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Household determinants of cooking fuel use and motivation to adopt LPG: The case of the Kinondoni Municipality, Dar es Salaam, Tanzania

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HOUSEHOLD DETERMINANTS OF COOKING FUEL USE AND MOTIVATION TO ADOPT LPG:

THE CASE OF THE KINONDONI MUNICIPALITY, DAR ES SALAAM, TANZANIA.

By

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May 2022

Declaration

I, John Jnr. Doku-Marfo, author of the thesis titled “Household determinants of cooking fuel use and motivation to adopt LPG: The case of the Kinondoni Municipality, Dar es Salaam, Tanzania” hereby declares that this submission is my work towards the Master of Science (MSc.) Degree in International Environmental Studies. To the best of my knowledge, except where due acknowledgment has been fully made, it contains no material previously published by another person or material which has been accepted for the award of any degree by any other University.

…………………….…

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Abstract

In Sub-Saharan Africa, 70-90% of the energy supply for cooking, lighting, and heating is primarily sourced from biomass. The use of biomass, therefore, represents about 82% of the total energy consumed in the sub-region. However, the adverse impacts of household air pollution (HAP) associated with the over-reliance on traditional solid fuels contribute to global black carbon which is the second most contributing gas to climate change. In Tanzania, women, and children lose precious time for income-producing activities and education because they must gather fuel or spend time cooking with these slow, inefficient, traditional solid fuels. In addition, the pollution associated with the indoor burning of solid fuels (in traditional cookstoves) mostly under poorly ventilated conditions, causes the loss of about 33,024 lives annually. The widespread uptake of clean fuels is, therefore, necessary to improve health and reduce HAP. In this quantitative study, a cross-sectional design was adopted to obtain household information from purposively sampled Wards in the Kinondoni Municipality of Dar es Salaam, Tanzania (n=477). Three main results are reported in this study. First, the energy use pattern in all the surveyed households followed the multiple fuel use hypothesis, and households use multiple fuels (LPG, charcoal, kerosene, firewood, and electricity) for different cooking purposes. Secondly, household income, size, residential location, households' connection to electricity, degree of buying, and unavailability of fuel highly correlate with the choice of cooking energy. Lastly, household income, fuel unavailability, frequency of refilling, the number of household inhabitants, and a household's connection to electricity are good predictors for the choice of PAYG LPG among the surveyed households.

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1 Introduction

Global energy demand which is a premise for socio-economic development and wealth creation has risen in the past century, and it is projected to continually rise (Newell et al. 2020). According to Rehfuess et al. (2006) and Legros et al. (2009), close to half of the world's population rely on coal, dung, or biomass (solid fuels) to satisfy their cooking energy needs. The situation is not different in Sub-Saharan Africa (SSA) where biomass is the primary source of energy (70-90% of energy supply) for cooking, lighting, and heating (Karekezi, 2002). The use of biomass, therefore, represents about 82% of the total energy consumed in the sub-region (World Bank Group, 2014). Meanwhile, the smoke that emanates from these cooking fires has been associated with about 3.9 million untimely annual deaths, with its soot regarded as a major contributor to global warming (IPCC, 2022; IPCC, 2018; Wilson et al. 2016; Ramanathan & Carmichael, 2008).

The adverse impacts of household air pollution (HAP) associated with the over-reliance on traditional solid fuels contribute an estimated 25% of global black carbon which is one of the contributing gases to climate change (IPCC, 2018). In SSA, the exposure to HAP from cooking with solid fuels in 2016 resulted in an estimated 23 million disability-adjusted life years (DALYs) (a measure of the sum of years lost due to premature death and disability) and about 520,000 early deaths (representing 6.8% of all reported deaths) (GBD, 2016). The resulting economic costs due to the loss of productive income-producing time to gather and cook with solid fuels are substantive and estimated to be approximately US$30 billion (Lambe et al. 2015). Following the WHO Guidelines for indoor air quality: household fuel combustion (2014), governments, health policymakers, various stakeholders, and implementing partners were admonished to develop and/or accelerate efforts to make clean energy solutions including electricity and LPG more available to protect the public from adverse health effects of HAP from burning biomass fuels. This has therefore necessitated the development and use of improved cookstoves (ICS) as they potentially offer climate benefits and improve environmental quality and household health (Lewis & Pattanayak, 2012). However, ICS has its challenges; most of the stoves tagged as "improved" do not either meet the WHO/ESMAP Tier 4 requirement for "clean" cooking or offer complete protection against HAP associated with cooking with biomass fuels. The patronage and subsequent adoption of clean fuels especially in SSA have also been on the low (World Bank Group, 2014).

Clean cooking fuels such as liquefied petroleum gas (LPG) and electricity can reduce HAP in households and are promising substitutes for traditional solid fuels (Gould et al. 2020a). LPG is a safe and efficient cooking fuel that can potentially offer environmental, health, and development benefits (Bruce et al. 2017). The fuel is broadly available across several regions of SSA although its uptake remains limited (Pope et al. 2018). According to the World Bank Group, annually, there is less than 5% growth in LPG users in SSA and the number of households who exclusively use either LPG or electricity for cooking is likely less than 5% of the total population in the region (2014). Rural and urban electrification has gained attention in most SSA countries and has consequently led to a reduction in the number of households without access to electricity from 613 million in 2013 to about 572 million in 2019 (IEA, 2022). However, not all households connected to electricity use it for cooking. This could largely be due to the cost of electricity and electric stoves, and the erratic nature of the power supply (Makonese et al. 2018; Ifegbesan et al. 2016). About 572 million people still lack access to electricity in the SSA region and this remains a barrier to the transition to cooking with electricity. Subsequently, several articles have reported on reasons why different energy sources are adopted in households in the sub-region. For instance, the adoption of charcoal, LPG, biogas, animal dung, coal, electricity, grass, etc. for cooking in SSA countries has been influenced by access to electricity, wealth, educational background, household income and size, residential location, age, and sex of household head (Makonese et al. 2018; Ozoh et al. 2018; Owili et al. 2017; Karimu, 2015).

In Tanzania, about 60% of the residents use firewood for cooking (Global Alliance for Clean Cookstoves, 2014), although its gathering and use have been associated with time-wasting, cough, headache, eye itching, snake attacks, etc. (Massawe, 2019; World Bank Group, 2014). The country relies primarily on traditional biomass for domestic energy needs although imported petroleum is widely used in the industrial and transport sectors (Sarakikya et al. 2015). Aside from firewood, Tanzanians use charcoal, sawdust, kerosene, LPG, electricity, biogas, and solar for cooking (Abdalla & Makame, 2017; Sarakikya et al. 2015, Massawe, 2019). To improve the efficiency of biomass in the country, the GoT through mainly NGOs introduced and developed ICS generally considered transitional fuels into the market, although their development and uptake have been faced with some challenges including the cost of stoves, inadequate information about ICS, large household sizes, etc. (Kulindwa et al. 2018; Puzzolo et al. 2013).

In the largest city of Tanzania – Dar es Salaam, charcoal is used as the primary cooking fuel by 58.9% of all households (URT, 2019), and the daily consumption of charcoal according to Msuya et al. (2011) ranged from 34,000 to 47,000 bags. The use of charcoal has been linked to deforestation, with both contributing to climate change (Bailis et al. 2017). Deforestation in Tanzania is very alarming as Tanzania's Forest Services Agency (2015) reported that close to 373,000 ha of forest cover was lost between 1995 and 2010. To discourage this, the government of Tanzania (GoT) instituted a ban on charcoal production and trade, and transportation across district boundaries in 2006 and 2017 respectively (Doggart et al. 2020; Sarakikya et al. 2015; Van Beukering et al. 2007), although its enforcement was faced with resistance from consumers and traders (Sander et al. 2013; Doggart et al. 2020). Additionally, the GoT through Tanzania's NEP has sought to improve the country's energy sector to accommodate and make available more modern energy services to its citizens.

The NEP has undergone a series of changes since its enactment to support more environmentally friendly, sustainable, and modern energy services. The policy was first formulated in 1992 but later replaced in 2003 with a revised version that aimed at ensuring ease in access to reliable and affordable energy supply to support national development goals (Sarakikya et al. 2015). The sector however was entrenched with policy, legal, and regulatory challenges and so the policy was revised and re-launched in 2015 to address these challenges. The policy also emphasized improving access to modern energy services including access to electricity and clean cooking infrastructure (Pignatti et al. 2014). Among this clean cooking infrastructure is the Pay-as-you-Go (PAYG) LPG service which allows households to buy LPG in desirable quantities and according to their budget currently being rolled out in urban areas of the country. Despite the efforts of the Tanzanian government to increase access to these modern technologies, their adoption has been faced with some challenges. Prevalent among them is multiple fuel use (*fuel stacking*), a common practice of using both traditional and modern fuels by households (Choumert et al. 2019; Doggart et al. 2020). Meanwhile, pollution associated with the indoor burning of solid fuels (in traditional cookstoves) mostly under poorly ventilated conditions, causes the loss of about 33,024 lives annually in the country (GBD, 2016). Additionally, women and children lose precious time for income-producing activities and education because they must gather fuel or spend time cooking with these slow, inefficient, traditional solid fuels (Austin & Mejia, 2017; Lewis & Pattanayak, 2012).

This quantitative study, therefore, by using household survey data from the 4CImpacts project seeks to determine the socio-economic and cultural factors that influence the daily choices of fuel usage among the people of Kawe, Mbezi, Mbezi_Juu, and Wazo Wards within the Kinondoni

Municipal Council in Dar es Salaam, and the determinants of their possible adoption of LPG for cooking. The survey data were subjected to statistical analysis to describe the characteristics of the households, determine the factors that influence the adoption of cooking energy, and particularly drivers for the uptake of PAYG LPG. The Universal Energy Access: the role of Clean Cooking and Climate Change Impacts (4CImpacts) project aims at providing adequate knowledge of the drivers of equitable LPG uptake and improving the understanding of the potential positive impacts of 'clean' cooking energy transition among households in Tanzania.

1.1 Research question/ sub questions

How do socio-economic and cultural factors influence people's daily choices of fuel usage and motives to adopt LPG for cooking in Dar es Salaam, Tanzania?

- What cooking energies exist in the selected wards in Dar es Salaam?
- What sociocultural factors affect the choice of fuel and cooking technology?
- What factors influence people's adoption of the delivery model (PAYG LPG) for cooking?

1.2 Hypotheses

Hypothesis 1: Household income influences the choice of household cooking energy.

Hypothesis 2: The unavailability of fuel affects its adoption.

Hypothesis 3: The frequency of buying fuel impacts the decision to adopt it for cooking.

Hypothesis 4: A household's connection to electricity affects the choice of cooking fuel.

Hypothesis 5: Residential location affects the choice of cooking fuel.

1.3 Structure of the thesis

This thesis is structured into 7 chapters. The first chapter gives a brief introduction, defines the problem, and states the research questions and hypothesis that form the basis of this study. The second chapter gives a background description of the energy situation in Tanzania while highlighting the institutional and policy context and development-led interventions in the energy sector. In Chapter 3, the concepts underlying energy transitions and the general adoption of new technology are described. Chapters 4 and 5 present the methods and results of the study respectively whereas Chapter 6 analyzes and discusses the results. In the last chapter, conclusions are drawn from the results.

2 Background

2.1 The energy situation in Tanzania

Tanzania has several sources of energy resources including biomass, solar, natural gas, coal, uranium, hydro, wind, tidal, waves, and geothermal. Its coal reserve is estimated at 1.9 billion tonnes although only 25% is proven while its uranium deposits have been estimated at 200 million pounds. The average insolation is about 200 W/m^2, and the country utilizes only 12% of its 4.7 GW hydro potential. Average wind speeds of 5-9 m/s have also been reported at several sites in the country (URT, 2015). The energy consumption pattern in 2010 mainly comprised of residential (72.5%), industry (14.4%), transport (5.5%), agriculture (4.2%) and others (3.1%) (URT, 2015). In lighting, 36.3% of households mainly use electricity, while 30.3% and 23.0% use solar and rechargeable lamps/ torches respectively. Users of kerosene reduced from 22.3% in 2016/17 to 6.4% in 2019/20 while other energy sources made up 4.0% of all lighting energy sources (URT, 2020). Meanwhile, the primary cooking fuel used in households in mainland Tanzania is firewood (63.5%), followed by charcoal (26.2%), LPG (5.1%), and electricity (3.0%), with all others including kerosene, solar, etc. representing 2.2% (URT, 2020). Although widely used, firewood is commonly preferred for cooking in most rural households (84.8%) than urban households (17.4%) (URT, 2019).

Biomass (mainly charcoal and firewood) dominates the national energy balance and contributes about 82% of the total, primary energy consumption in the country, with petroleum, electricity, coal, and renewable energies making up the remaining 18% (IEA, 2020). Inhabitants rely mainly on biomass to satisfy their domestic energy needs as charcoal and firewood are the main sources of energy, especially for urban and rural dwellers respectively (URT, 2015; Sarakikya et al. 2015). The consumption of charcoal increased almost twice its quantity in 2005 due to urbanization and scarcity or the high cost of alternative sources like LPG, electricity, and kerosene. Charcoal demand is further expected to rise to about 4.6 million tonnes by 2030 if no interventions are made (URT, 2015). The government, therefore, provided tax relief packages on LPG to promote its usage, and to reduce the demand for firewood and charcoal. Particularly in 2008-2009, the value-added tax (VAT) and import duties for LPG were removed. Consequently, LPG use increased significantly particularly in urban centers as the volume of imported LPG rose from about 20,000 metric tonnes to more than 145,000 metric tonnes in 2010 and 2019 respectively (EWURA, 2019). LPG demand however differs across Tanzania, with the coastal zone which comprises Dar es

Salaam, Morogoro, Tanga, and Pwani regions consuming about 50%. The Northern and Lake zones consume 23% and 12% respectively, while the remaining four zones share 15% of the market (EWURA, 2019). In Dar es Salaam, LPG ranks second to charcoal as the primary fuel used by 13.3% and 58.9% of households respectively (URT, 2019).

The availability of domestic biomass energy particularly firewood and charcoal ensure the security of energy supply in Tanzanian households. The increasing demand for charcoal especially in urban areas of the country has expanded the charcoal sector and has increased employment and revenue generation in the sector. However, this dependence on biomass energy comes with a variety of challenges. Among these is the depletion of forest resources and deforestation caused by the unsustainable use of fuelwood and the clearing of new lands for agriculture. According to Tanzania's Forest Services Agency (TFS), the country consumes an estimated 62.3 million cubic meters of biomass energy although it sustainably produces an estimated 42.8 million cubic meters. This leaves a deficit of about 19.5 million cubic meters of forest loss (TFS, 2015). Consequently, between 1995 and 2010, Tanzania lost about 373,000 hectares/year of its forest (TFS, 2015). These losses may contribute to climate change through the release of stored carbon dioxide into the atmosphere, and local environmental degradation such as loss of topsoil to erosion and lower water retention capacity in catchment areas.

Generally, in households, females and males have distinct roles and responsibilities. In rural areas of Tanzania where firewood is the most utilized form of cooking energy, women and children lose precious time for income-producing activities and education because they must gather fuel or spend more time cooking with this slow, inefficient fuel. According to Matinga et al. (2013), spinal injuries, cataracts, and adverse pregnancy outcomes are some health problems related to the gathering of firewood and using traditional cooking technologies. Additionally, women and girls also get exposed to smoke emanating from traditional biomass and cooking practices which may ultimately have a detrimental impact on their health (WHO, 2021; Adkins et al. 2010). They may even suffer injuries from scalds and burns (WHO, 2014).

Furthermore, the smoke and high particulate matter released from the inefficient burning of biomass energy increases the disease burden of the country and has caused several premature deaths. According to the Global Burden of Disease (GBD) (2019), air pollution is second to malnutrition as a risk factor that drives most death and disability in Tanzania. Indoor air pollution alone causes an estimated 33,024 premature deaths per year and about 1,414,699 DALYs in the country (GBD, 2016).

2.1.1 Institutional and policy context

The energy sector is a vital component of every country's socio-economic development. In 1992, the GoT launched its NEP to effectively manage the sector (URT, 2015). Since then, the policy has undergone several changes to accommodate various public sector reforms as well as address the challenges faced in the sector. Consequently, a new policy was launched in 2003 to update the previous one and later revised and re-launched in 2015. Currently, the NEP (2015) which provides a comprehensive framework to address institutional, regulatory, and legal issues regarding renewable energies, electricity, and energy efficiency is being used. The policy also seeks to set Tanzania on a path towards sustainably enhancing the provision of reliable, adequate, and affordable modern energy services to the citizens of Tanzania.

The GoT mandated the then Ministry of Energy and Minerals (now Ministry of Energy since 2017) to oversee and guide the implementation of the policy. Additionally, the Ministry was tasked to facilitate improvement in investment in the sector by providing a conducive environment to ensure effective private sector participation, consequently accelerating the country's socio-economic transformation (URT, 2015). The Rural Energy Agency (REA) and Energy and Water Utilities Regulatory Authority (EWURA) were subsequently established under the Ministry of Energy (MoE) to promote and regulate modern energy services and the water sector in Tanzania. While REA was tasked to ensure the availability and accessibility of modern energy services in rural mainland Tanzania, EWURA was tasked to regulate the technical and economic aspects of providing electricity, petroleum, LPG, and water in Tanzania.

In addition to REA and EWURA, the GoT established the Petroleum Bulk Procurement Agency (PBPA) and Tanzania Petroleum Development Corporation (TPDC) to promote and regulate LPG operations (Norad, 2020). In Tanzania, all LPG sold is imported and so the recently adopted bulk procurement system (BPS) in 2015 has made importing LPG into the country more effective. In Dar es Salaam and Tanga alone, there are about nine LPG receiving facilities with a combined storage capacity of 16,973 metric tonnes.

With a vision to expand the use of LPG, the GoT has several plans and strategies. These include the Development Vision 2025 (1999), Energy Subsidy Policy (2013), National Natural Gas Policy

(2013), Public-Private Partnership Policy (2009), and the National Energy Policy (2015). The framework for the successful implementation of the NEP includes the EWURA Act (2001 & 2006) and its Amendment No 6 of 2019, the Rural Energy Act (2005), the Public-Private Partnership Act No 18 (2010), and the Petroleum Act (2015).

2.1.2 Development-led interventions

Firewood has been the primary energy source in most households in Tanzania although urbanization has shaped household preferences and driven a shift from firewood to charcoal. Firewood still remains part of the energy mix in the country (Doggart et al. 2020) and according to the United Republic of Tanzania (2019), about 90% of all households used either firewood (69%) or charcoal (21%) as their main cooking energy in 2017. The burning of these fuels has however been linked to the depletion of forest resources, generation of about 1.9-2.3% of global greenhouse gas emissions, deforestation, increased deaths arising from indoor and outdoor pollution, and other social and environmental problems (Conibear et al. 2018; Doggart & Meshack, 2017; Roy, 2016; Butt et al. 2016; TFS, 2015; Bailis et al. 2015). Consequently, to address these issues, the GoT has used various policy tools to reduce the consumption of these fuels including the sustainable production of charcoal, an institution of a ban on charcoal production and transportation in 2006 and 2017, the removal of the VAT and import duties on LPG in 2008-2009 to increase adoption, the promotion of biogas and fuel-efficient stoves (improved cookstoves) and the introduction of PAYG LPG to reach the semi-urban and rural population (Doggart et al. 2020; URT, 2015; Sarakikya et al. 2015; Van Beukering et al. 2007; URT, 1992).

Biogas was introduced by the GoT through the Small Industries Development Organization (SIDO) in 1975 for households to use as cooking energy (Leary et al. 2019). However, its uptake has been on the low as the SE4ALL 2015 Action Agenda reported an estimated 0.1% and 0.0% household use in urban and rural areas respectively. This could partly be because its use is limited to locations with suitable feedstock, and the high upfront costs of its biodigesters (Leary et al. 2019). The GoT then established the Energy Department in 1990 to facilitate efforts to improve cleaner cooking solutions in the country (Leary et al. 2019). Consequently, the Tanzania Traditional Energy Development Organization (TaTEDO) and other key stakeholders mainly NGOs in Tanzania adopted and introduced some prototypes of ICS into the market to aid entrepreneurs and NGOs who dealt with the production and sale of stoves. Its adoption has over the years somewhat increased as TaTEDO (2015) reported that the uptake of ICS in Dar es Salaam is more than 40% and 10% in the countryside. However, its development has not been able to keep up with the ever-growing population to upscale the required transition. Additionally, the uptake of ICS has been lower than expected owing probably to a lack of inadequate understanding of the local context, unsuitability to cook for large family sizes, inappropriate technological features, households' budgetary constraints, accessibility of new technologies, etc. (Stevens et al. 2019; Kulindwa et al. 2018; Puzzolo et al. 2013; Troncoso et al. 2013; World Bank, 2004). Furthermore, most of the stoves tagged as "improved" do not offer complete protection against the health impacts of cooking with biomass fuels nor meet the WHO/ESMAP Tier 4 requirement for "clean" cooking. The global focus has since then shifted from making available fuels cleaner to making 'clean' fuels like LPG and electricity available (Goldemberg et al. 2018). Subsequently, policymakers have sought to transition from biomass fuels to modern ones such as LPG, natural gas, and electricity (URT, 2015).

Although LPG use has been strongly associated with 'clean' fuels (WHO, 2014; ESMAP, 2020) and is thought to contribute to the achievement of SDG7, it is unusual how it has received little attention from the international donor community for the reason being that any investment in LPG is support for fossil energy (Norad, 2020). Nonetheless, some global organizations including DFID, WHO, UNDP, Clean Cooking Alliance, and the Global LPG Partnership have emphasized the major role that LPG plays in ensuring 'clean' cooking (Norad, 2020).

Over the years, LPG supply and use have increased in Tanzania due to its cost-effectiveness, cleanliness, and speed of cooking especially among high- and middle-income consumers (Norad, 2020; Bruce et al. 2017). Unlike efforts to promote ICS through aiding mostly entrepreneurs and NGOs who dealt with the production and sale of stoves, the LPG market since its introduction has been mainly dominated by commercial operators. EWURA (2019) reported that in 2018, 49% of the LPG market share was held by Oryx Gas, 18% by Mihan (Taifa) Gas, 12% by Lake Gas, 11% by Manjis Gas, 6% by Oilcom Gas, 2% by Orange Gas and 1% by Mount Meru Gas. The upfront costs of adopting LPG, however, remain a barrier to its uptake and have led to the reliance on biomass fuels especially charcoal which can be purchased in small quantities (Ndunguru, 2021). Efficient distribution systems/ delivery models are therefore required to ensure that LPG reaches a majority of the semi-urban and rural population.

Pay-as-you-Go (PAYG) LPG

One of the delivery models to ensure the spread of LPG to the majority of the semi-urban and rural population is PAYG which is currently being implemented in Dar es Salaam. The model allows households to purchase LPG in smaller quantities and according to their budget. This helps to overcome the affordability barrier normally faced by low-income households and others with variable incomes. It only takes about USD 0.43 (TZS 1,000) to purchase cooking gas (Ndunguru, 2021). In 2018, Circle Gas (Kopagas) was established as one of the PAYG models.

The Company which partners with Oryx Energies in Tanzania have capitalized on the advent of mobile money services in East Africa to develop a software and PAYG smart meter for LPG cylinders. It was established to ensure that "clean cooking" reaches low-income households as the cylinder, smart meter, and stove are normally leased to customers (Ndunguru, 2021). The model has since then attracted many customers, particularly in the Kinondoni Municipality as the burden of initial costs and refilling charges are reduced. The company is believed to have increased the distribution of smart meters from about 2,000 in 2018 to about 10,000 in 2019 (Ndunguru, 2021).

Figure 2-1: Smart meter fixed on LPG cylinder   Source: Ndunguru 2019

Although Tanzania has a significant amount of offshore gas reserves, natural gas is not used as a cooking fuel (Doggart et al. 2020). However, the GoT through the Ministry of Energy and Minerals in 2016 prepared the Natural Gas Utilization Master Plan (NGUMP) which among others seeks to promote the use of natural gas as a substitute for the domestic use of liquid fuels, charcoal, and firewood (URT, 2016). The NGUMP also assumes that by 2045, about 10% of Tanzanian households will be supplied with natural gas for cooking (URT, 2016). As a start, the Tanzania Petroleum Development Corporation (TPDC) is providing natural gas to households and industries as a pilot to the Kinondoni Municipality and Mkuranga District (URT-NAO, 2019). Thus, based on the current trend, it is likely that an increasing number of Tanzanian households will get access to natural gas after two or three decades (Doggart et al. 2020).

Access to electricity in Tanzania has significantly increased from about 13% in 2008 to 76% in 2018. The number of villages with access to electricity increased from 2,018 in 2015 to 9,112 in 2020 (IEA, 2020; URT, 2020). Yet, the widespread connectivity has not translated into the prevalent use of the energy for cooking since only about 2.5% of Tanzanian households use electricity to cook (URT, 2020). The untapped potential, therefore, needs to be greatly considered as part of the transition to cleaner cooking fuels.

2.2 Conceptual developments

The International Workshop Agreement (IWA 11:2012), together with the International Organization for Standardization (ISO) through the adoption of standards and performance tiers for both total and indoor stove emissions, fuel safety, and efficiency in 2012 created common terminologies concerning cooking solutions (Putti et al. 2015). These were later revised and replaced with ISO/TR 19867-3:2018 by the ISO/TC 285 Technical Committee in 2018. Some of the terminologies according to ESMAP (2020) include:

- **Clean cooking solutions** – these refer to both fuels and stoves that have emission performance measurements of Tier 4 or above on the ISO/TR 19867-3:2018 Voluntary Performance Targets (VPTs). These targets are voluntary because they offer useful information to guide the testing of cookstoves to help countries and organizations trading in household energy technologies, fuels, and related products.

- **Multi-Tier Framework (MTF) for cooking** – this is a multidimensional tiered approach that is used to measure a household's access to cooking solutions across six contextual and technical attributes, and six levels of access (Tier 0 = no access to Tier 5 = full access).
- **Modern Energy Cooking Services (MECS)** – refers in a household context, to those that have met Tier 4 or higher of the standards across all six attributes of the MTF, i.e., exposure, efficiency, convenience, safety, affordability, and fuel availability.
- **Improved cooking services** – contextually refer to households that have met at least Tier 2 of the MTF standards across all the six attributes. Households are said to be in ***Transition*** when they meet MTF Tier 2 or 3.

3 Conceptual framework

For over four decades, researchers have been seeking to better understand how households transition from one cooking fuel to another (from ‘dirtier’ to cleaner forms). As a result, several theories underlie the energy transition process. The emphasis has however been on socioeconomic factors as the key driver (Barnes et al. 2005; Barnes and Floor, 1996, Hosier and Dowd, 1987) although several authors have questioned why socio-cultural factors have not been considered (Arnold et al. 2006; Dovie et al. 2004; Odihi 2003; Campbell et al. 2003). Generally, the literature on the energy transition of households from one type of fuel to another is centered mainly on two theories: the energy ladder and multiple fuel use.

3.1 The energy ladder

Since its inception in the 1980s, the ‘energy ladder’ theory which describes a positive relationship between socio-economic level and household energy use has been the dominant energy transition approach (Barnes and Floor, 1996; IEA, 2011). In the area of household energy, it underlies lots of research and policy formulation (Heltberg, 2004). The theory suggests that households’ transition from traditional biomass to cleaner and more costly but efficient energy sources depend on increasing income levels (Treiber et al. 2015; Rajmohan and Weerahewa, 2007). This theory has been supported by other studies including Barnes and Floor (1996), Hosier and Dowd (1987), and Leach (1992), and has also been used to explain different behaviours related to the household choice of fuel (Abakah, 1990; Leach, 1992). The energy ladder theory conceptualizes fuel switching in three progressive stages (Figure 3-1). The first stage represents the universal dependence on biomass fuels such as wood, dung, and crop residues. The second stage emphasizes a shift to ‘transitional’ fuels such as kerosene or charcoal with increasing income and other factors like urbanization and biomass scarcity (Heltberg, 2004). The adoption of ‘clean’, modern fuels like LPG or electricity for cooking characterizes the final stage of the ladder. Barnes and Floor (1996) reported that increasing incomes and the relative prices of fuel are determinants of the speed at which households switch fuels and move up the ladder.

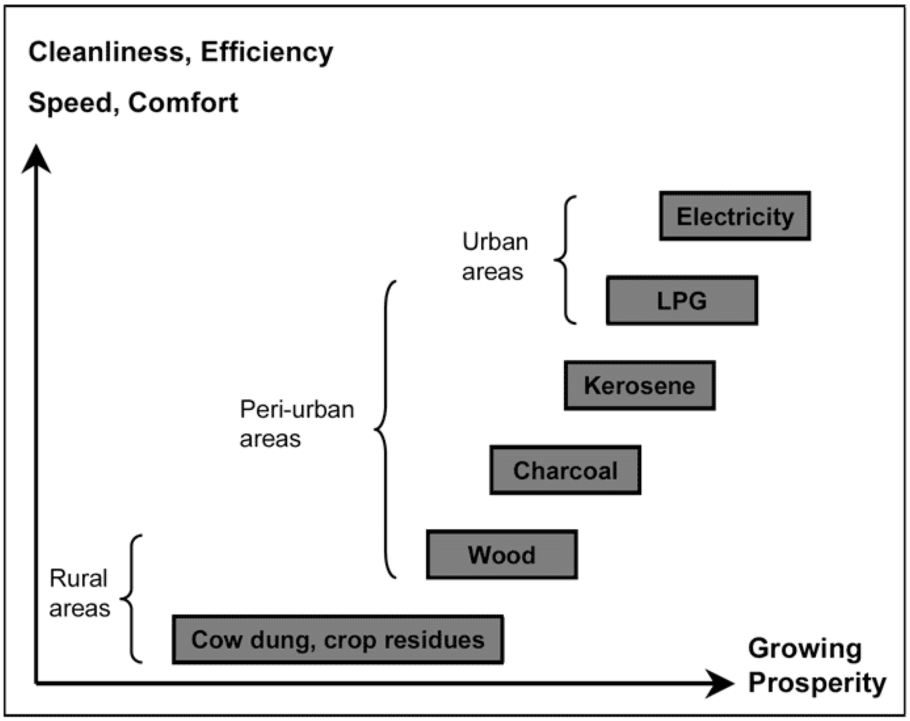

Figure 3-1: Energy ladder in developing countries (adopted from Fatmi, 2017)

Several authors have over the years reported barriers to the potential upwards movement on the ladder including fuel access and availability (Hosier and Kipyonda, 1993; Leach, 1992). In SSA, high upfront costs for a stove unit, and poor and underdeveloped road infrastructure mainly constrains the supply and thus the adoption of clean, modern fuels (Schlag and Zuzarte, 2008; Abakah, 1990). Households that are unable to overcome these hurdles are likely to remain at a particular level of the ladder.

The sole focus of the theory on income as the rationale for moving up the ladder, however, has been critiqued in various studies. Hiemstra-van der Horst and Hovorka (2008) in their study in Botswana reported that firewood was burnt in most households regardless of socioeconomic status, hence, the theory is not always true. Even Barnes et al. (2005) who supported the theory, further stated that on the occasion when wood is readily available and inexpensive, well-off households use it as much as other households. Kebede et al. (2002) also suggested that a rise in income could cause an increase in the demand for traditional fuels. Furthermore, the choice of taking on modern energy services is not dependent only on finances or convenience but also on gendered identities. This is because the access to and use of clean cooking technologies by women is deeply rooted in the interaction between gender relations and social differentiation (Kim and Standal, 2019; Matinga, 2010). Moreover, the energy ladder suggests a complete move from traditional fuels to modern ones when climbing up the ladder. However, this has not been the case as multiple fuel use (*fuel stacking*) has been observed especially in households in developing economies (Treiber et al. 2015; Akpalu et al. 2011; Heltberg, 2004; Masera et al. 2000). In their studies in Kenya and

Tanzania, Treiber et al. (2015) and Grimsby et al. (2016) respectively reported that multiple fuels are used for different purposes within most households. For instance, among peri-urban households, LPG and kerosene are used mostly to boil water and warm up food. Similarly, Masera et al. (2000) reported that in rural Mexico, people continue to use firewood to cook tortillas even though they can afford LPG because it is thought that using LPG to prepare tortillas is time-consuming and negatively affects its taste. Again, firewood is preferred for cooking heavy foods like ugali while LPG and kerosene are commonly used to prepare light meals such as tea, porridge, etc. which do not require long cooking times (Treiber et al. 2015).

3.2 Multiple fuel use

Most households in SSA countries use multiple fuels to satisfy their energy needs (Gould et al. 2020b; Makonese et al. 2018; Quinn et al. 2018). This way of multiple fuel use also known as *"fuel stacking"* is a common practice of households with different income levels, particularly in urban areas where many substitutes exist (Choumert et al. 2019; Doggart et al. 2020). To these households, it provides security of supply and offers low-cost energy use although this may hamper the development of new energy sources (Norad, 2020).

The *fuel stacking* theory was formulated contrary to the *energy ladder* theory by Masera and Navia in 1997 during their study of household energy patterns in Mexico. This model argues that most households in developing countries do not follow the discrete, stepwise upward movement from traditional to modern fuels but use multiple fuels simultaneously (Masera and Navia, 1997; Heltberg, 2004; Leach, 1992; Masera, 2000). This is because households select from a wide range of high-and low-cost fuels based on their preferences, income, convenience, household attributes (household size, education), etc., and keeping traditional fuels ensures security in the event of a shortage of supply or fluctuations in prices of modern fuels like LPG and electricity (Hosier and Kipondya, 1993; Mensah and Adu, 2015). Additionally, traditional cooking methods that are entrenched in local cultures require multiple fuels to cope with the different cooking practices and hence, constrain the total shift to modern fuels (Tinker, 1980; Masera, 2000; Murphy, 2001). Therefore, households' multiple fuel use patterns are the result of not only income rise but a complex interaction between economic, social, and cultural factors (Masera et al. 2000).

Since its inception, the fuel stacking model has been widely embraced as a better explanatory model which reflects reality and has been supported by other studies including Hiemstra-van der Horst and Hovorka (2008) and Treiber et al. (2015). However, in previous attempts to implement clean cooking technologies in households, attention has been drawn to the need to improve our

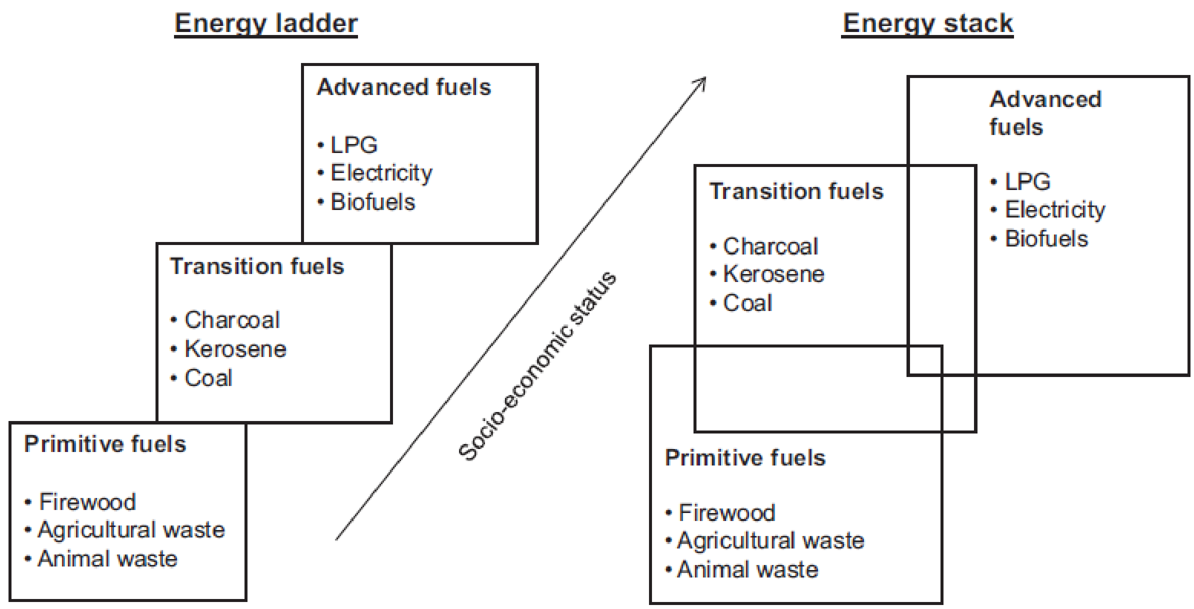

Figure 3-2: Energy transition processes (adopted from Van der Kroon et al. 2013)

understanding of such an energy transition in the context of the social and political economy of gender and women's role in unpaid reproductive labour (Kim and Standal 2019; Standal, 2018). This is because the choice of cooking technologies by households does not only dwell on convenience, comfort, or market principles and financial agency but also on women's role in food preparation (Kim and Standal 2019; Standal and Winther 2016; Matinga 2010). Moreover, the reliability of supply and issues of security associated with clean fuels can influence households to return to cooking with biomass fuels (Aunan et al. 2019; Kim and Standal 2019; Treiber et al. 2015).

3.3 Innovation Diffusion Theory

Another theory that is relevant to understanding the uptake of a new cooking technology is the "innovation diffusion theory" by Rogers (1962) which fundamentally explains the adoption of a new technology by an individual or a group in five stages.

First, *awareness* of the technology which leads to *persuasion* in stage two and taking a *decision* in stage three. Stage four follows with *implementation*, and then there is a *re-evaluation* of whether or not to keep the technology in the last stage. Again, Rogers (2003) in his "perceived attributes theory" stated that the rate at which a technology will diffuse depends on 5 attributes: relative advantage, compatibility, complexity, trialability, and observability. *Relative advantage* was defined by Rogers (2003) as the degree to which a technology/innovation is perceived as better than existing ones. It is normally characterized by low initial cost, social prestige, economic profitability, comfort, and timesaving. To be able to diffuse, a technology must be compatible with the users. Rogers (2003) defined *compatibility* as the rate at which an innovation is thought of as being coherent with the needs of potential adopters, past experience, and existing values. The third attribute *complexity* explains the difficulty to understand or use a technology. Although the complexity of an innovation largely depends on adopter characteristics (Tanye, 2016), it should be made easy and simple since there is a negative correlation between perceived complexity and adoption of a technology (Rogers, 2003). *Trialability* of an innovation is essential to reduce uncertainty and increase acceptability and adoptability (Tanye, 2016). It was defined by Rogers (2003) as the degree to which a technology may be experimented on a limited-time basis. Lastly, *observability* was described as the rate at which the results of an innovation are visible to others (Rogers, 2003). Practically, when the benefits of an innovation are obvious to others, it increases the rate of diffusion (Rogers, 2003).

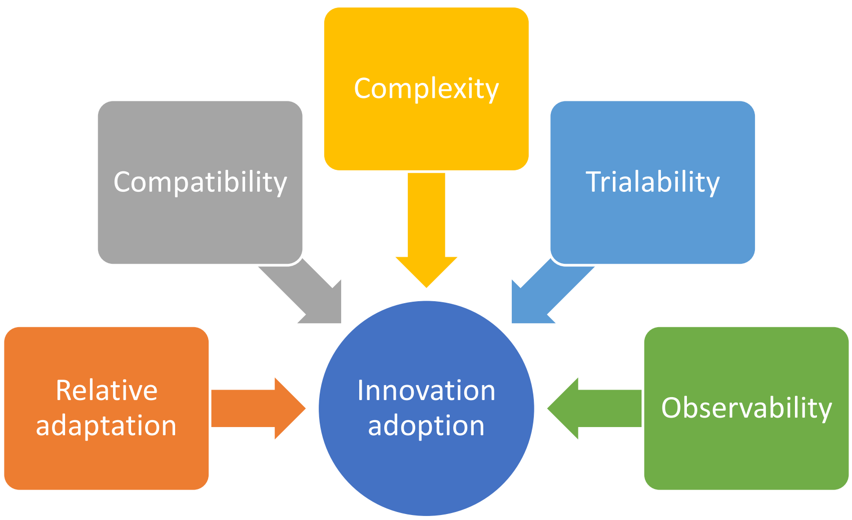

Figure 3-3: Perceived attribute theory

4 Methods

This chapter describes the main methods adopted for the study. Research methodology describes the specific practices or procedures used to investigate, process, and analyze information about a topic of interest. Simply, it explains how data was gathered and analyzed. Generally, three methodological strategies are available to adopt when conducting research – qualitative, quantitative, and a combination of the two (mixed) methods. According to O'Dwyer and Bernauer (2013), quantitative research aims at breaking down complex phenomena into simpler representatives which are easy to interpret and have the potential to generalize conclusions. It is a deductive approach that emphasizes objective measurements and the collection of numerical data through questionnaires, surveys, or polls to exhibit a relationship between theory and research (Bryman, 2012; Babbie, 2010). A quantitative survey with questionnaire administration is appropriate and therefore was adopted for this current study. The study as part of the 4CImpacts project was designed as a cross-sectional study where information on household energy demand and use was obtained from five wards in the Kinondoni Municipality of the Dar es Salaam region of Tanzania. 4CImpacts is a research project led by CICERO Center for International Climate Research, Norway, assisted by the Universities of Liverpool and Dar es Salaam, and the Norwegian University of Life Sciences. It is supported by the Norwegian Research Council [grant number 303066].

This chapter has been segmented into five sections. The first of which gives information about the location, temperature and rainfall patterns, and sources of cooking energies in the study area. The second and third sections describe how data was collected from the wards and analyzed respectively. The reliability and validity of the study were discussed in the fourth section while the ethical considerations and epistemological positioning of the study formed the fifth section.

4.1 Study area

The Kinondoni Municipality of Dar es Salaam Region in Tanzania was used as a case to study energy use in urban areas. A case study has been described as the in-depth and intensive examination and analysis of a single social phenomenon at a particular period (Babbie, 2021; Bryman, 2012). This study sought to investigate the energy use in urban areas and used the Kinondoni Municipality as a case for easy transferability to other urban centers to foster the energy development agenda of the Tanzanian government.

In the Municipality, five wards – Bunju, Kawe, Mbezi, Mbezi Juu, and Wazo were selected for the study. These Wards are among the 27 Wards that make up the Kinondoni Municipality within Dar es Salaam, Tanzania. The Kinondoni Municipality lies within the tropical coastal belt and so experiences quite high temperatures and precipitation. In March 2021, the Municipality received between 25°C and 33°C of insolation and a monthly high rainfall of 554mm in April 2021 (World Weather Online, 2021). Generally, the Municipality is humid and hot throughout the year with temperatures averaging 29^{o}C normally experienced between October and March, and relatively cool with temperatures around 25°C from May to August. Additionally, it averagely receives about 1300mm of rainfall annually. According to the 2012 Population and Housing Census, Kinondoni Municipality has a population of 1,775,049 comprising 860,802 and 914,247 males and females respectively. The Municipality has about 441,240 households with an average household size of approximately four (URT, 2016). The main sources of energy for cooking in the Municipality are charcoal, paraffin, electricity, firewood, and LPG, and a minority rely on coal, biogas, and solar energies (PHC, 2012).

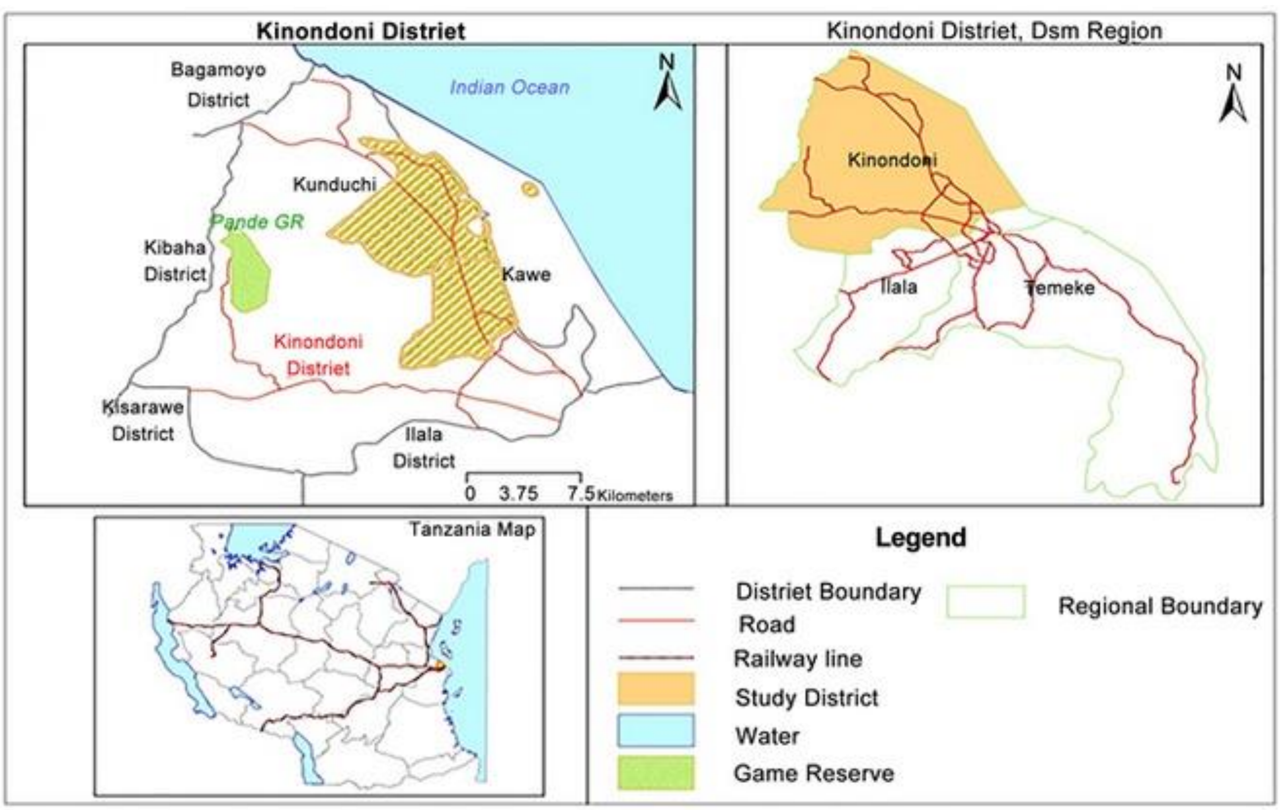

Figure 4-1: A map of Tanzania showing the study district and wards

4.2 Sampling and data collection

As a part of the 4CImpacts project, this study employed the cross-sectional study design given that data were collected once from each household. Participants were selected from the Bunju, Kawe, Mbezi, Mbezi-Juu, and Wazo Wards for the study. These wards were purposively chosen due to the high density of PAYG LPG customers. Even with high density, their numbers were too low to be considered for random sampling, hence, the adoption of purposive sampling. The sample is thus stratified into two groups: households that use PAYG LPG (consume >200 g LPG/day) and non-users (users of other cooking fuels). According to O'Dwyer and Bernauer (2013, p 80), a stratified random sampling procedure divides a population into blocks depending on a known population characteristic, and a sample is selected from each block. This is useful to obtain a representative sample from a target population.

4.2.1 Questionnaire design and administration

A close-ended questionnaire comprising of questions with single and multiple responses, multiple-choice questions, and rating scales was administered to about 500 selected participants from Bunju, Kawe, Mbezi, Mbezi-Juu, and Wazo Wards. The questionnaire was segmented into portions of:

a. Personal information
b. Fuel and stove information
c. Information on households not using LPG
d. Information on households using LPG, and
e. Information on households using PAYG LPG (Kopagas)

The questions primarily comprised the type, use, and frequency of usage of cooking fuels in the households, and the socio-cultural factors that influenced the choice of adoption of specific cooking fuel. The motives for adopting LPG and the PAYG LPG technology as the source of energy for cooking were also inquired. The questionnaire was pre-coded for easy transformation of the information gathered into a computer-readable format. These data processing instructions were necessary to identify where specific pieces of information would be stored until further processing and analysis.

The close-ended questionnaire was chosen because it is easier to complete and process and reduces the possibility of bias in recording answers (Bryman, 2012). After pilot studies were organized, 8 trained enumerators who were fluent in English and Swahili conducted the surveys using tablets/mobile phones in May 2021.

4.3 Data analysis

All the questionnaires were accessed and downloaded with the Mobenzi software package before processing and analysis with the RStudio software. Descriptive statistics were employed to describe the demographic details of the respondents. This tool was adopted because it is used to extract and summarize information to reveal data patterns that would have otherwise been unclear from examining raw data (O'Dwyer and Bernauer, 2013). Additionally, logistic regression with the choice of fuel (either LPG, charcoal, firewood, kerosene, or electricity) as the dependent variable and socio-economic determinants like education, income, location, etc. as independent variables was used to determine the socio-cultural factors that affect the choice of fuel for cooking. Furthermore, logistic regression with similar socio-economic determinants as independent variables but with the use of PAYG LPG as the dependent variable was used to determine the factors that influence people's adoption of PAYG LPG for cooking. Some of the basic assumptions for the logistic regression included lack of strongly influential outliers, linearity in the logit for continuous variables, absence of multicollinearity, and independence of errors (Stoltzfus, 2011)

4.4 Reliability and validity

In the quantitative tradition of research, establishing that the measurement instrument provides valid and reliable information is an integral component. An instrument is reliable when it yields consistent information when applied repeatedly to the same object (Babbie, 2010; O'Dwyer and Bernauer, 2013). To ensure reliability, the measure of socio-economic status (SES) including employment, income, education, household size, etc. which has been widely used by researchers who have studied the association between choice of fuel and socio-economic factors was adopted. Additionally, to ensure consistency in the results and reduce the possibility of bias in recording answers, fixed-choice answers were provided to the various questions in the questionnaires. However, there is a possibility of losing out on interesting answers from respondents which may have not been covered by the fixed answers provided.

Validity on the other hand refers to the degree to which an empirical measure reflects the true meaning of a concept under study (Babbie, 2010). To ensure validity, the questions in the questionnaire were precisely phrased and based on previous findings and established theories. In addition, the population studied was clearly defined. Again, the subpopulation of PAYG LPG users (households that consume >200g LPG/day) selected for the study was biased and left out other users who consumed <200g LPG/day. Although it allowed for exploring the associations between PAYG LPG use and social patterns at the household level, it limited the generalizability of the results of this study.

4.5 Ethical aspects and epistemological positioning

Research permits were acquired from the Norwegian Centre for Research Data (NSD) and the Kinondoni Municipality of Tanzania through the 4CImpacts project. In addition, consent for participation or withdrawal at any point during the administration of the questionnaire was sought from the respondents.

There could be possible physical and/or social risks associated with the study. This could have arisen from aggrieved sellers of charcoal, gatherers of firewood, and other stakeholders involved in alternative sources of energy apart from LPG. Even with LPG producers who are likely to benefit from the results of the study, there could be ‘friction’ because the study was mostly centered on PAYG LPG users and the possibility to recruit potential users onto the delivery model. To avoid or minimize these risks, the respondents were anonymized, with their names and other sensitive information only made available to the researchers. Also, the results of the study will be made available for easy access through a publication.

This study was strictly quantitative and as such was conducted and analyzed without influence from values and preconceptions. All procedures and processes were objectively conducted, and the information derived from the data were simply records of observation, hence reflecting reality.

5 Results

5.1 Demographic details of LPG and non-LPG respondents

Table 5-1 below shows the demographic description of the LPG and non-LPG respondents of the study population. Altogether, 356 respondents comprising 57 men and 299 women representing 16% and 84% respectively partook in the survey. Among these, 267 (75.0%) are LPG users while the remaining 89 (25.0%) represented users of other forms of energy including charcoal, firewood, etc. A majority (62.9%) of the respondents are married and have gone through either primary (44.1%) and/or secondary (32.6%) schools while a few have managed to obtain either vocational training/ a bachelor's degree or gone through postgraduate education. Most of the respondents (44.4%) are employed in the private sector while about 50.6% earn on average between 101,000 and 500,000 shillings every month. At the household level, most heads have either gone through primary, secondary, and/ or vocational training/ bachelor's, with a few obtaining a master's or Ph.D. degree. Majority of the households 83.4% are connected to electricity and so the main source of lighting energy is grid electricity, although others use candles, solar energy, battery, solar, or kerosene lamps. The primary energy source of these households in increasing order is firewood, charcoal, and LPG.

Table 5-1: Demographic details of LPG and non-LPG respondents

Description	**Total (n = 356)**		**LPG users (267)**		**Non-LPG users (89)**	
	No	**%**	**No**	**%**	**No**	**%**
Gender						
Male	57	16.0	46	17.2	11	12.4
Female	299	84.0	221	82.8	78	87.6
Educational level						
Below primary	39	11.0	26	9.7	13	14.6
Primary school	157	44.1	108	40.4	49	55.1
Secondary school	116	32.6	93	34.8	23	25.8
Vocational/ bachelor's	42	11.8	38	14.2	4	4.5
Master's/ PhD	2	0.6	2	0.7	-	-
Marital status						
Married	224	62.9	174	65.2	50	56.2
Living together with partner	44	12.4	32	12.0	12	13.5
Single	66	18.5	46	17.2	20	22.5
Widowed	20	5.6	13	4.9	7	7.9

Divorced	2	0.6	2	0.7	-	-
Occupation						
Maid for people	1	0.3	-	-	1	1.1
Day labourer	19	5.3	9	3.4	10	11.2
Entrepreneur	13	3.7	8	3.0	5	5.6
Private sector employee	158	44.4	122	45.7	36	40.4
Shop/ business owner	15	4.2	13	4.9	2	2.2
Government employee	14	3.9	13	4.9	1	1.1
Runs the household	51	14.3	36	13.5	15	16.9
Retired	9	2.5	8	3.0	1	1.1
Currently unemployed	63	17.7	46	17.2	17	19.1
Other	13	3.7	12	4.5	1	1.1
Household income/ Shillings						
≤ 100 000	46	12.9	27	10.1	19	21.3
101 000 – 500 000	180	50.6	129	48.3	51	57.3
501 000 – 1 000 000	71	19.9	57	21.3	14	15.7
1 001 000 – 1 500 000	24	6.7	23	8.6	1	1.1
1 501 000 – 2 000 000	10	2.8	9	3.4	1	1.1
> 2 001 000	6	1.7	6	2.2	-	-
Don’t know	19	5.3	16	6.0	3	3.4
Household decision						
Respondent	117	32.9	84	31.5	33	37.1
Other male family member	33	9.3	26	9.7	7	7.9
Other female family member	13	3.7	9	3.4	4	4.5
Joint decision	192	53.9	147	55.1	45	50.6
Don’t know	1	0.3	1	0.4	-	-
Main cook						
Yes	308	86.5	227	85.0	81	91.0
No	48	13.5	40	15.0	8	9.0
Household Head education						
Below primary	5	1.4	2	0.7	3	3.4
Primary school	71	19.9	50	18.7	21	23.6
Secondary school	67	18.8	53	19.9	14	15.7
Vocational/ bachelor’s	30	8.4	26	9.7	4	4.5
Master’s/ PhD	-	-	-	-	-	-
Respondent as household head	183	51.4	136	50.9	47	52.8
Household Head occupation						
Maid for people	-	-	-	-	-	-

Day labourer	11	3.1	5	1.9	6	6.7
Entrepreneur	27	7.6	21	7.9	6	6.7
Private sector employee	105	29.5	78	29.2	27	30.3
Shop/ business owner	7	2.0	7	2.6	-	-
Government employee	11	3.1	9	3.4	2	2.2
Runs the household	-	-	-	-	-	-
Retired	7	2.0	6	2.2	1	1.1
Currently unemployed	-	-	-	-	-	-
Other	5	1.4	5	1.9	-	-
Respondent as household head	183	51.4	136	50.9	47	52.8
Connection to electricity						
Yes	297	83.4	235	88.0	62	69.7
No	59	16.6	32	12.0	27	30.3
Main source of lighting energy						
Grid electricity	296	83.1	235	88.0	61	68.5
Solar panel	17	4.8	8	3.0	9	10.1
Kerosene	9	2.5	5	1.9	4	4.5
Candle	20	5.6	11	4.1	9	10.1
Battery/ solar lamp	10	2.8	6	2.2	4	4.5
Other	4	1.1	2	0.7	2	2.2
Primary fuel used						
Charcoal	153	43.0	83	31.1	70	78.7
Firewood	27	7.6	8	3.0	19	21.3
Briquettes, sawdust etc.	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-
LPG	176	49.4	176	65.9	-	-
Electricity	-	-	-	-	-	-

Figures 5-1 to 5-6 below compare various variables between PAYG LPG, conventional LPG, and non-LPG (other) users for the total sample (n=477). It can be seen from Figure 5-1 that PAYG LPG users are better off in terms of wealth and are well educated (Figure 5-2) than both LPG and other users. Additionally, the majority of PAYG LPG users prefer LPG, charcoal, and firewood as primary, secondary, and tertiary cooking fuels respectively while LPG and other users prefer LPG, charcoal, firewood, and kerosene as primary, secondary, and tertiary fuels respectively (Figures 5-3 to 5-5). Figures 5-6 show that the few households that used firewood as a primary fuel mostly obtained it for free.

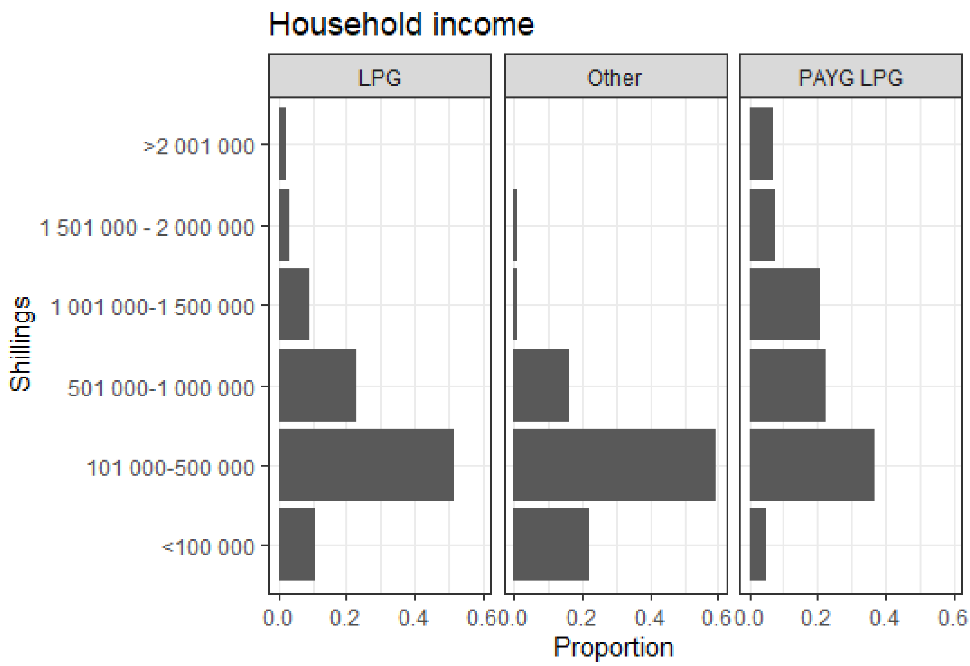

Figure 5-1: Average monthly salary

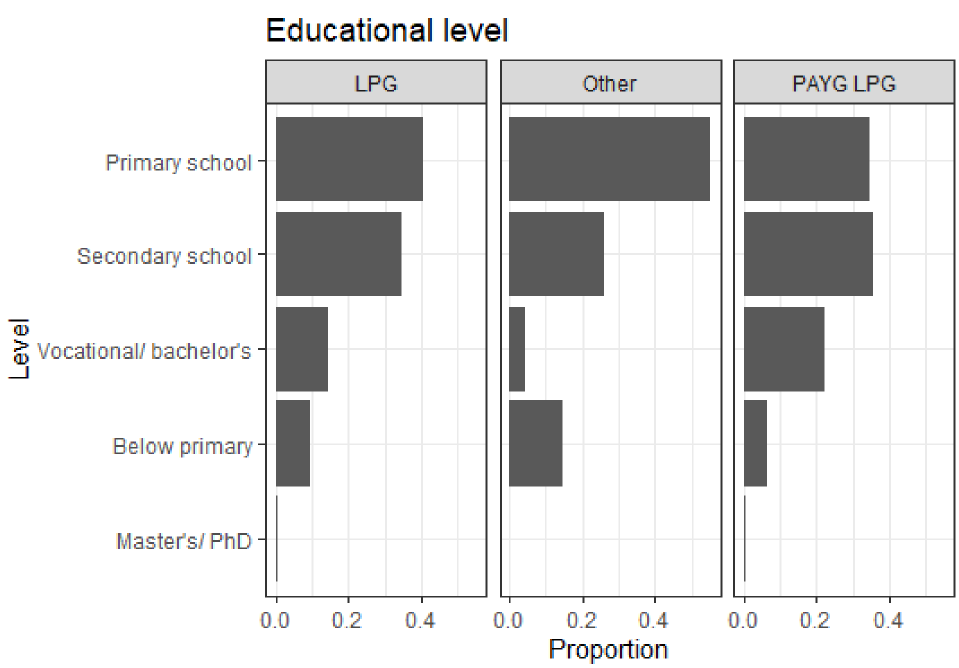

Figure 5-2: Educational level of respondents

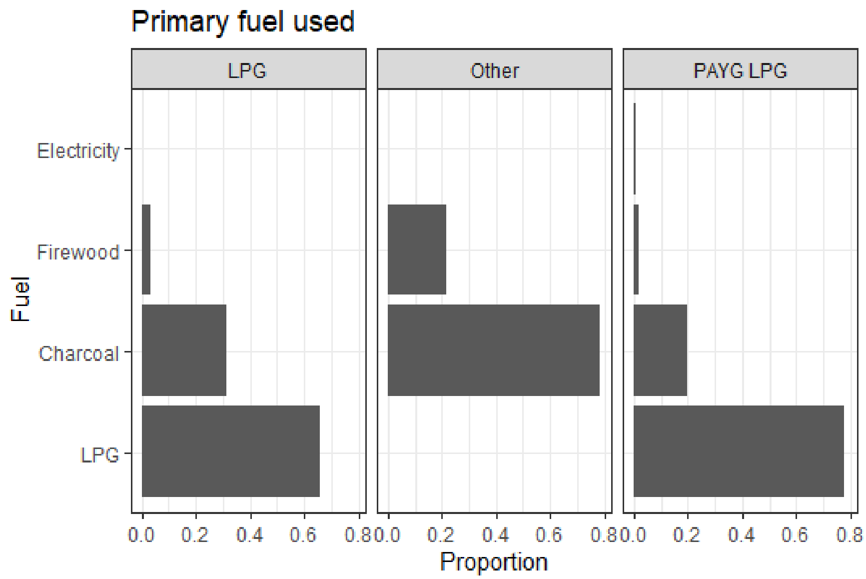

Figure 5-3: First choice of cooking fuel

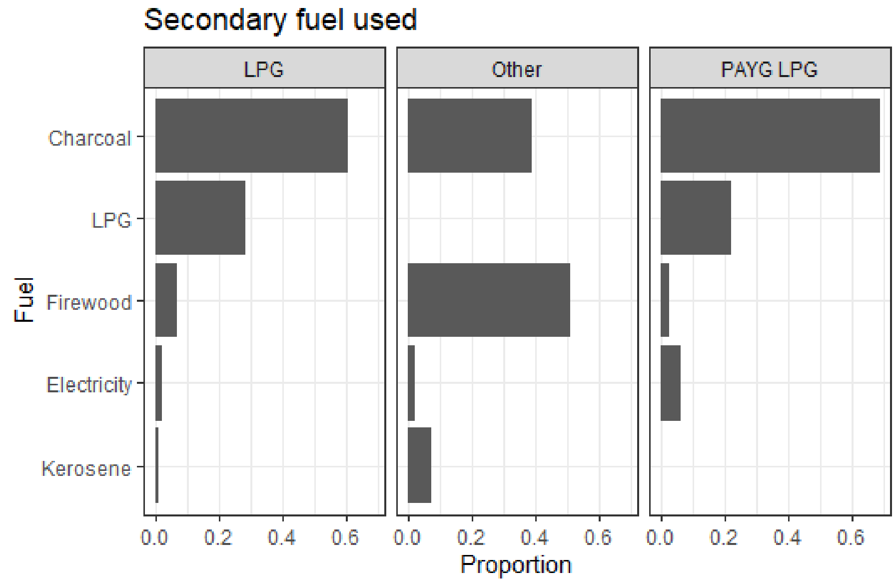

Figure 5-4: Secondary cooking fuel

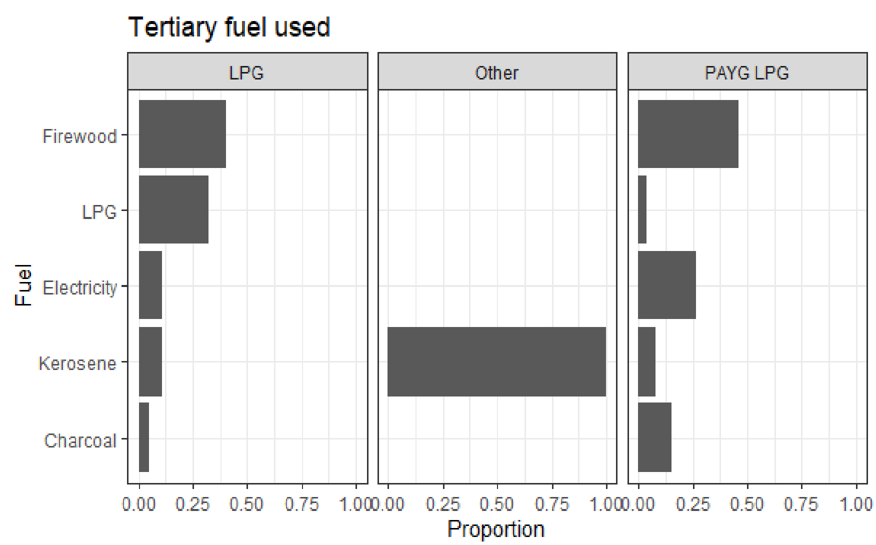

Figure 5-5: Tertiary cooking fuel

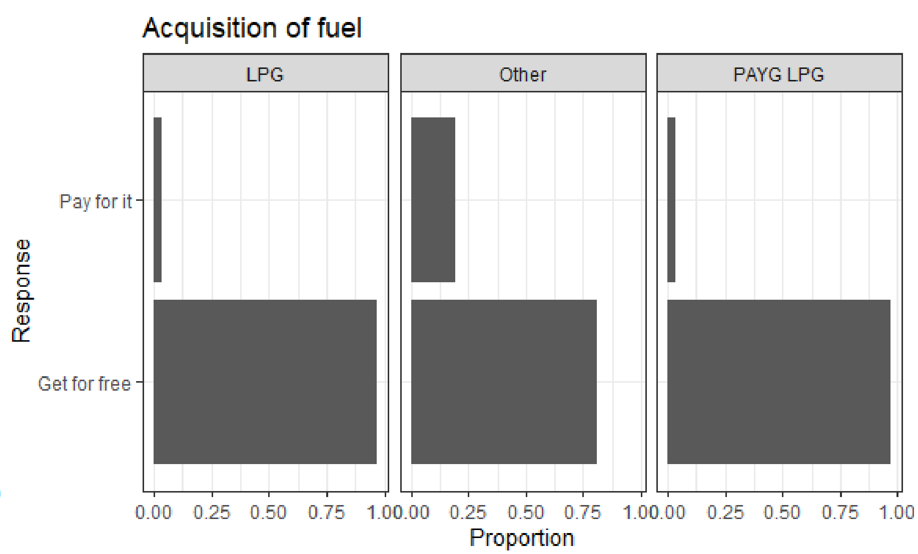

Figure 5-6: Firewood acquisition (n=29)

5.2 Available cooking energies and their uses for the total sample

Primarily, LPG is preferred for preparing breakfast (36%) and for cooking light meals (30%) like rice, pasta etc. Charcoal and firewood are preferred for cooking heavy and light meals, and for preparing breakfast. The only respondent who uses electricity as a primary energy to cook used it for all the above mentioned as well as for heating water for bathing. Those that used LPG as a secondary fuel use it mainly to prepare breakfast (45%) while charcoal users use it to cook heavy meals (55%) like ugali, makande etc. Others mostly use kerosene to prepare breakfast (43%) and cook light meals (29%) while firewood is used mainly to cook heavy meals (41%). Electricity as a second choice is used to heat water for bathing (31%) and for preparing breakfast and cooking light meals (28%). LPG is used to prepare breakfast (44%) and for cooking light meals (43%) when used as a third choice of fuel while charcoal (78%) and firewood (45%) are generally preferred for cooking heavy meals. In general, LPG is preferred for cooking light meals while charcoal and firewood are preferred for cooking heavy meals. Additionally, LPG and charcoal are the most common combination of fuels used in these households.

Table 5-2: Energy sources and their main uses for the total sample (n=477)

	Main use		**Percentage**			
		LPG	**Charcoal**	**Kerosene**	**Firewood**	**Electricity**
Primary	To boil water for bathing	28	21	-	23	25
	For cooking light meals (for example, rice, pasta etc.)	30	30	-	28	25
	For cooking heavy meals like ugali, makande etc.	6	31	-	26	25
	For preparing breakfast	36	18	-	23	25
Secondary	To boil water for bathing	24	16	21	26	31
	For cooking light meals (for example, rice, pasta etc.)	29	24	29	18	28
	For cooking heavy meals like ugali, makande etc.	2	55	7	41	13
	For preparing breakfast	45	5	43	15	28
Tertiary	To boil water for bathing	13	11	25	27	24
	For cooking light meals (for example, rice, pasta etc.)	43	11	25	21	41
	For cooking heavy meals like ugali, makande etc.	-	78	4	45	-
	For preparing breakfast	44	-	46	7	35

The Figures (5-7 to 5-9) below indicate the energy/ fuel mostly preferred as either the first, second or third choice for cooking. In increasing order, LPG < charcoal < firewood is preferred as the main cooking energy source while charcoal < LPG < firewood < electricity < kerosene is normally desired as a secondary fuel. As a tertiary fuel, firewood is preferred to LPG, electricity, kerosene, and charcoal in decreasing order as a cooking energy.

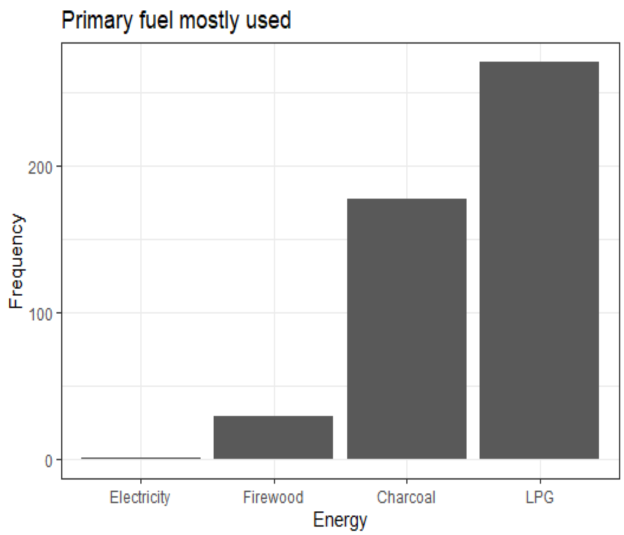

Figure 5-7: Primary preferred fuel for all energy users (n=477)

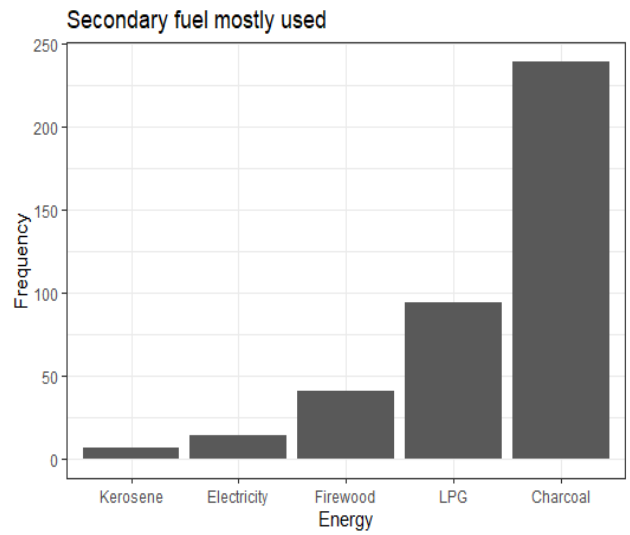

Figure 5-8: Second most preferred fuel for all energy users (n=477)

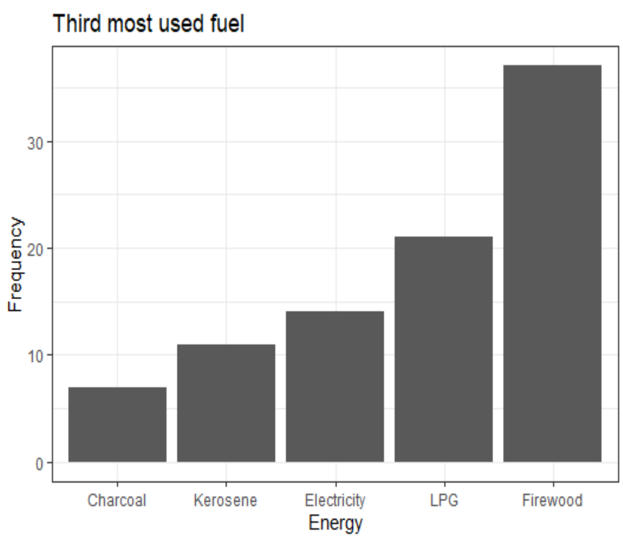

Figure 5-9: Third most preferred fuel for all energy users (n=477)

5.3 Factors that influence people's choice of cooking energy

The Table 5-3 below shows the results from a logistic regression with the individual energy/ fuel sources as dependent variables and the variables in the first column as independent variables. It shows that increasing household income significantly increases the choice of LPG as a cooking fuel (β=0.536). The unavailability of LPG (*more than once, 4-12 times a year, less than 4 times a year, always available*) significantly affects its choice (β= -0.741) and may discourage adoption if scarce. Additionally, the degree of re-fueling of LPG (β= 0.516) either daily, every 2 or 3 days, weekly, every 2 weeks, monthly or irregular highly affects choosing LPG as a cooking fuel. Although none of the independent variables significantly affects the choice of charcoal, an increase in the frequency of buying the fuel and educational level, as well as household connection to electricity may reduce the preference for the fuel. An increase in household income (β= -0.485) and connection to electricity (β= -0.867) decrease people's choice of firewood. However, an increase in the number of household inhabitants (β=0.273) and the location of the respondent (Mbezi Juu [β=1.208] and Wazo [β=1.191]) influence the choice of firewood as a cooking fuel. None of the independent variables significantly affect the choice of kerosene. Yet, increasing household income and number of inhabitants, the unavailability and frequency of buying fuel, and household connection to electricity may reduce the choice of kerosene for cooking. Choosing electricity for cooking is highly dependent on educational level (β=1.233).

Table 5-3: Factors that influence choice of cooking energy/ fuel

Variable	**Energy/ fuel**				
	LPG	Charcoal	Firewood	Kerosene	Electricity
Household income	0.536**	0.015	-0.485***	-0.247	0.236
Unavailability of fuel (*More than once a month [4], less than 4 times a year [3], 4-12 times a year [2], always available [1]*)	-0.741***	0.218	0.143	-0.024	-0.063
Frequency of buying fuel (*daily [1], every 2 or 3 days [2], weekly [3], every 2 weeks [4], monthly [5], irregular [6]*)	0.516***	-0.175	-0.123	-0.120	-0.149

No of household inhabitants	0.039	0.057	0.273***	-0.006	0.059
Respondent's educational level	0.204	-0.247	-0.203	0.327	1.233***
Household connection to electricity	0.739	-0.303	-0.867*	-1.187	15.920
Ward (Ref. Bunju=0)					
Kawe	-1.194	-0.873	1.087	-0.146	-0.004
Mbezi	-1.293	0.001	0.311	1.002	-0.596
Mbezi Juu	-0.789	0.131	1.208*	0.737	-1.211
Wazo	-1.092	0.001	1.191*	-0.229	-0.908
Intercept	-0.314	3.031**	-1.112	-2.430	-23.060
N	452	452	452	452	452
R^2	0.340	0.046	0.141	0.092	0.224

Asterisks indicate coefficient significance level: **'*'** p<.05, **'**'** p<.01, **'***'** p<.001, **'.'** p<0.1

5.4 Delivery model innovation

This section characterizes PAYG LPG users and their experiences with the delivery model and non-PAYG LPG users' knowledge and willingness or otherwise to adopt the model.

5.4.1 PAYG LPG users (n=121)

Table 5-4 below briefly describes PAYG LPG users and their experiences with using the model. It is observed that most of the customers (91%) were already users of LPG before adopting the model. Although majority of the customers have not experienced challenges with either topping up payment (83%) or with the stove/ cylinder (84%), quite a handful (12%) have discontinued the use of the model for reasons mentioned further in this section.

Table 5-4: The experience of PAYG LPG users

Question	**Response (n = 121)**			
	Yes		**No**	
	No	%	No	%
Were you using LPG before becoming a PAYG LPG customer?	110	91	11	9
Have you ever experienced any problems in topping up a payment?	20	17	101	83
Have you experienced any problems with the PAYG LPG stove and/or cylinder?	19	16	102	84
Have you ever discontinued using your PAYG LPG?	15	12	106	88

Most of the model users have been using LPG for cooking for 6-12 months, followed by 1-2 years, less than 6 months, and more than 5 years (Figure 5-10). When asked why they chose to adopt the delivery model (Figure 5-11), majority of the respondents said the model has value for money and so they are able to save compared to other available options. Others adopted it due to either a recommendation by a friend, for convenience or better safety. They further stated that the model is cheap, although a few of them said it was very expensive (Figure 5-12). While most of them cited slow processing of transaction as a challenge to topping up payment for the gas (Figure 5-13), they mentioned that their burners either stopped working, gas meters malfunctioned, or gas meters read inaccurately as challenges they have faced with the stove/ cylinder (Figure 5-14). The very few that had discontinued the use of the model alluded to lack of money, delays in supply from the company, problems with the stove or opted for cheaper options (Figure 5-15) as the reasons. That notwithstanding, majority of the users are happy with both the customer service (Figure 5-16) and home delivery service (Figure 5-17) offered by the company.

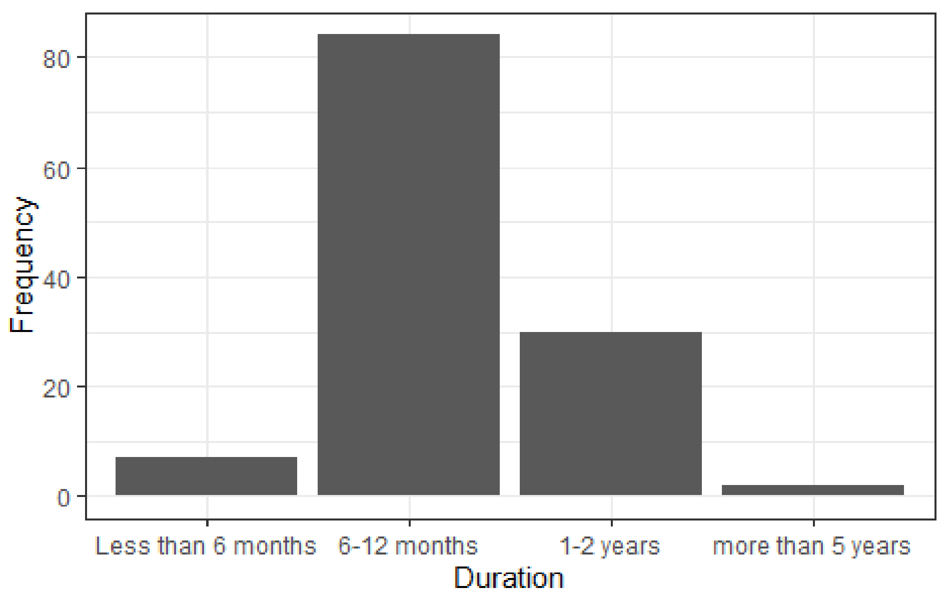

Figure 5-10: Duration of cooking with LPG (n=121)

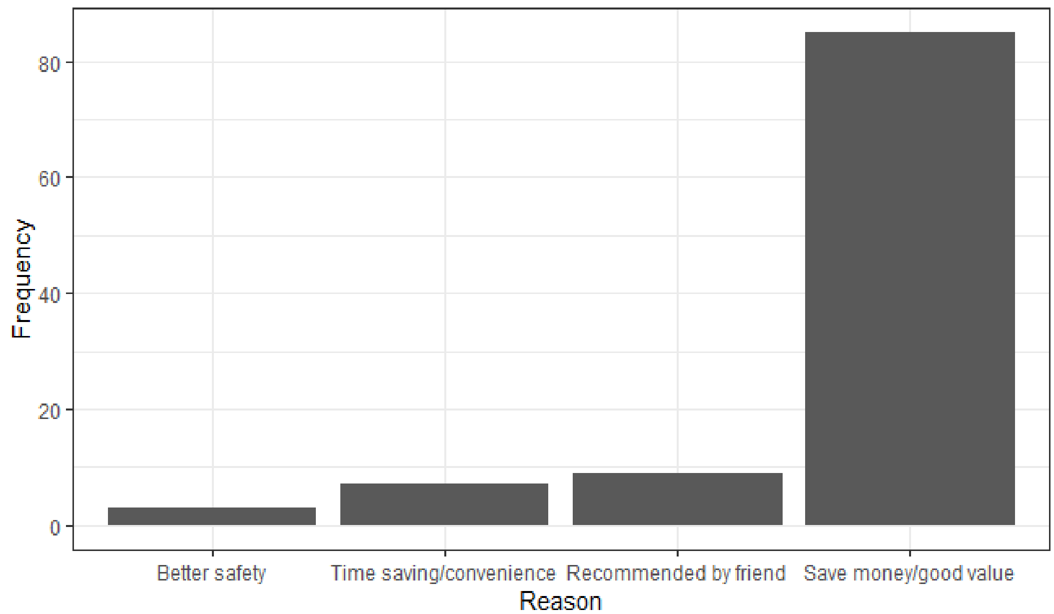

Figure 5-11: Reasons for choosing PAYG LPG (n=121)

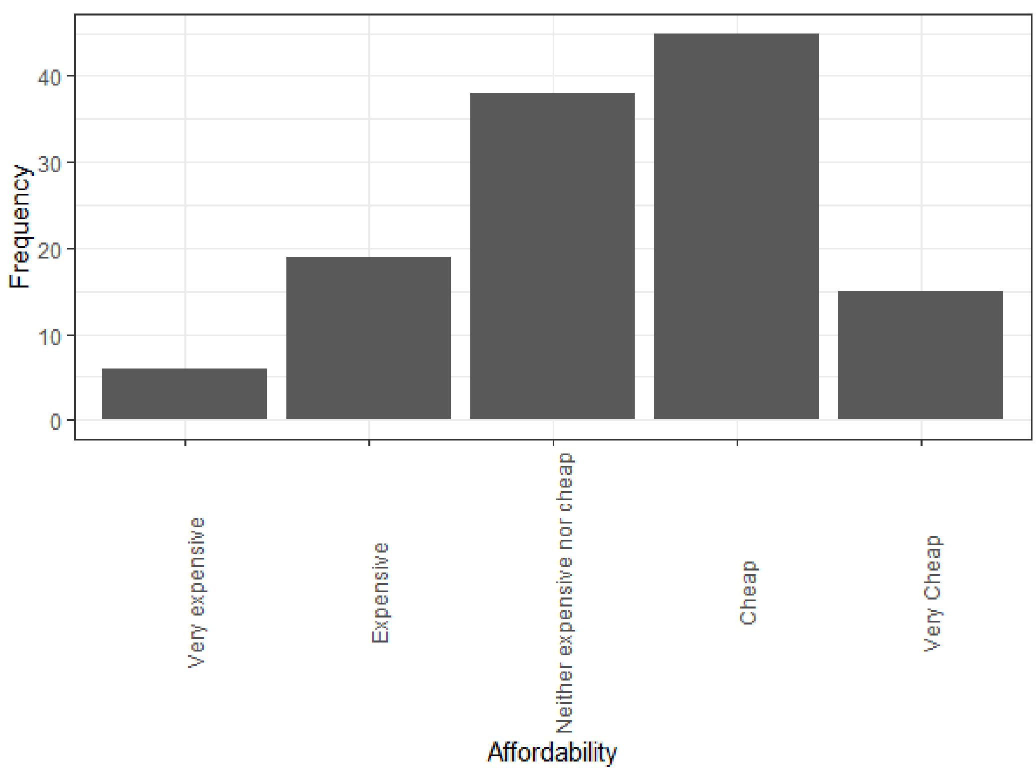

Figure 5-12: Affordability of PAYG LPG (n=121)

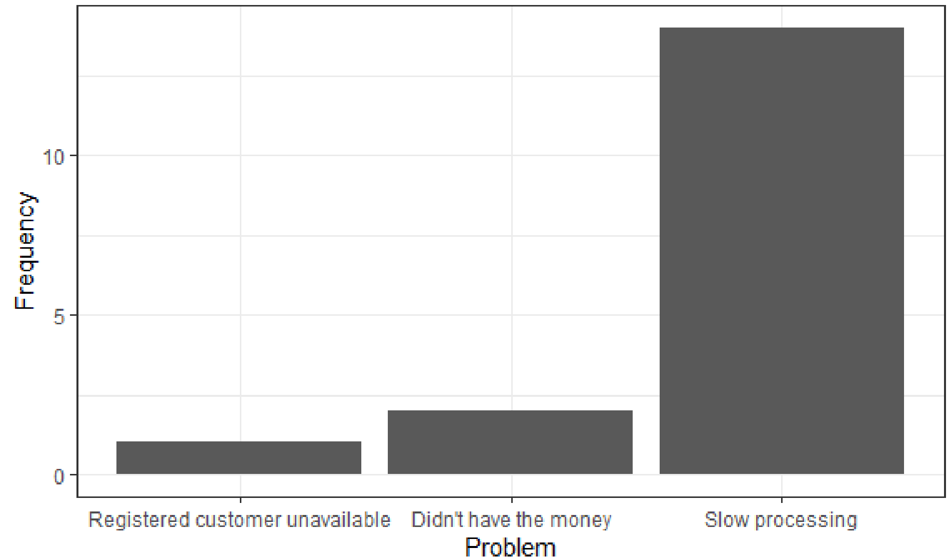

Figure 5-13: Problems with topping up payment (n=20)

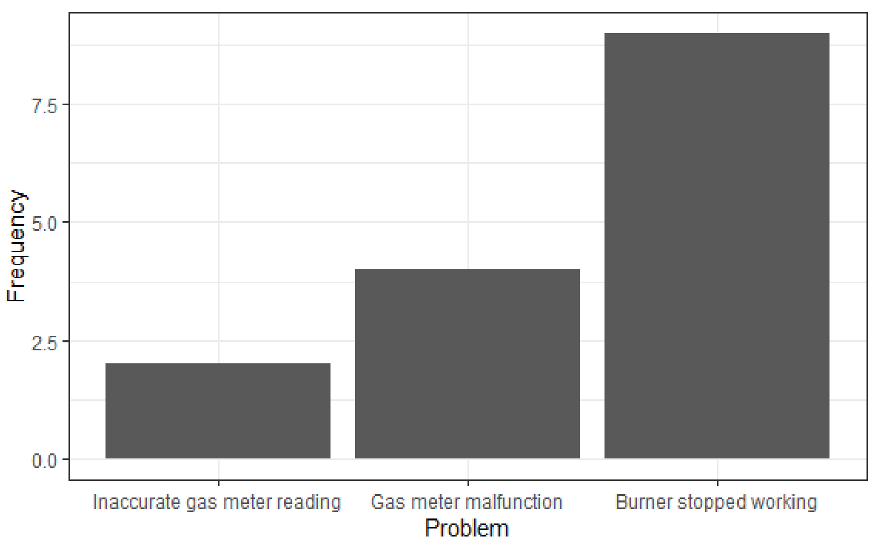

Figure 5-14: Problems with stove/ cylinder (n=19)

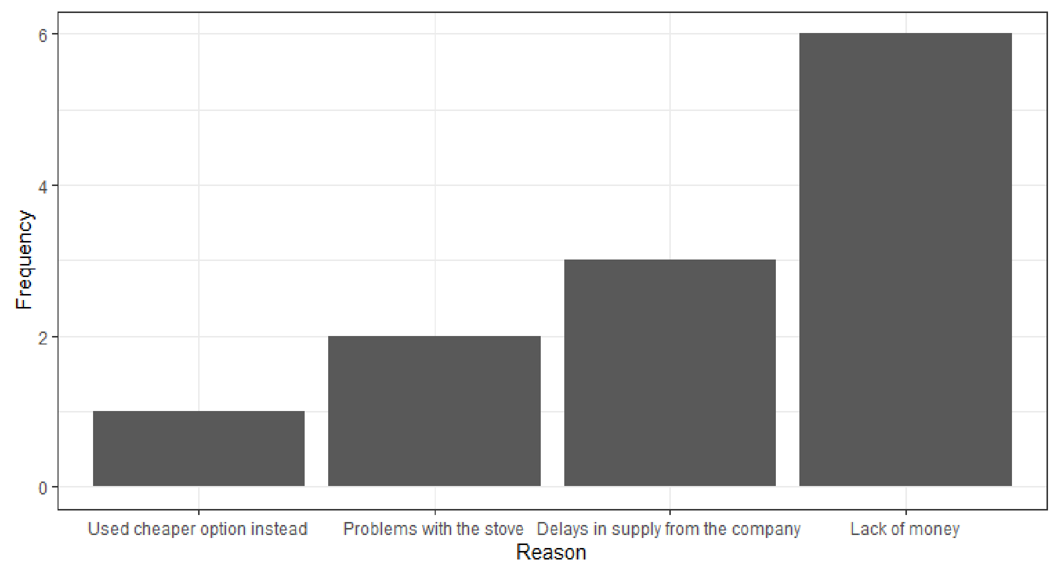

Figure 5-15: Reasons for discontinued use of PAYG LPG (n=15)

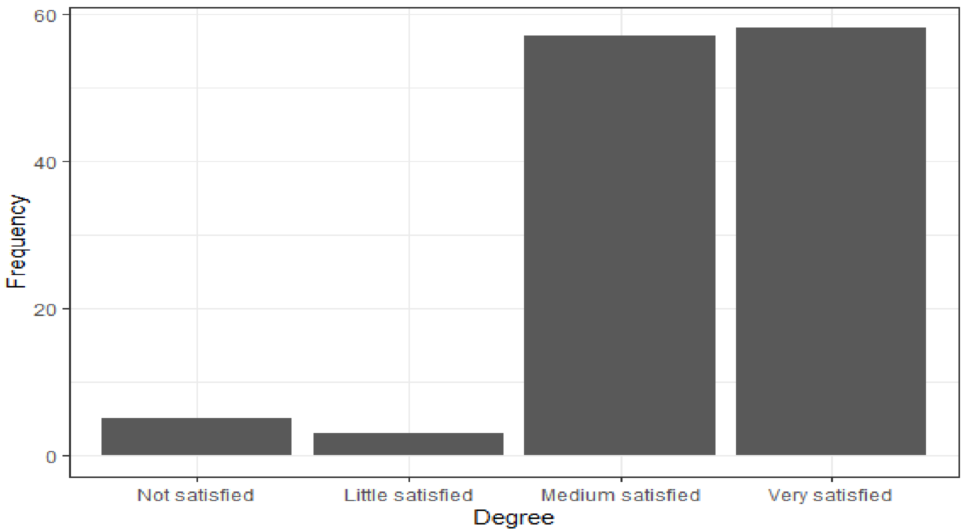

Figure 5-16: Satisfaction with customer service (n=121)

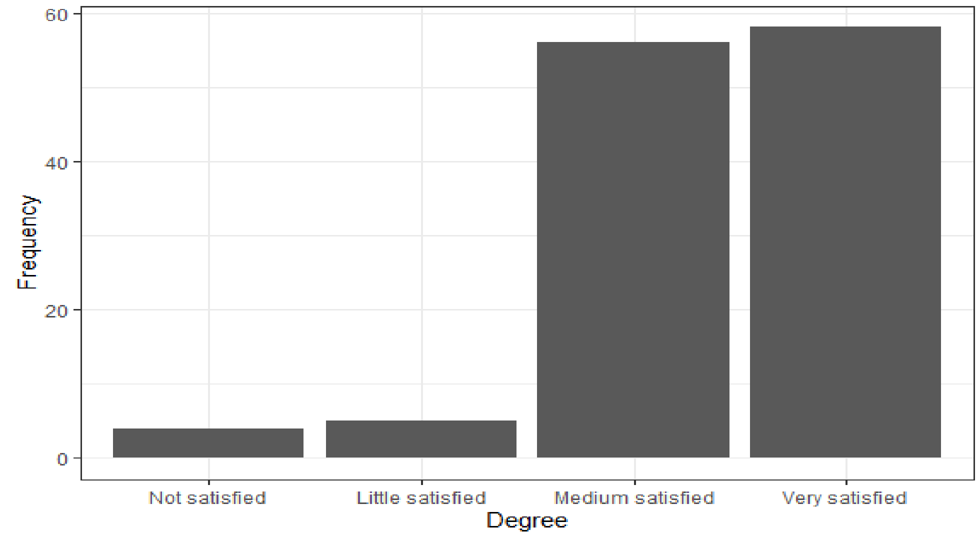

Figure 5-17: Satisfaction with home delivery service (n=121)

5.4.2 Non-PAYG LPG users (n=356)

Although most of the non-users have knowledge of the model, quite a number do not (Figure 5-18). Even with knowledge, it does not interest nearly all of them to register for the service as shown in Figure 5-19. The few that would like to register for the service cited "good value" and "convenience" as the main reasons while the others who do not want to, mentioned that they have not been visited by a PAYG LPG sales agent or were happy with their current fuel as indicated in Figures 5-20 and 5-21 respectively. Others further added that the initial deposit for the service is too expensive, they have no knowledge of how to sign up, gas too expensive, negative word of mouth or safety as barriers to why they would not opt for the service (Figure 5-21).

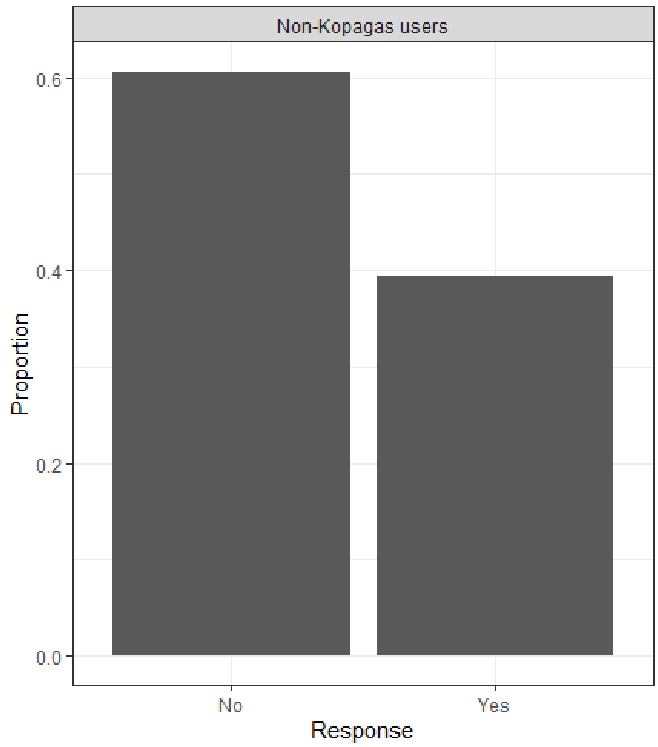

Figure 5-18: Knowledge of PAYG LPG (n=89)

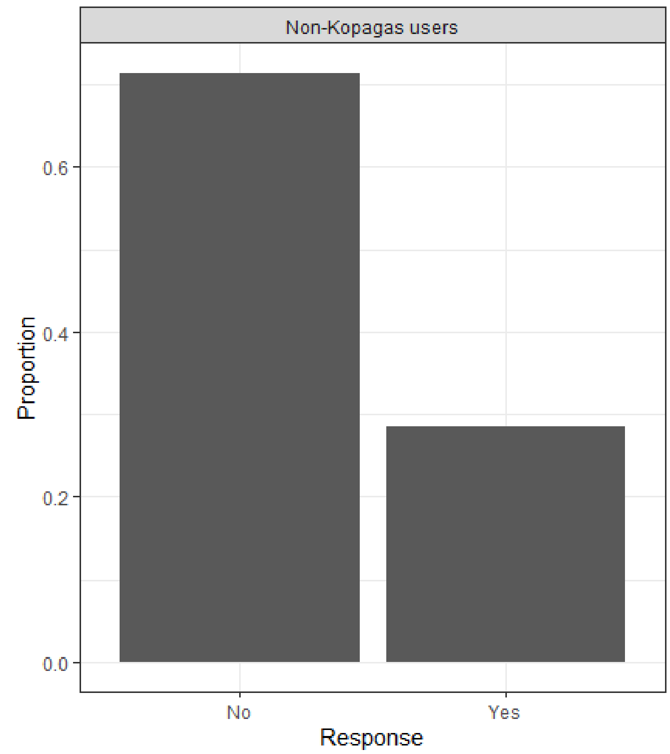

Figure 5-19: Registration with PAYG LPG (n=35)

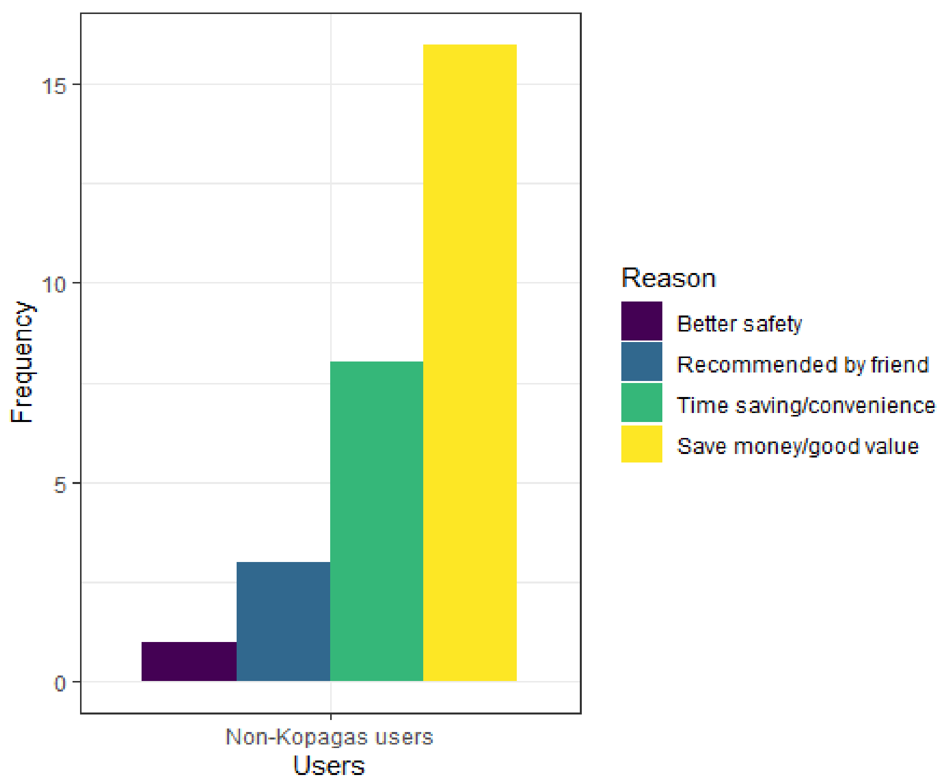

Figure 5-20: Factors that will influence the choice of PAYG LPG (n=9)

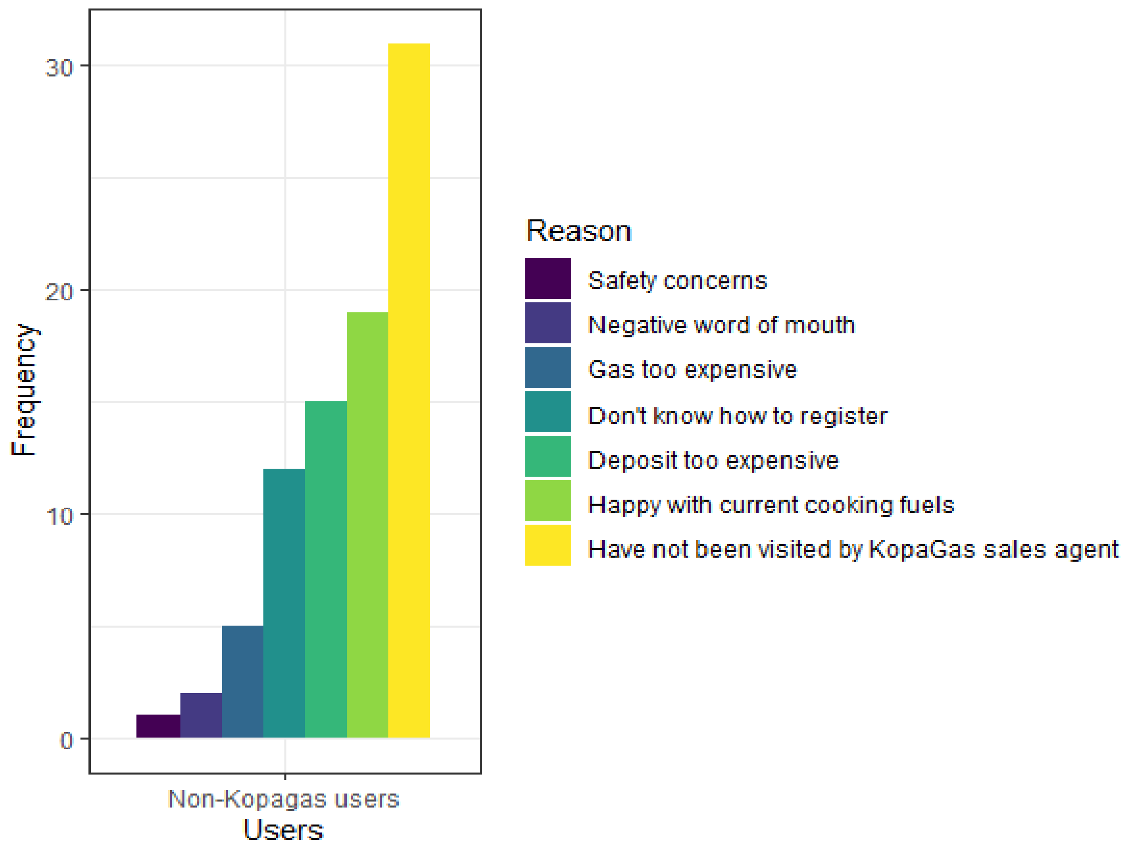

Figure 5-21: Barriers to choosing PAYG LPG among non-users (n=21)

Table 5-5 below shows the results from a logistic regression with the use of PAYG LPG as the dependent variable. Model 1 has four independent variables (household income, decisions, unavailability of fuel and frequency of refilling), with all variables significantly contributing to the use of PAYG LPG at $p<0.001$ except household decisions. It is however worthy to note that household decisions taken by women alone and/or shared between men and women may encourage the adoption of PAYG LPG for cooking. While increasing household income may increase the preference for PAYG LPG use, the unavailability and frequency of refilling fuel may discourage people from using the service. Additionally, increasing the number of inhabitants increases the likelihood of choosing PAYG LPG in model 2 ($p<0.01$). However, increasing the number of household members who are aged less than 18 may reduce the adoption of the service ($\beta=-0.314$).

Respondent's education and location do not significantly affect the choice of PAYG LPG but a household's connection to electricity significantly increase the preference for PAYG LPG use ($p<0.01$) in Model 3.

Table 5-5: Logistic regression, dependent variable: use of PAYG LPG

Variable	**Model 1**		**Model 2**		**Model 3**	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
Household income	0.583***	0.100	0.553***	0.107	0.454***	0.113
Household decisions (Ref. Respondent=1)						
Male family member [2]	-0.419	0.527	-0.533	0.558	-0.540	0.575
Female family member [3]	0.881	0.581	0.865	0.588	0.743	0.607
Joint decision [4]	0.333	0.265	0.292	0.277	0.290	0.283
Fuel unavailability (*More than once a month [4], less than 4 times a year [3], 4-12 times a year [2], always available [1]*)	-0.569***	0.145	-0.521***	0.148	-0.468**	0.149
Frequency of buying fuel (*daily [1], every 2 or 3 days [2], weekly [3], every 2 weeks [4], monthly [5], irregular [6]*)	-0.280***	0.066	-0.251***	0.069	-0.277***	0.071
No of household inhabitants			0.242**	0.081	0.242**	0.084
Household members aged <18			-0.314**	0.116	-0.301*	0.122
Respondent's education					0.154	0.146
Ward (Ref: Bunju=0)						
Kawe					-0.598	0.759
Mbezi					-0.654	0.545
Mbezi Juu					-0.653	0.507
Wazo					-0.600	0.449
Household connected to electricity					2.769**	1.043
Intercept	-1.009*	0.453	-1.679**	0.544	-3.883**	1.192
N	450		438		438	
R^2	0. 126		0.147		0.184	

Asterisks indicate coefficient significance level: '*' p<.05, '**' p<.01, '***' p<.001, '.' p<0.1

6 Analysis and discussion

This chapter analyzes and discusses the results of the study. The chapter is sectioned into three parts. The first section discusses the available cooking fuels and their various uses in the selected wards. This is followed by a section that describes the socio-cultural factors that influence a household's decision to adopt certain cooking fuels. Lastly, section 3 discusses the factors that influence people's adoption of the PAYG delivery model for cooking.

6.1 Available cooking energies in the selected wards in Dar es Salaam

All the surveyed households use multiple fuels (LPG, charcoal, kerosene, firewood, and electricity) for different cooking purposes. For instance, most households preferred LPG for cooking light meals like rice, pasta, etc. while charcoal and firewood are normally used to prepare heavy meals like ugali and makande (Table 5-2). Some households use kerosene to prepare breakfast and to cook light meals whereas electricity is preferred for boiling water for bathing (Table 5-2). This practice of using different fuels for various cooking purposes is similar to the findings of Treiber et al. (2015) and Masera et al. (2000). According to Treiber et al. (2015), LPG and kerosene are normally preferred for warming up food and preparing light foods that do not require long cooking times because of their speed and great thermal efficiency. Preparing heavy meals, however, requires many hours of cooking and so households prefer cooking with either charcoal or firewood which is relatively cheaper compared to LPG (Van der Kroon et al. 2013) or other modern forms of cooking energy. Even though electricity access has increased significantly in Tanzania, it has not led to the widespread use of the energy for cooking. According to URT (2020), electricity is primarily used for lighting (76% of households) in Tanzania Mainland, although it is used for other purposes including water boiling, laundry, welding, etc. with only 0.8% of the households using it for cooking purposes. This could particularly be due to the intermittent supply of power and the high costs of electricity and electric stoves (Makonese et al. 2018; Ifegbesan et al. 2016). As modern energy, LPG is preferred to electricity in the surveyed households probably because of easy accessibility and control.

As a primary fuel, LPG is mostly used to prepare breakfast and cook light meals (Table 5-2). Charcoal and firewood on the other hand are preferred for cooking both heavy and light meals, while the only user of electricity as a primary fuel used it for all the above mentioned as well as for boiling water for bathing (Table 5-2). Kerosene is not used as a primary fuel among the surveyed households. When used as a secondary fuel, LPG is mostly preferred in preparing breakfast whereas charcoal and firewood are typically used in cooking heavy meals (Table 5-2). Kerosene is preferred when making breakfast while electricity is used to boil water for bathing. In households that use LPG as a tertiary fuel, they mostly use it to prepare breakfast and cook light meals. Charcoal and firewood are used to cook heavy meals while kerosene and electricity are preferred for preparing breakfast and cooking light meals respectively (Table 5-2). Even in some instances, a household may have three or more fuels complementing each other depending on the cooking needs of that particular household. The stacking of fuels as seen in the data corresponds to the multiple fuel use model and parallels similar findings by Choumert et al. (2019) and Doggart et al. (2020) who reported that the fuel stacking model better explains trends of fuel use in Dar es Salaam, Tanzania. Fuel stacking patterns have been attributed to culinary, convenience, and economic factors (Gould et al. 2020b). Some households have remarked that certain fuels have an impact on the taste of traditional foods and so the desire to keep the taste of these foods leads to multiple fuel use (Gould and Urpelainen, 2018; Hollada et al. 2017; Lambe and Atteridge, 2012). For instance, some households in Mexico reported that they preferred to make tortillas with firewood than LPG because the latter changes the taste of the tortillas (Masera et al. 2000). Furthermore, firewood or charcoal is normally the favourite choice of fuel when making foods such as roasted maize or meat. Also, restaurants prefer other energy sources to kerosene due to the flavour it leaves on foods (Treiber et al. 2015). The high costs of electricity and LPG, sporadic blackouts and the unreliable supply of LPG have been cited as reasons for the multiple fuel use in households (Gould et al. 2020b; Shupler et al. 2021).

It is worthy to note that LPG is the most frequently used primary fuel in the surveyed households (Figure 5-7) owing to its availability, speed of cooking, safety, cleanliness, and ability to cook most dishes. Whereas charcoal is mostly used as a secondary fuel to LPG (Figure 5-8) perhaps, because of its relative affordability (Doggart et al. 2020) and accessibility, firewood is the third most preferred fuel (Figure 5-9) conceivably due to long collection times and its increasing scarcity (Gould et al. 2020a). This finding of LPG as the main fuel among the surveyed households is contrary to findings by Choumert et al. (2019) and Doggart et al. (2020) who reported that charcoal was the most used primary fuel in Dar es Salaam. Together with d'Agostino et al. (2015), however, acknowledged that the demand for LPG is on the rise and will continue to increase due to urbanization. Additionally, the removal of the 2008-2009 value-added tax (VAT) and import duties on LPG by the Tanzanian government has contributed to its increased adoption (Doggart et al. 2020). This swift increase in LPG use in Tanzania matches the rise in its importation from about 20,000 metric tonnes in 2010 to more than 145,000 metric tonnes in 2019. Kerosene on the other hand, was only used as a secondary or tertiary fuel among the surveyed households. Its use has drastically declined over the last decade owing partly to the increase in excise duty on the fuel in 2011 and its impact on the taste of food (Doggart et al. 2020). Consequently, most households have replaced kerosene as their main cooking fuel with other fuels (Table 5-2). Generally, LPG and charcoal are the most common combination of fuels in most of the surveyed households (Table 5-2). This finding agrees with Doggart et al. (2020) who reported a charcoal/LPG mix as the most commonly used combination of fuels in Tanzania.

6.2 Socio-cultural factors affecting the choice of cooking fuel

Several factors including household income, fuel unavailability and frequency of refilling/buying, number of household inhabitants, education, household connection to electricity, and location affect the choice of fuel for cooking in the surveyed households (Table 5-3).

From Table 5-3, household income significantly correlates with the choice of LPG and firewood for cooking among the households. Increasing household income increases the chances of choosing LPG as cooking fuel (β=0.536). In contrast, increasing household income decreases the choice of cooking with firewood (β= -0.485). This finding is in agreement with other studies including d'Agostino et al. (2015) who stated that households in Tanzania move away from cooking with firewood with increasing income. However, the movement is not a complete transition to modern fuels but a substitution with mostly charcoal stacked with other fuel types. Although it plays a major role in the transition process to modern energy and related technologies, income is not the sole determinant of fuel choice in SSA (Makonese et al. 2018). Other socio-cultural and economic determinants and household characteristics like level of education, number of household inhabitants, etc. play a vital and intricate role.

The unavailability of LPG (*more than once, 4-12 times a year, less than 4 times a year, always available*) and the degree of refilling the cylinder either daily, every 2 or 3 days, weekly, every 2 weeks, monthly or on irregular basis significantly correlate with the choice of LPG (Table 5-3). In effect, the less available the fuel is the less chances of people adopting it for cooking. This finding is in agreement with Makonese et al. (2018) who reported a strong association between high levels of LPG use and ease of accessibility in Angola. Additionally, Shupler et al. (2021) reported that the unreliable supply of LPG deters households from fully transitioning to clean cooking. They further expressed that regardless of socio-economic status, households that have access to retailers who always have LPG available had a 25% higher chance of adopting LPG as their main fuel than households who have access to retailers that had LPG unavailable for purchase at least once per month. Although it is determined by the size of the cylinder and frequency of usage, the frequency of refilling positively affects the adoption of LPG (β=0.516). Essentially, the longer the refilling time, the better the chances of choosing LPG for cooking. Associated with cost, the frequency of refilling correlates with possible uptake. According to Shupler et al. (2021), an increase in cost per kilogram of LPG refill decreases consumption and as well contributes to the discontinued use of the fuel for cooking. They explained that 37% of previous LPG users stopped using the gas and fell exclusively on polluting fuels to cook due to unaffordable refill costs. Practically, cylinder refills remain a critical barrier for both current and previous LPG users.

Household size also positively correlates with the choice of cooking energy. Increasing the number of household inhabitants increases the possibility of adopting firewood for cooking (β=0.273). This aligns with Makonese et al. (2018) who found that among others, household size is a major determinant of household choice of cooking energy. According to Shupler et al. (2021), an increase in household size normally increases the amount of fuel needed and demands a larger stove surface area to prepare more meals to feed the whole family. Typically, it will be easier for a large-sized family with more children to gather biomass to support cooking on open fires that can accommodate larger pots than a single-burner LPG stove (Campbell et al. 2021; Ngui et al. 2011; Van der Kroon et al. 2013). The development and promotion of multiple-burner LPG stoves may address the above-mentioned transition barrier and thus increase LPG uptake.

The educational level of the respondents correlated with their choice of cooking fuel. Practically, the higher the educational level, the better the chances of using electricity to cook (β=1.233). In a similar study, Mekonnen and Köhlin (2008) observed that a rise in education increases the likelihood of adopting electricity for cooking. Likewise, Makonese et al. (2018) in their study of household fuel use patterns and determinants across Southern Africa reported that the level of education is an important factor in influencing people's choice of cooking fuel in Lesotho. Additionally, Treiber et al. (2015) stated that education influences people's behaviour toward an energy source and consequently influences adoption. Education may then be essential for increasing awareness of clean and improved fuels and the health implications of adopting traditional biomass energy for cooking. In sharp contrast, Gould et al. (2020a) reported that education does not positively correlate with attitudes toward clean cooking fuels. They suggested that household perceptions are greatly independent of educational achievement, although a higher female educational level may influence household perceptions of cooking and health.

Furthermore, a household's connection to electricity correlates negatively with the decision to use firewood. A household's connection to electricity reduces the possibility of adopting firewood for cooking (β= -0.867). According to Makonese et al. (2018), most households without access to grid electricity use firewood and charcoal as cooking energies whiles electricity and LPG are mostly preferred by households connected to electricity. However, Choumert et al. (2019) found that household connection to electricity is not a sufficient condition for the exclusive use of modern fuels. This is the same for this study as the logistic regression (Table 5-3) showed a non-significant association between the use of modern fuels (LPG, kerosene, and electricity) and household connection to electricity.

Likewise, residential location significantly affects the choice of firewood as an energy source for cooking. Living in either Mbezi Juu (β=1.208) or Wazo (β=1.191) ward increases the likelihood of cooking with firewood. This could probably be due to the difference in the general level of affluence, population density and distance to infrastructure in these areas. Thus, the determinants likely to influence fuel choices among others include the geographical location of residence (Ekholm et al. 2010). Essentially, rural households are more likely to use firewood and animal residue for cooking (Doggart et al. 2020; Choumert et al. 2019) while urban households are likely to adopt 'clean' cooking fuels like electricity and LPG (Choumert et al. 2019).

6.3 Factors influencing people's adoption of the delivery model (PAYG LPG) for cooking

Most of the PAYG LPG consumers (91%) surveyed in this study were users of the conventional LPG and so were familiar with cooking with the fuel before adopting the delivery model (*"compatibility"* in Rogers' (2003) theory). Just as Rogers put it, when a technology is consistent with existing values, past experience and the needs of potential adopters, it makes it easier to adopt. Since most of the PAYG LPG users had experienced the use of conventional LPG, it was easier to accept and register with the service. Besides, they have additional benefits of buying fuel in smaller quantities according to their budget and have control over their consumption. The PAYG LPG users chose the model primarily because of good value and/or via a recommendation by a friend, for convenience or safety (Figure 5-11). According to Ndunguru (2021), Kopagas has customer service centres that supply gas and assist customers with technical issues spread out in the Kinondoni Municipality, and this offers convenience and comfortability to its customers. This could be likened to the *"relative advantage"* and *"complexity"* attributes of Rogers' "perceived attributes theory" (2003). According to Rogers, a technology has *relative advantage* when it offers comfortability, has low initial costs, and saves time. This apparent advantage however depends on the characteristics of the prospective adopter and the nature of the technology. With the assistance of customer service centres spread out in the Kinondoni Municipality, PAYG LPG becomes easy to use and thus encourage uptake. To Rogers, the *complexity* of a technology although relative, breeds resistance to adoption. Most of the users further added that the gas was cheap although a handful thought it was very expensive (Figure 5-12). This finding agrees with Ndunguru (2021) who reported that some households believed the PAYG model is cheaper while others thought otherwise.

Some of the model users however pointed out some challenges faced when using the service. Prominent among them were issues concerning topping up payments (n = 20). They revealed that the processing was oftentimes slow, and sometimes lack of money hindered their use. If the registered customer is unavailable, topping up becomes an issue as well (Figure 5-13). Another key challenge cited was problems with either the stove or cylinder (n = 19). The few respondents that commented that they had had problems stated that their burner abruptly stopped working while in use. Others mentioned issues regarding the gas meter as either malfunctioning or were inaccurately reading (Figure 5-14).

Subsequently, about a handful (n = 15) of customers discontinued the use of LPG from PAYG. The major cause of this was a lack of money. Affordability is a major condition in the choice of cooking fuel. As observed by Treiber et al. (2015), a hike in prices of LPG and kerosene in Kenya rendered them uneconomical and so their use was discontinued. Other reasons included in descending order delays in supply from the company, problems with the stove, and/or opting for cheaper options (Figure 5-15). Ndunguru (2021) attributed the delay in cylinder supplies in Kinondoni, Dar es Salaam to unplanned settlements normally without proper addressing systems, unmotorable roads, and poor drainage systems. Thus, customers residing in such areas will likely face delayed delivery services. Nevertheless, most of the users are happy with both the customer service (Figure 5-16) and the home delivery service (Figure 5-17) offered by the company.

Thirty-five (representing 39%) out of the 89 non-LPG households in the survey had heard about PAYG LPG (Figure 5-18) but only 10 (29%) were willing to register with the service (Figure 5-19). They cited "good value" and "convenience" as the main reasons that will drive them to adopt the model (Figure 5-20). They further added that a recommendation by a friend and safety reasons will influence them to choose the service. As reported by Rogers (2003), when results of an innovation are obvious to others (*observability*), it encourages adoption and diffusion. Although these potential adopters had not used the service, they knew it had good value and so were ready to adopt it. The convenience factor also cited as a determinant to adoption of PAYG LPG is a sub-dimension of *relative advantage*.

On the other hand, several reasons influence the unwillingness to register with PAYG, with the main barrier being that non-users have not been visited by a sales agent (Figure 5-21). Other reasons cited included contentment with current cooking fuels, expensive upfront cost, inadequate knowledge of registration procedure, gas being too expensive, negative word of mouth, and safety concerns. The upfront cost has however been found to reduce with the PAYG service in Tanzania because customers do not necessarily have to pay a deposit for the cylinder and its related accessories (Ndunguru, 2021). Further education is therefore required to increase awareness of the conditionalities and operational schemes for accepting the model to increase its adoption. A survey of households also showed that it was more expensive to refill gas cylinders with smart meters than the conventional model because payment for the leased cylinders and smart meters although paid in small amounts, is gradually done during gas recharge (Ndunguru, 2021).

Results from the logistic regression with adoption of PAYG LPG as the dependent variable (Table 5-5) showed that household income, fuel unavailability, and frequency of refilling significantly correlate with the choice of PAYG in Model 1 ($p<0.001$). Higher costs of transportation of cylinders and the proximity of households to LPG retailers among others have been cited as barriers to LPG uptake (Shupler et al. 2021). The PAYG LPG service however removes these long transportation times and high costs through the home delivery of cylinders (Shupler et al. 2021).

Additionally, with PAYG LPG, households may have more control over the frequency of refilling since they are able to monitor their consumption.

In addition to household income, fuel unavailability, and frequency of refilling, the number of inhabitants within a household significantly affects the likelihood to opt for the PAYG service ($p<0.01$) in Model 2. Practically, increasing the number of inhabitants in a household increases the chances of adopting LPG from PAYG as a cooking fuel (β=0.242). This is contrary to findings from Shupler et al. (2021) who reported that families with larger sizes are more likely to adopt open fires that can accommodate larger pots for substantive cooking. Conversely, when the number of household members aged <18 is increased, the probability of choosing the service declines (Table 5-5). This may probably be because of the fear of fire with LPG use (Ozoh et al. 2018) especially when most of the household members are aged <18.

While the respondents' educational level and residential location yield no significant effect on the use of the PAYG service in Model 3, a household's connection to electricity positively affects the choice of the service (β=2.769). The metering services with the PAYG equipment rely on batteries that require adequate charging to function properly. According to Ndunguru (2021), these meter batteries need electricity to charge, and customers are normally advised to check the battery level at any time before using the stove. This is because cooking with a meter on a low battery may shut it down and erase all data. To avoid this, PAYG customers revealed that they recharged their batteries every morning even if they are half-empty (Ndunguru, 2021). Experiencing an inadequate or erratic supply of electricity will affect the use of the smart metering service, hence, the positive association between a household's connection to electricity and adoption of PAYG LPG.

Policy implications

It is evident from the findings that the removal of the VAT and import duties for LPG in 2008-2009 by the Government of Tanzania has consequently increased the adoption of LPG as a cooking fuel in the surveyed households in the Kinondoni Municipality. The ban on charcoal production and trade, and transportation across district boundaries in 2006 and 2017, although its enforcement was faced with resistance from consumers and traders, have driven production and trade into informal operations whereas the increase in excise duty on kerosene in 2011 has contributed to the reduction in the usage of the fuel for cooking.

To further address issues concerning environmental degradation and health consequences associated with cooking with traditional biomass fuels, evidence from this current study indicate that formulating policies based on the multiple energy use model might be more useful in Tanzania than the energy ladder model. Therefore, future energy interventions should be focused on making available multiple, efficient energy fuels including traditional biomass fuels and related novel technologies like improved cookstoves, and modern fuels like LPG and electricity for households to choose from. This would ensure environmental sustainability and improvement in health while households still can choose from multiple fuels. Perhaps, if future policies and energy transition programmes would acknowledge stacking and consider the range of daily household energy needs, stacking with biomass fuels could be reduced. Rather than rely on a single, clean fuel to meet all cooking needs, maybe promoting the multiple use of modern fuels "*clean stack*" would be a game-changer. Furthermore, the GoT through its policies can take advantage of and internalize new international developments like the new guidelines with "clean" (Tier 4+) cooking solutions.

Additionally, PAYG LPG may aid the transition from biomass fuels to modern fuels, particularly LPG because it offers households with variable income levels the opportunity to use bottled gas for cooking. Furthermore, PAYG addresses some key areas of concern to most low-income households including upfront cost reduction, comfortability (ability to monitor consumption level), and fuel affordability (through buying in small quantities according to one's budget). The GoT, under the auspices of the Ministry of Energy and regulating agencies, and relevant stakeholders should therefore target and increase investments in improving access to PAYG LPG to a majority of the semi-urban and rural population to reduce the disease burden of the country while improving air quality.

7 Conclusion

All the surveyed households use multiple fuels (LPG, charcoal, kerosene, firewood, and electricity) for different cooking purposes like boiling water for bathing, cooking light and heavy meals, and preparing breakfast. Primarily, LPG is mostly preferred for preparing breakfast and cooking light meals while charcoal and firewood are mostly used to prepare heavy meals. LPG was found to be the most frequently used primary fuel among the surveyed households whereas charcoal and firewood were the second and third most preferred fuels respectively. Generally, LPG and charcoal are the most common combination of fuels in most of the surveyed households.

Household income, the unavailability of LPG, and the frequency of refilling the cylinder positively correlate with choosing the fuel for cooking. However, a household's connection to electricity and increasing income reduce the chances of adopting firewood for cooking. Household size and residential location on the other hand, positively correlate with the choice of firewood whiles increasing the educational level of respondents, highly correlates with adopting electricity for cooking.

Most of the PAYG LPG consumers surveyed in this study were users of the conventional LPG before adopting the service, and they opted for it because of good value, through a recommendation by a friend, for convenience or safety reasons. Some of the service users however mentioned that they had faced issues with topping up payments, either the stove or cylinder and the gas meters. The logistic regression showed that household income, fuel unavailability, frequency of refilling, the number of household inhabitants, and a household's connection to electricity are good predictors for the choice of PAYG LPG among the surveyed households. On the other hand, the respondents' educational level, residential location, and the number of household members aged <18 yielded no significant effect on the use of the PAYG service.

There is a need for further studies based on these findings. Firstly, further research is needed to better understand the popularity of charcoal in the energy mix considering the various policy tools instituted to reduce its adoption. Additionally, further research should target the aspects of gender and women's role in the adoption or otherwise of modern fuels and the implications of cooking fuels on the health of women and children. Lastly, there is a need to better understand user preferences and the factors that influence the adoption of PAYG LPG to ensure widespread uptake.

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Appendices

Appendix I - Multi-Tier Framework (MTF) for cooking solutions. Source: World Bank

Attribute	*Measurement indicators*	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Exposure	ISO's voluntary performance targets on emissions-default ventilation $PM_{2.5}$ (mg/MJd) CO (g/MJd)	> 1030 > 18.3	≤ 1030 ≤ 18.3	≤ 481 ≤ 11.5	≤ 218 ≤ 7.2	≤ 62 ≤ 4.4	≤ 5 ≤ 3.0
	High ventilation $PM_{2.5}$ (mg/MJd) CO (g/MJd)	> 1489 > 26.9	≤ 1489 ≤ 26.9	≤ 733 ≤ 16.0	≤ 321 ≤ 10.3	≤ 92 ≤ 6.2	≤ 7 ≤ 4.4
	Low ventilation $PM_{2.5}$ (mg/MJd) CO (g/MJd)	> 550 > 9.9	≤ 550 ≤ 9.9	≤ 252 ≤ 5.5	≤ 115 ≤ 3.7	≤32 ≤ 2.2	≤ 2 ≤ 1.4
Efficiency	Stove efficiency, using ISO's voluntary performance targets (%)	<10	≥ 10	≥ 20	≥ 30	≥ 40	≥ 50
Convenience	Fuel acquisition and preparation time (hours/week)	≥ 7		< 7	< 3	< 1.5	< 0.5
	Stove preparation time (minutes/meal)	≥ 10			<10	< 5	< 2
Safety	Severity of accidents caused by the stove over the past year	Serious			Minor	None	
Affordability	Fuel cost as a share of household expenditure (%)	≥ 10			< 10	< 5	
Availability	Ready availability of primary fuel when needed (% of the year)	≤ 80			> 80	> 90	100

Appendix II – Variables and their codes used in the logistic regression analysis

Question: Who makes decisions on how household money is spent (e.g., purchase of large household items etc.)?
Variable Label: Household Decision
Values: Respondent, other male family member, other female family member, joint decision, don't know
Value Labels: 1=Respondent, 2=other male family member, 3=other female family member, 4=joint decision, 99=Don't know

Question: In your household, please estimate your total average monthly income (shillings)?
Variable Label: Household Income
Values: ≤100 000, 101 000 – 500 000, 501 000 – 1 000 000, 1 001 000 – 1 500 000, 1 501 000 – 2 000 000, >2 000 000, Don't know
Value Labels: 1=≤100 000, 2=101 000 – 500 000, 3=501 000 – 1 000 000, 4=1 001 000 – 1 500 000, 5=1 501 000 – 2 000 000, 6=>2 000 000, 99= Don't know

***Question*:** In the past 12 months, how often was this fuel or energy source unavailable in the quantity you desired?
Variable Label: Unavailability of fuel
Values: More than once a month, less than 4 times a year, 4-12 times a year, always available
Value Labels: 1=More than once a month, 2=less than 4 times a year, 3=4-12 times a year, 4=always available

Question: How often does your household buy or collect, or otherwise obtain the main fuel?
Variable Label: Frequency of buying fuel
Values: Daily, every 2 or 3 days, weekly, always available, every 2 weeks, monthly, irregular
Value Labels: 1=Daily, 2=every 2 or 3 days, 3=weekly, 4=every 2 weeks, 5=monthly, 6=irregular

Question: What level of education have you completed?
Variable Label: Respondent's education
Values: Less than primary, primary school, secondary school, vocational training/bachelor's degree, Master's degree/PhD
Value Labels: 1=Less than primary, 2= primary school, 3= secondary school, 4= vocational training/bachelor's degree, 5= Master's degree/PhD

Question: Is your house connected to the electric grid (TANESCO)?
Variable Label: Household's connection to electricity
Values: Yes, No

Value Labels: 1=Yes, 0=No

Question: In which ward do you reside?
Variable Label: Ward
Values: Wazo, Mbezi, Bunju, Mbezi Juu, Kawe
Value Labels: (Ref. Bunju=0)

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