remains dominant and the overall share actually increased from 2010. About 90% of low-income households report firewood as the primary source, with less than 10% charcoal. Other reported cooking fuels, gas, electricity, and solar are negligible. An overall increase in firewood use for cooking fuel is seen between 2010 and 2015, indicating a backwards shift in clean cooking fuel access in The Gambia.

The 2015 survey collected additional information on collected and purchased firewood. At the national level, 84% of firewood was collected versus purchased by households with firewood as the primary cooking fuel. In urban households, 39% of firewood was collected and 60% was purchased. The opposite is observed in rural households, with 93% of firewood being collected and only 7% purchased. This is not surprising considering it is likely that many rural households have easier access to collecting firewood and may not have the money to purchase firewood.

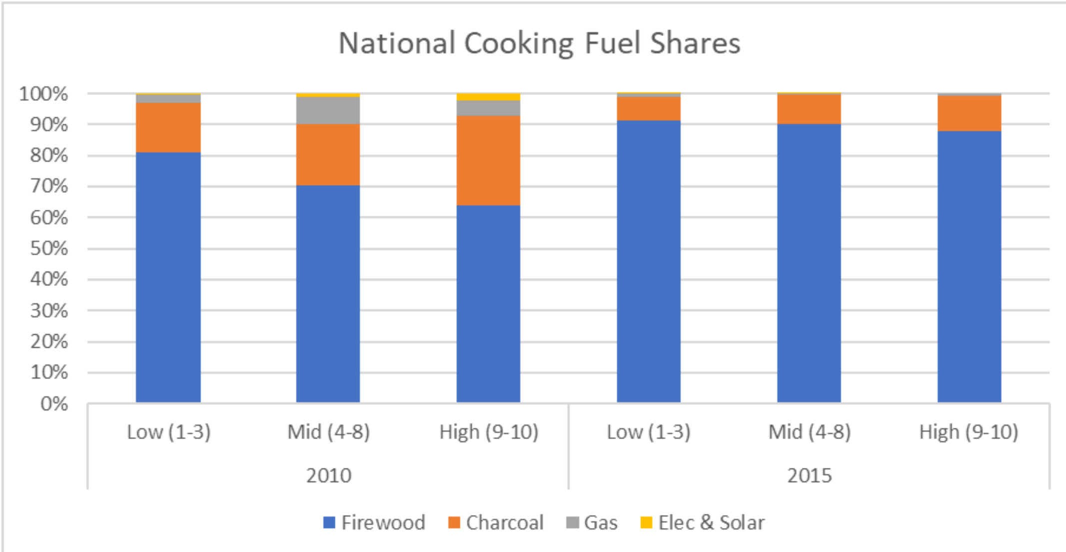

Figure 8: National cooking fuel share by income class category (low, medium, and high) of Gambian households in 2010 and 2015 (IHS data)

At an urban level in 2010 (Figure 9), firewood accounts for a majority of primary cooking fuel. For low-income households, firewood makes up about 60%, followed by charcoal at 30%. Firewood decreases slightly with income class. In 2015, firewood remains dominant, but an increased share of charcoal was reported. For low-income household, firewood makes up about 55% and charcoal makes about 40% (a 10% increase in charcoal. The share of firewood increases slightly with income class.

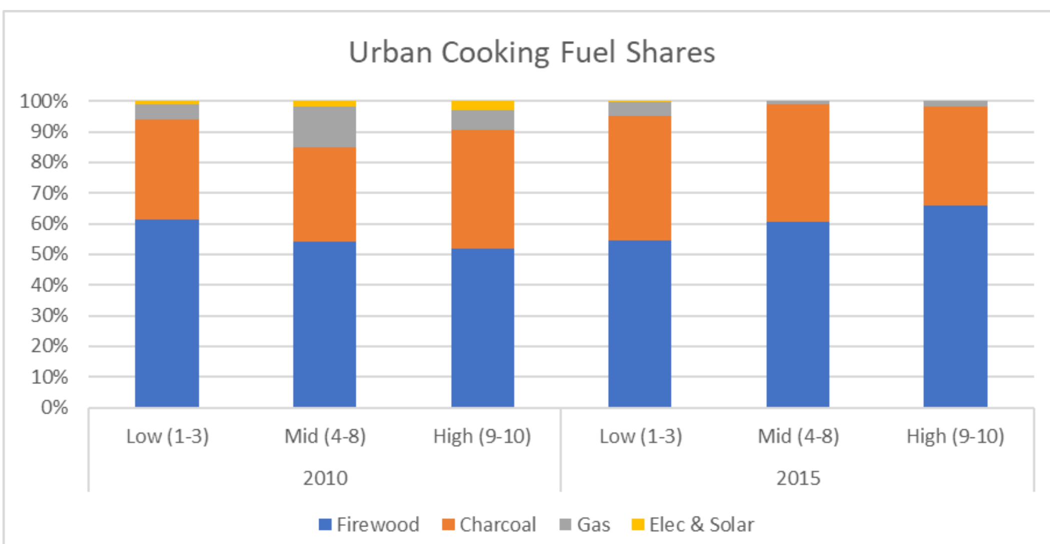

Figure 9: Urban cooking fuel share by income class category (low, medium, and high) of Gambian households in 2010 and 2015 (IHS data)

At the rural level in both 2010 and 2015 (Figure 10), firewood makes up an overwhelming amount of primary cooking fuel (93-97%) and all other fuels are almost negligible. This indicates little change in cooking fuel use in rural households occurs between 2010 and 2015, highlighting an extreme disparity between urban and rural access levels to cleaner cooking fuels.

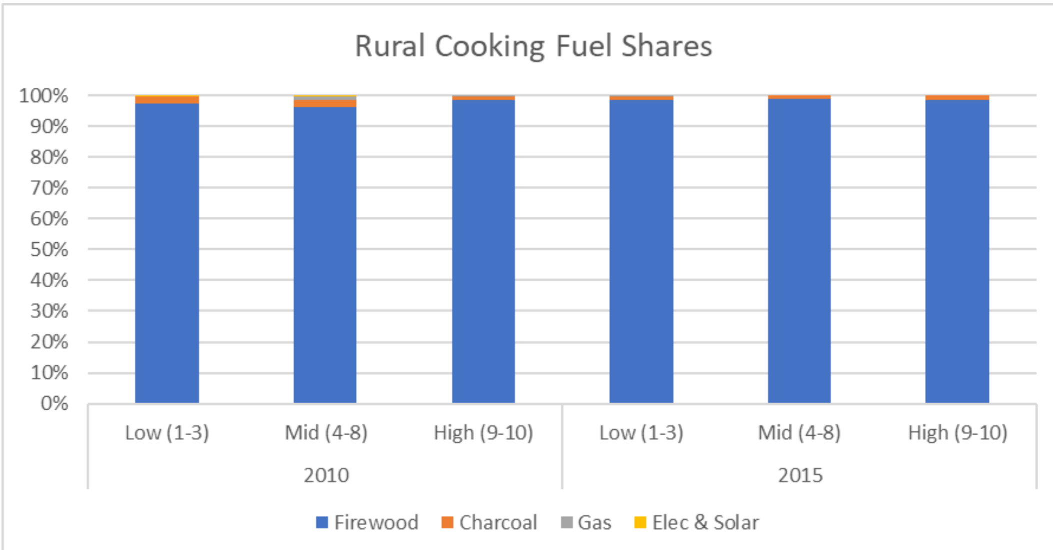

Figure 10: Rural cooking fuel share by income class category (low, medium, and high) of Gambian households in 2010 and 2015 (IHS data)

The following figures (Figures 11-13) provide a better understanding of the transition in primary cooking fuels over time among households by income classes, across urban and rural. At a national level in both years, firewood remains dominant across income classes. Charcoal works as a direct substitute for firewood. Firewood use increased in 2015, indicating that clean cooking remains a major challenge for The Gambia as a whole.

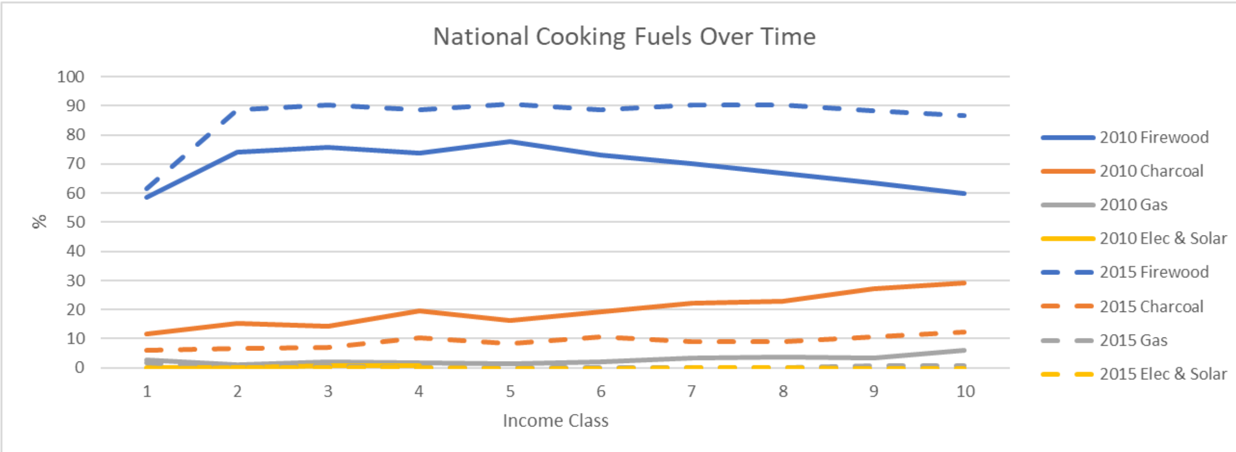

Figure 11: National cooking fuels over time by income class of Gambian households in 2010 and 2015 (IHS data)

At an urban level (Figure 12), firewood remains dominant, but an increased share of charcoal is present.

A similar pattern to the national level is seen with firewood and charcoal as direct substitutes.

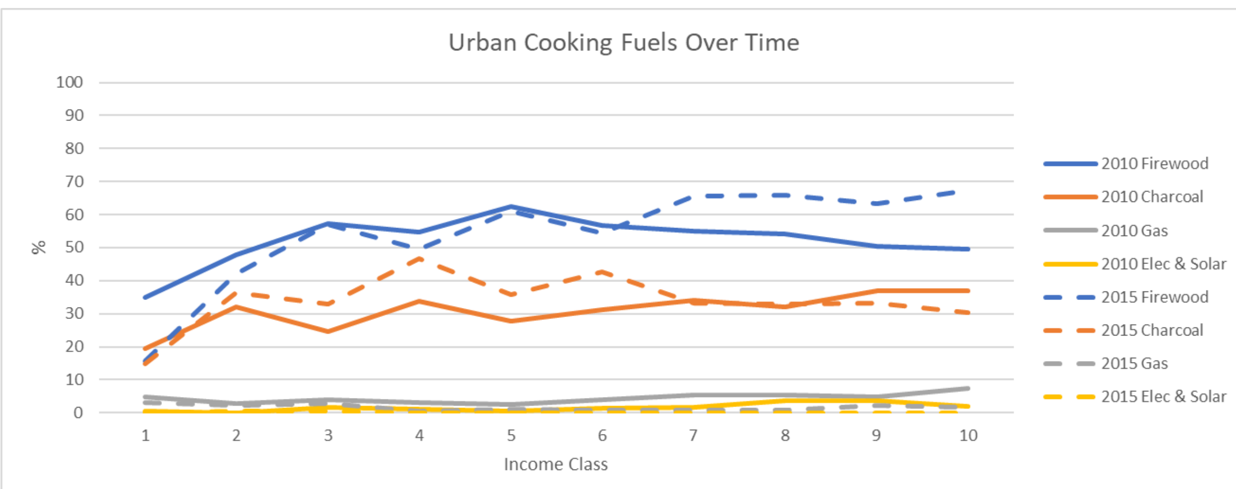

Figure 12: Urban cooking fuels over time by income class of Gambian households in 2010 and 2015 (IHS data)

At a rural level (Figure 13), there is little differentiation among income classes and cooking fuel over time.

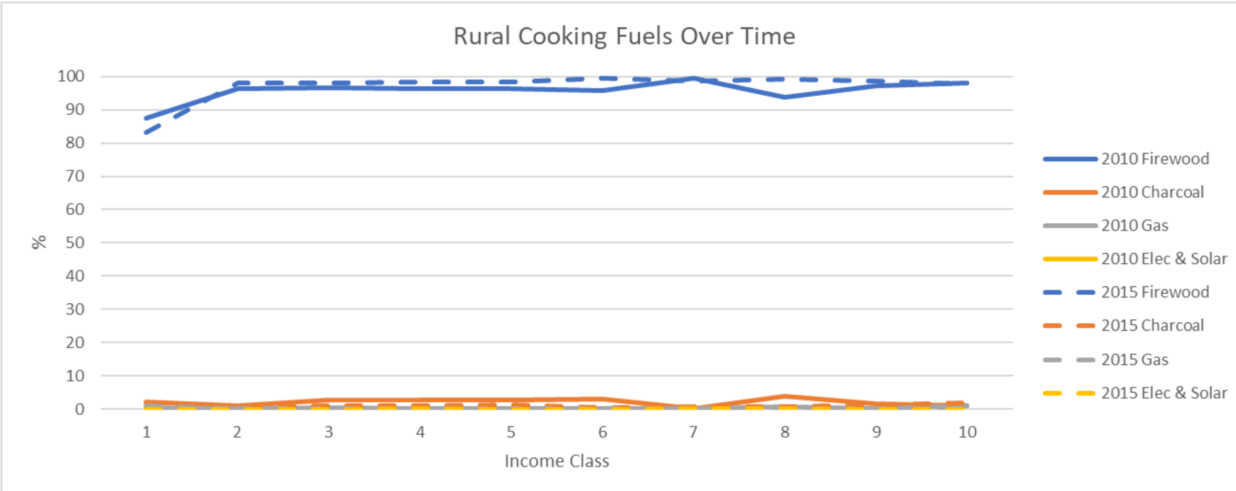

Figure 13: Rural cooking fuels over time by income class of Gambian households in 2010 and 2015 (IHS data)

The types of cookstoves used in households can also be captured from the IHS (Table 1). It is clear that a three stones stove, which burns firewood, dominates both urban and rural households in both 2010 and 2015. In 2010, a 'kumba gaye,' another type of wood burning stove, is the second most used in urban households, at 23%, to a three stones stove. In 2015, 'Furno noflie' and 'Furno jambarr' stoves appear to replace kumba gayes in urban settings, although three stones remains dominant at 47% for urban and 94% for rural. Furno noflie and furno jambarr are both types of cookstoves fueled by briquettes, which are typically block of coal dust or other biomass material. These may have been distributed as part of The Gambia's Ministry of Petroleum & Energy efficient cookstove distribution campaign. Interestingly, the share of Furno noflie and furno jambarr stoves are much more concentrated in urban households, highlighting the disproportionate access to clean cooking technology between urban and rural areas.

Table 1: Cookstove comparison by type in rural and urban households in 2010 and 2015 (IHS data)

	Urban		Rural	
Cookstove	**2010**	**2015**	**2010**	**2015**
Three stones	30%	47%	90%	94%
Kumba gaye	23%	7%	2%	1%
Sinkirikuto	16%	3%	3%	2%
Cooker (gas, electric)	0.3%	0.2%	0.1%	0.01%
Gas bottle	2%	1%	0.1%	0.2%
Mudstove	1%	-	1%	-
Furno noflie	-	23%	-	2%
Furno jambarr	-	10%	-	0.4%
Pottery stove	-	1%	-	0.2%
Coal pot	-	7%	-	0.4%
Rocket stove	-	0.1%	-	0.05%

$^{+}$ the 2015 dataset captured information on more types of cookstoves than 2010

Results

Lighting Model

The dependent variable for the binary model is 'electricity access,' indicated by '1' if electricity is the primary lighting fuel report and '0' for any other fuel. A multinomial logit model is used to show the probability of choosing any of the seven lighting fuel sources relative to electricity. The dependent variable for the multinomial model is 'primary lighting fuel' for a household and includes grid electricity, generator, kerosene, candles, solar, improvised torch, and other. Each fuel option was assigned a number to be used in the code: (1) grid electricity, (2) generator, (3) kerosene, (4) candles, (5) solar, (6) improvised torch, and (9) other. Urban and rural households were modeled separately to capture the different behaviors of each.

The independent variables included in this analysis are the following:

1) *Education Level*: This variable reflects the highest education level reported of the household, regardless of gender.

2) *Income Class*: This variable captures the income status of the household. Income classes were created using deciles of household expenditure, from 1-10 with 10 being the highest income class. The classes were then organized into three groups for the purpose of the model, low (1-3), medium (4-7), and high (8-10).

3) *Expenditure on energy*: This variable is calculated as the fraction of expenditure on energy out of total household expenditure.

4) *Household Ownership*: This variable captures the occupancy status of the recorded household as rent vs. own.

5) *Gender of Household Head*: The gender of the household head was recorded as male (1) or female (2).

Binary Model (1):

$$
\begin{aligned}
(Electricty\ Access) &= \alpha + \beta_{1.1}(Education\ level) + \beta_{1.2}(Income\ class\!: low) \\
&+ \beta_{1.3}(Income\ class\!: medium) + \beta_{1.4}(Income\ class\!: high) \\
&+ \beta_{1.5}(Expenditure\ on\ energy) + \beta_{1.6}(Household\ ownership) + \beta_{1.7}(Gender)
\end{aligned}
$$

Multinomial Model (2):

$$
\begin{aligned}
(Primary\ lighting\ fuel) &= \alpha + \beta_{2.1}(Education\ level) + \beta_{2.2}(Income\ class\!: low) \\
&+ \beta_{2.3}(Income\ class\!: medium) + \beta_{2.4}(Income\ class\!: high) \\
&+ \beta_{2.5}(Expenditure\ on\ energy) + \beta_{2.6}(Household\ ownership) + \beta_{2.7}(Gender)
\end{aligned}
$$

Where, $\beta_{i.j}$ = coefficient, such that, model number (i) = {1,2}, and, variable number (j) = {1,…,n}

Results from model (1) are shown in Table 2. In the 2010 rural model, income class, expenditure on energy, and household ownership are significant in influencing electricity access. The same variables are significant for urban, with the addition of education level. The income variables are both significant and negative, indicating that as households move toward lower incomes, electricity access decreases. Both of these variables have the same coefficient size, indicating that electricity access in rural households below the high-income classes have the same impact. Additionally, as expenditure on energy increases and households move toward owning a home (versus renting), the likelihood of electricity access increases. In the 2015 rural model, education level, income class, expenditure on energy, and gender are significant. Only education level, income class, and household ownership are significant in the urban model. The income variables are again significant and negative. Although significant, education seems to have a marginal affect in both years. The gender variable indicates that female headed households are more likely to have electricity access in rural households in 2015. Also notable is the decrease is magnitude of the energy expenditure variable from 2010 to 2015, which could be a sign of improved electricity access over time, lessening the effect of expenditure on access. Household ownership is a key driver of access in 2010, but not in 2015. Comparing all four models indicates that access becomes less of a problem for urban households over time, which could be a result of disproportionate investment on urban infrastructure over rural.

Table 2: Coefficients of the binary model for the electricity access variable for 2010 and 2015

	2010		**2015**	
Electricity Access	Rural	Urban	Rural	Urban
Intercept	0.081	0.489	-0.003	0.647
Education Level	-0.000	-0.001*	-0.010*	-0.020*
Income Class: Low	-0.072*	-0.313*	-0.088*	-0.146*
Income Class: Medium	-0.071*	-0.168*	-0.061*	-0.059
Expenditure on energy	3.296*	3.586*	0.257*	0.187
Household ownership	0.034*	0.088*	0.007	0.053*
Gender	-0.014	-0.039	0.092*	0.096

*Denotes variable is significant at 95% confidence

[+]Model (1) dropped the 'Income class: high' variable because it serves as the base for the income variables. Income classes low and medium are calculated relative to the income class high variable.

Results from model (2) are shown in Table 3 for 2010 and Table 4 for 2015. In 2010, both candles and battery powered lights are significant for low- and medium-income classes in both urban and rural households. Education level is significant for most fuels but has a marginal effect. Expenditure on energy is significant across all fuels with very high coefficient values, indicating that as the share of energy expenditure increases, the likelihood of using anything using anything other than electricity decreases. Private generator use has a much lower coefficient value in the rural model, which could be due to the source being less common among rural households compared to urban. In 2015, candles and battery powered lights are still significant, with the addition of kerosene across all income classes. Education level is still significant, but again with a marginal effect. Household ownership has more of an effect in 2010, which is consistent with the results in model (1). The gender variable is significant for various fuels in both urban and rural households and has a stronger coefficient value in 2015, also consistent with model (1). The magnitude of the expenditure on energy coefficients are drastically smaller in 2015, with some fuels no longer being significant, which could be an indication of increases access to both grid electricity and cleaner lighting sources (battery powered lights). Overall, fuel use decreases from 2010 to 2015, which could be due to both cost and improved grid electricity penetration.

Table 3: Coefficients of the 2010 multinomial model for lighting fuels

			Education Level	Income Class: Low	Income Class: Medium	Income Class: High	Expenditure on Energy	Household ownership	Gender
2010	**Rural**	Generator	-0.019*	-0.637	1.276*	-0.406	-6.137*	-1.128*	1.175
		Kerosene lamp	0.001	0.339	0.232	-1.438*	-78.57*	-0.322	0.539
		Candles	0.007*	0.865*	0.972*	-0.152	-64.23*	-0.319	0.250
		Solar	-0.003	0.201	0.323	0.127	-71.40*	-0.409	0.133
		Battery powered light	0.007*	1.341*	0.962*	-0.259	-51.27*	-0.908*	0.122
		Other	0.024*	0.077	-0.169	-2.280*	-55.84*	-0.925	1.043
	Urban	Generator	0.003	-0.533*	-0.751*	-0.013	-43.14*	-0.882*	0.403
		Kerosene lamp	0.008	0.123	-0.274	-1.852*	-23.35*	-0.939	0.299
		Candles	0.006*	0.868*	0.263*	-0.615*	-45.56*	-0.306*	0.321*
		Solar	0.006	-0.211	-0.218	-0.690*	-49.62*	-1.115*	0.316
		Battery powered light	0.009*	1.121*	-0.112	-1.266*	-43.98*	-0.538*	0.250
		Other	0.050*	-1.859*	-6.890*	-2.677*	-33.28*	0.211	4.437*

*Denotes variable is significant at 95% confidence

Table 4: Coefficients of the 2015 multinomial model for lighting fuels

Year	Area	Fuel	Education Level	Income Class: Low	Income Class: Medium	Income Class: High	Expenditure on Energy	Household ownership	Gender
2015	Rural	Generator	-0.024	-0.722	-0.178	-0.303	1.383	-0.199	-0.422
		Solar	0.053*	0.039	0.137	0.042	-1.465	0.055	-0.589*
		Kerosene	0.953*	-3.403*	-3.333*	-4.134*	-0.207	0.090	-0.030
		Other Kerosene	0.126	0.080	0.350	-0.319	-9.203*	0.130	-5.809
		Candles	0.067*	0.581*	0.145	-0.325*	-4.229*	-0.078	-0.748*
		Battery powered light	0.114*	1.088*	0.683*	-0.077	-2.386*	-0.111*	-0.956*
		Other	0.329	1.134	0.294	-6.522	2.189*	-0.327	-1.510
	Urban	Generator	-0.011	-50.55*	15.71*	15.93*	3.542	-0.496	-1.085
		Solar	0.022	-0.808*	-0.460	-0.504*	2.131	-0.481*	-0.476
		Kerosene	-0.116	-0.217	-17.16*	-29.60*	0.653	0.070	21.97*
		Other Kerosene	-0.133	-11.66*	23.45*	-15.63*	-39.42*	0.161	-24.04*
		Candles	0.099*	0.027	-0.685*	-1.105*	-2.151	-0.174	-0.221
		Battery Powered light	0.109*	0.231*	-0.156	-0.451*	-1.130	-0.303*	-0.570*
		Other	4.815*	-5.422*	-6.238*	-38.29*	1.357	0.434	0.772

*Denotes variable is significant at 95% confidence

Cooking Model

A multinomial logit model is used to show the probability of choosing any of the five cooking fuels relative to firewood. The dependent variable for the multinomial model is 'primary cooking fuel' for a household and includes firewood, charcoal, gas (*liquefied petroleum gas*, or LPG), or electricity. Solar cooking is included in the original survey questionnaire, but the variable removed from the model due to a negligible number of responses as primary cooking fuel. The "Other" option was also removed. The "Does not cook" variable was included in the model. Electricity was removed from the rural model because only three households responded with this as its primary cooking fuel source, and only one of those three actually had access according to the corresponding lighting fuel response. Electric cooking was included in the urban model because 49 households responded with this as their primary lighting fuel, however responses without electricity access were omitted. Each fuel option was assigned a number to be used in the code: (1) firewood, (2) charcoal, (3) gas, and for 2010 (4) does not cook, and 2015 (4) electricity, and (5) does not cook. Urban and rural households were modeled separately to capture the different behaviors of each.

The independent variables included in this analysis are the following:

1) *Education Level*: This variable reflects the highest education level reported of the household, regardless of gender.
2) *Income Class*: This variable captures the income status of the household. Income classes were created using deciles of household expenditure, from 1-10 with 10 being the highest income class. The classes were then organized into three groups for the purpose of the model, low (1-3), medium (4-7), and high (8-10).
3) *Expenditure on energy*: This variable is calculated as the fraction of expenditure on energy out of total household expenditure.
4) *Household Ownership*: This variable captures the occupancy status of the recorded household as rent vs. own.
5) *Gender of Household Head*: The gender of the household head was recorded as male (1) or female (2).

Multinomial Model:

$$(Primary\ cooking\ fuel) = \alpha + \beta_{1.1}(Education\ level) + \beta_{1.2}(Income\ class\colon low) + \beta_{1.3}(Income\ class\colon medium) + \beta_{1.4}(Income\ class\colon high) + \beta_{1.5}(Expenditure\ on\ energy) + \beta_{1.6}(Household\ ownership) + \beta_{1.7}(Gender)$$

Where, $\beta_{i.j}$ = coefficient, such that, model number (i) = {1,2}, and, variable number (j) = {1,…,n}

Results are shown in Table 5 for 2010 and Table 6 for 2015. The 2015 survey included an option to select "collected firewood" or "purchased firewood." For direct comparison to 2010, the results in Table 5 are for all combined firewood, which is simply the additional of collected and purchased responses. Collected and purchased firewood are modeled separately in Table 6 to study the effects of each variable on other cooking fuels.

In 2010, as education level increases, the likelihood of charcoal or gas or not cooking over firewood decreases; but coefficient is almost zero, so education has a very negligible effect on fuel choice for cooking. Rural, low-income households are less likely to use charcoal or gas over firewood, which is expected because firewood is typically available at low or no cost (collected). Middle-income households are less likely to use any of the fuel alternatives to firewood and the most significant impact is gas. High-income is only significant to not cooking. In urban households, all income variables are significant except electricity for high-income. All significant cases of income have negative coefficients, indicating that being in any of the three income classes is less likely to use any of the alternate fuels compared to firewood. As the share of expenditure on energy increases, there is a significant decrease in the likelihood of cooking with gas over firewood, again likely due to the availability of collected firewood. Gas as a cooking fuel choice is constrained by both accessibility/availability and affordability. Additionally, as share of expenditure on energy increases, there is higher likelihood of using charcoal or gas or not cooking. Households that rent are more likely to use charcoal, gas, or not cook compared to firewood. Lastly, female headed households are less likely to use charcoal over firewood. This result is surprising because most literature suggests that female headed households tend to use cleaner cooking fuels compare to male headed households. While burning charcoal is slightly better than firewood in terms of indoor air pollution and human health, firewood is often cheaper and easier to obtain than charcoal.

In 2015, the education variable has a slightly affect than the 2010 results for rural and urban, but the pattern remains the same. Rural, low- and medium- income households are still less likely to use charcoal, but more likely to use gas over firewood. Similar patterns are observed in 2015 for urban households as were seen in 2010. Contrary to 2010, female headed households seem to be more likely to use charcoal over firewood in 2015 for both urban and rural.

Table 5: Coefficients of the 2010 multinomial model for cooking fuels

			Education Level	Income Class: Low	Income Class: Medium	Income Class: High	Fraction Expenditure on Energy	Household ownership	Gender
2010	**Rural**	Charcoal	-0.012*	-1.547*	-1.096*	-0.701	-0.398	1.613*	-1.236*
		Gas	0.003	-1.956*	-25.79*	-0.855	-8.967*	1.711*	21.94*
		Does not cook	-0.009*	-0.617	-2.182*	-1.907*	4.328	1.312*	0.826
	Urban	Charcoal	-0.007*	-0.407*	-0.400*	-0.247*	6.814*	0.668*	-0.246*
		Gas	-0.008*	-0.818*	-1.100*	-0.639*	8.144*	0.560*	0.088
		Electricity	-0.002	-2.417*	-1.432*	0.081	-3.620*	0.114	0.418
		Does not cook	-0.007*	0.313*	-1.508*	-1.797*	7.280*	0.783*	0.861*

*Denotes variable is significant at 95% confidence

Table 6: Coefficients of the 2015 multinomial model for cooking fuels

			Education Level	Income Class: Low	Income Class: Medium	Income Class: High	Fraction Expenditure on Energy	Household ownership	Gender
2015	**Rural**	Charcoal	-0.182*	-1.000*	-1.377*	-1.015*	5.707*	0.193*	0.918*
		Gas	-0.286*	49.07*	46.99*	-148.5	6.951*	0.347*	-0.714
		Does not cook	-0.206*	18.10*	14.87*	-50.80*	6.148*	0.345*	-2.379*
	Urban	Charcoal	-0.096*	-0.386*	-0.315*	-0.416*	2.446*	0.745*	0.290*
		Gas	-0.169*	-0.137	-1.602*	-1.188*	-13.676*	1.001*	0.160
		Does not cook	-0.163*	2.499*	-0.837*	-2.538*	1.349	0.798*	-2.043*

*Denotes variable is significant at 95% confidence

+only 1 electricity response was recorded so the data point was removed

In Table 7, the coefficients are shown in respect to collected firewood. This aggregated data was only available in the 2015 round of the IHS survey. For rural households, as education level increases, it is less likely that they will use purchased firewood, charcoal, or gas, and has a marginal effect overall. Low- and middle- income households, are less likely to use purchased firewood and charcoal over collected firewood. They are also more likely to use gas over collected firewood. High-income rural households are less likely to use any alternative to collected use any, with the most pronounced being gas and not cooking. As expenditure on energy increases, households are more likely to use purchase firewood, charcoal, and gas. Households that rent are more likely to use purchased, gas, or charcoal. Female headed households are more likely to use purchased firewood and charcoal, and less likely to not cook over using firewood. In urban households, as education increases, it is less likely that they will use charcoal or gas, however this variable again has a very small effect. Contrasting to rural households, collected firewood is no longer significant. As income and expenditure on energy increase, an urban household is more likely to use purchased firewood over collected. This is consistent with what is seen in similar literature (Benti et al., 2021). Similar to rural households, female headed urban households are more likely to use purchased firewood or charcoal over collected firewood, however the effect of charcoal is about half the magnitude as in rural.

Table 7: Coefficient of the 2015 multinomial model for cooking fuels, with collected and purchased firewood

			Education Level	Income Class: Low	Income Class: Medium	Income Class: High	Fraction Expenditure on Energy	Household ownership	Gender
2015	**Rural**	Purchased firewood	-0.081*	-1.775*	-0.826*	-0.366*	19.60*	0.165*	0.995*
		Charcoal	-0.191*	-1.301*	-1.423*	-0.985*	19.48*	0.216*	1.082*
		Gas	-0.292*	2.014*	0.269	-8.315*	20.48*	0.366*	-0.529
		Does not cook	-0.213*	3.931*	0.965*	-9.138*	19.24*	0.362*	-2.208*
	Urban	Purchased firewood	-0.028	-1.083*	-0.550*	0.131	31.23*	0.703*	0.260
		Charcoal	-0.116*	-0.989*	-0.599*	-0.176	30.22*	1.212*	0.465*
		Gas	-0.186*	-0.693*	-1.830*	-0.948*	11.52	1.453*	0.330
		Does not cook	-0.186*	1.903*	-1.113*	-2.290*	29.21*	1.260*	-1.880*

*Denotes variable is significant at 95% confidence

Discussion and policy implications

Given that households in The Gambia continue to rely on dirty fuels such as kerosene, diesel generators or even candles, the quality of lighting services remain sub-optimal for most households. While there is an increase in decentralized energy sources, the transition to smaller solar home systems, designed to provide basic lighting and a small 5A charging point, can go a long way in improving electricity access outcomes for consumers. These will require a better understanding of household electricity needs and innovations in business models, such as daily renting and pay-as-you-go models. Alternatives such as solar micro-grids can also be considered to provide improved electricity access outcomes, with such infrastructure acting complementary to the primary electricity grid infrastructure. Decentralized

Renewable Energy (DRE) alternatives such as micro-grids can be an interim viable solution but will need to have performance benchmarks and system standards to ensure quality, reliability and safety to end users. Lastly, fuel subsidies including grid electricity tariffs in The Gambia, can be rationalized to provide targeted incentives for cleaner and reliable electricity sources, such that households can sustain a transition.

Fulfilling minimum energy access to serve basic needs should be a governments first priority. Following the energy ladder framework rigidly would imply complete fuel transitions amongst households, which is clearly not the case in many developing countries. Policies that provide multiple fuel options for lighting and cooking needs could drive greater transition and technology adopt rates. There is a lack of knowledge about the health and environmental consequences of traditional fuels. Many households are either unaware of the risks or do not consider these significant factors in fuel choices. Increasing access to education about clean fuels and health benefits should also be a priority in energy access policy making.

Gender plays a key role in household energy transition. Results of this study indicate that women headed household are more likely to choose cleaner fuel for lighting and cooking. However, there are additional factors of the gender dimension that should be considered, but could not be analyzed with the present data. Miller and Mobarak (2013) studied gendered preferences for types of cookstoves in Bangladesh and found that women have stronger preferences for cleaner cookstoves, but often lack the decision-making power to obtain them. These authors further suggest that policies intended to promote cookstove technology may have limited influence if women cannot make cookstove choices. Specific cookstove and fuel incentives that are targeted toward women and their role as beneficiaries could serve as a major driver in the energy transition. Financial incentive tied to women being the beneficiary empowers them to drive some decision making.

Conclusions

Using data from the 2010 and 2015 rounds of the IHS survey, this study finds that household's primary lighting fuel shows an overall decline in fuel use and rise in decentralized energy sources, instead of electricity. Further, grid electricity is concentrated in urban areas compared to rural, as observed in many other developing countries. This is reflective of the constraints in expanding and upgrading grid infrastructure to both rural and urban areas. Given that the data does not have information on the reliability and quality of electricity being supplied, it still remains a challenge to estimate household electricity access accurately. Electricity access is typically measured as a household having a connection, but does not account for a connection that is reliable (such as hours of supply and voltage quality), affordable (cost of electricity per kWh), and more importantly, serves basic needs. Household primary cooking fuel trends shows a continued reliance on firewood and a backwards transition to cleaner alternatives. Charcoal use is concentrated in urban areas and is virtually non existent in rural areas. Improved cookstoves are also concentrated in urban areas by 2015, further indicating the disproportionate distribution of access to clean energy. Overall, The Gambia has made little progress toward SDG 7 and electricity access in the country.

The following limitations in the research are recognized. This study is intended to provide new insights on the lighting and cooking fuel transitions in The Gambia. Data was obtained from an overarching survey of the country with very limited information on specific energy consumption at a household and willingness to pay, limiting the ability to dive deep into the role of decentralized energy resources. Regional geography impacts electricity use patterns and fuel consumption, requiring different space heating/cooling and lighting needs. We have not found any studies that perform similar disaggregated, geographical analyses in The Gambia. Limited information is available on how these landscapes affect energy consumption in The Gambia.

Future work is recommended to include more recent data and dive deeper into household energy and fuel consumption. The most recent data available for this study are from 2015. If further data becomes available, analysis could be expanded to include transitions between the additional time periods, and for energy and fuel consumption changes over time. For example, household level energy use and willingness to pay surveys could be deployed to better assess electrification and infrastructure needs in rural areas.

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