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Uplifting Low-Income Households along the Energy Ladder in East Africa: Analysis of the Pay-as-you-cook Model

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Abstract

In East Africa, household cooking energy use replicates the energy ladder theory. Many low-income families rely on traditional biomass because they cannot afford modern, clean cooking energy such as electricity and Liquefies Petroleum Gas (LPG). Introducing and disseminating the Pay-as-you-cook model offers an excellent opportunity for low-income households to use LPG. This study aims to appraise the influence of Pay-as-you-cook in assisting lower-income households in adopting LPG for cooking. Specifically, it examines the upfront costs, observes the running costs, and assesses the challenges facing Pay-as-you-cook service provision. The documentary review method was used to collect data, and MySQL databases were used to retrieve data. A deductive approach was applied, starting from general specific. In the first stage, general information on cooking energy was reviewed. This was followed by information on clean cooking initiatives, LPG adoption, and specific data on the Pay-as-you-cook model. At the later stage, the study focused only on the countries that have introduced Pay-as-you-cook. Results show that the Pay-as-you-cook model helps address LPG affordability challenges to low-income households. The model reduces upfront costs by allowing LPG users to lease the cylinder instead of paying the cylinder deposit. Results reveal that the model relieves the running cost by enabling gas recharge in smaller quantities instead of a complete cylinder refill or exchange.

Additionally, the study discovered that reliance on imported fuel and its non-renewability status are potential risks to Pay-as-you-cook sustainability. Furthermore, it faces impenetrable roads, unreliable mobile money services, and poor internet connectivity. The study concludes that despite these challenges, Pay-as-you-cook is a better option for inspiring low-income households to use LPG. Clear policies and strategies, collaboration between the public and private sectors, and awareness-creation campaigns are recommended to support widespread deployment across the region.

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1. Introduction

In the East African region, almost 200 million people lack access to clean cooking (International Bank for Reconstruction and Development/World Bank- IBRD/WB, 2022). Many of them use three-stone fires and other traditional stoves. Such technologies have very low efficiencies, ranging from 10% to 25% (IEA, 2022; Pachauri et al., 2021; Alex et al., 2018). Due to incomplete combustion, traditional wood stoves produce harmful smoke and gases (IEA, 2010). They cause Household Air Pollution (HAP), dramatically impacting the quality of life, health, education, gender equality, and income generation opportunities (Alem et al., 2016; Urmee & Gyamfi, 2014). Extensive biomass energy utilisation also causes deforestation, desertification, and air pollution, compelling serious environmental problems after charcoal production. The felling of trees leaves bare land, exposing the topsoil to erosion and loss of fertility (Idiata et al., 2013; Alem et al., 2016; Lambe et al., 2015). This also results in low agricultural productivity, insecurity, and hunger.

With time, wood-based fuels are becoming scarce relative to the rapidly growing population, urbanisation, and agricultural developments (Food and Agriculture Organization, 2019). The biomass energy market is distressed, with demand surpassing sustainable supply from forest resources (East African Community-EAC, 2018). Land use change swiftly transforms forest areas into settlements, farms, mining fields, and other non-forest uses. This has compelled governments and actors in the energy sector to explore alternative energy sources such as electricity, natural gas, biogas and Liquefied Petroleum Gas (LPG) for cooking needs (Bauner et al., 2012). From the available alternatives, LPG stands a better chance of replacing traditional biomass.

From the early 2000s, LPG indicated a sharp increase in replacing traditional biomass fuels (African Clean Cooking Energy Solution Initiative – ACCES, 2014; Kenya National Bureau of Statistics KNBS, 2015; Pye et al., 2020), especially in urban areas. In 2007, the Energy Access Strategy was launched to promote clean cooking in the region. The target was to attain up to 55% of clean cooking by 2015 (Legros et al., 2009), with LPG among the options. In 2011, two more interventions, 'Cookstove Value Chain' and 'Foster an Enabling Environment,' were launched to promote LPG usage specifically. Individual countries also formulated strategic policies and regulations to facilitate the LPG market through the participation of the private sector and non-government organisations (Global Alliance for Clean Cooking-GACC, 2017; Deutsche Gesellschaft für Internationale Zusammenarbeit - GIZ, 2014; Heltberg, 2005). At the micro-level,

informal funding initiatives, including safety-net schemes (Chamaa in Kenya and Upatu in Tanzania), are being used to assist group members in affording the initial cost of an LPG starter pack. Ndunguru (2020) reports that a group of ten neighbouring households in Tandale, Dar es Salaam (a low-income vicinity) agreed that a contribution of 5,000 TZS will be collected every week (for ten weeks) for each household to purchase a 6kg LPG cylinder.

Despite the various interventions and efforts to promote the utilisation of LPG in the region, adoption is limited. The fuel has continued to be used primarily by high-income households, bypassing low-income households. Affordability remains the critical barrier to adopting and using LPG (Alem et al., 2015; Price, 2017; IBRD & WB, 2020). Evidence from various studies indicates that low-income households are unable to afford LPG due to high initial investment costs, which involve cylinder deposit and purchasing cookstove and other accessories (Hollada *et al.*, 2017; Schlag and, Zuzarte, 2008; Puzzolo *et al.*, 2013; Masera *et al.*, 2000; Bruce *et al.*, 2017; United Kingdom-UK aid, 2010). This has made LPG considered fuel for wealthy people because most of those who use it are from higher-income groups (Schlag & Zuzarte, 2008). Even when the fuel is subsidised, the subsidies could have been more influential on low-income households. Instead, they are benefiting the commercial cooking sector and wealthy households. Adoption and consumption of LPG in low-income households have continued to be negligible.

Whilst at the macro-level, many countries have plans in place to scale up LPG supply to achieve Sustainable Energy for All on clean and modern energy for cooking (Van Leeuwen et al., 2017), there have been different efforts at the micro-level to help credit-constrained households (Ndunguru, 2020; Shukla et al., 2019; GACC, 2012). This study aims to appraise the influence of Pay-as-you-cook technology in assisting lower-income households with access to clean cooking fuel, precisely liquefied petroleum gas. The study also aims to challenge the energy ladder theory, which holds that (low-income) households will only switch to clean fuel when their income increase.

2. The National Energy Policies

Energy access and utilisation are among the issues of concern in the East Africa region. Considering the negative impact associated with biomass energy on peoples' well-being and the environment, development actors are determined to explore any possible solution to address energy

challenges. Almost all countries have national policies regarding shifting the cooking energy subsector from conventional biomass to electricity and gas. The countries' energy policy documents constitute clear statements that complement and support using clean cooking energy sources.

The Tanzania National Energy Policy (NEP, 2015) appeals for the adoption and use of alternative energy sources to minimise environmental degradation and improve the quality of life of the people (United Republic of Tanzania-URT, 2015). Section 3.16 of the National Energy Policy informs on switching to alternative energy sources besides biomass. LPG has been mentioned as one of the potential alternative energy sources for cooking.

In Kenya, the National Energy Policy (2014) seeks to enhance the utilisation of LPG, an environmentally friendly and economically viable solution. In section 6.3 subsection 2, the Policy admits that biomass fuels lead to increased indoor air pollution, which causes Upper Respiratory Tract Infections (URTI). Thus, there is a need to shift energy users up the energy ladder, and 60% of cooking needs in the country are met using biomass (Republic of Kenya-RK, 2014).

The main objective of the Uganda National Energy Policy is to meet the energy needs of the Ugandan population for social and economic development in an environmentally sustainable manner. Section 3.1.3 of the Energy Policy for Uganda (2002) highlights fuel substitution as an essential step to minimise the negative impact of some fuels on the environment, noting that substituting wood fuels with LPG will slow down deforestation (Republic of Uganda-RU, 2002). The Rwandan Energy Policy, among other things, seeks to promote alternative forms of energy for household use and ensure that new technologies meet the highest health safety and standards, particularly LPG (and kerosene) (Republic of Rwanda-RR, 2011). The table below presents the strengths and weaknesses of three East African countries in promoting households' clean cooking energy.

Table 1: National Energy Policies for three East African countries: Strengths and Weaknesses

Nation	Strengths	Weaknesses
Tanzania	Encourages a switch from traditional to alternative energy sources, including LPG	It does not outline any strategies to promote alternative energy sources like LPG.
		It needs to show how different income groups would be reached.
	Encourages the development of the petroleum and gas sub-sector, including developing structures for refining, processing, liquefaction, transport, storage, and distribution	Neither does it show the timeframe for the development of the petroleum sub-sector nor provide disaggregated information for different categories, e.g. LPG, natural gas, etc
Kenya	Acknowledges LPG as among modern, clean energy sources and alternative to traditional biomass energy	It does not outline policies and strategies to promote LPG as an alternative to traditional biomass.
	Has timeframe for short, medium- and long-term strategies	-
Uganda	It admits the high cost of alternative cooking energy, including LPG, which many Ugandans cannot afford.	It does not propose any strategy to reduce the cost.
	Discloses extensive substituting traditional biomass with LPG will reduce the rate of deforestation	It does not provide policy statements or strategies to promote the adoption of LPG.

Source: (URT, 2015; RK, 2014; RU, 2002)

Despite LPG standing the chance of replacing biomass, the role of the LPG marketers and technology developers in inspiring and promoting its utilisation by low-income households has yet to be acknowledged. Mostly, they are considered profit-oriented entities rather than stakeholders in energy sector development, who are critical in promoting access to clean cooking energy. This study aims to evaluate the applicability of Pay-as-you-cook in helping low-income households use clean cooking energy. Specifically, the study examined the upfront costs for LPG adoption through Pay-as-you-cook, the LPG running costs of LPG refill through Pay-as-you-cook, and the challenges facing the Pay-as-you-cook service.

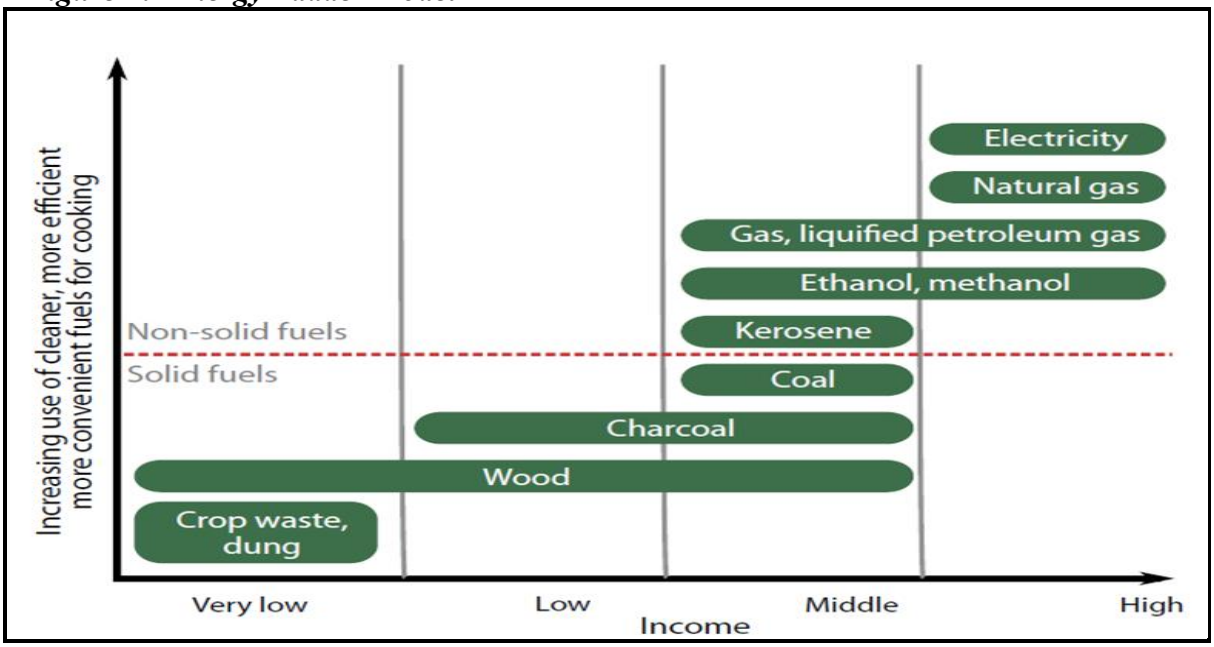
2. Theoretical Foundation

It is presumed that households switching from conventional, inefficient fuels and technologies to clean, efficient fuels are associated with increasing income. The energy ladder concept is a standard model that tries to express household energy transition in developing countries (Heltberg, 2005;

Choumert et al., 2019). The energy ladder model is constructed theoretically, which heavily emphasises income as the dominant variable in describing fuel choices and fueling.

In the hypothetical ladder, fuels are arranged according to their physical characteristics, which include neatness, comfortability during use, reduced cooking time, and efficiency (Hiemstra & Hovorka, 2008). Climbing up from one stair to another is regarded as abandoning relatively low-efficiency energy sources and adopting relatively high-efficiency ones (Heltberg, 2005).

Figure 1: Energy Ladder Model



Source: Paunio (2018)

LPG is among the fuels located at the top-right side of the energy ladder model, emphasising that for an individual or a household to adopt it, they should have adequate funds to afford the high upfront costs, plus a stable income flow to afford upkeep costs. The upfront cost has always been a significant barrier blocking low-income households from adopting LPG (Hollada et al., 2017; Bruce et al., 2017; Puzzolo et al., 2013; Schlag & Zuzarte, 2008; Masera et al., 2000). Low-income households need more purchasing power. Income is the primary determinant of energy usage; thus, they consume dirty fuels, further exacerbating their poverty because such fuels release toxic substances or smoke harmful to their health (Karakara & Dasman, 2019) and harm the environment.

To safeguard public health and promote sustainability, clean energy enthusiasts have kept inventing wheels to facilitate clean and efficient energy utilisation across all income segments, with attention to income-poor households.

4. Methodology

This study applies desk review to analyse interventions made in the previous four decades to reduce and promote clean cooking energy in East Africa. A review of literature travelled around the World Bank, World Health Organisation, International Energy Agency, Energy Sector Management Programme, Global Alliance for Clean Cookstoves and Clean Cooking Alliance databases. The review also included literature on energy ladder and energy stacking theories. Many journal articles and research reports were retrieved from Michael Wideness's Structured Query Language (MySQL) databases in which Elsevier, Springer and African Journals online-AJOL were reviewed. Also, National Energy Policies from three East African countries, Tanzania, Kenya and Uganda, were appraised. Search for related information covered reports regarding clean cooking energy, especially the production and dissemination of Improved Cookstoves (ICS) in East Africa and the transition to clean cooking energy, stakeholders' efforts to promote the adoption of LPG and the creation of an enabling environment for adoption and utilisation of LPG in low-income households. The review used a 'general-to-specific' approach. At the earlier stage, several journal articles, books, research reports, and conference proceedings were consulted to seek general information on household cooking energy situation at the global, regional and local levels. A review of the dissemination of improved cookstoves in East African countries and the adoption of liquefied petroleum gas followed this. At the later stage, an exhaustive literature survey was carried out to appraise the Pay-as-you-cook model in East Africa in which only four countries, Tanzania, Kenya, Uganda and Rwanda, remained. Therefore, the scope was narrowed down to four countries. Subsequently, a discussion was conducted to appraise the contribution of Pay-as-you-cook in uplifting low-income households along the energy ladder. The research seeks to answer the question, "How can low-income households climb the energy ladder without improving their income status?"

5. Results and Discussion

5.1 Cooking energy patterns

There is substantial evidence from different studies showing that the household cooking sector in East Africa largely conforms to the energy ladder model as traditional biomass such as crop residual, dung and firewood and is dominant in lower-income households, transitional fuels such as charcoal and kerosene are commonly used by low-to middle-income households and clean or sophisticated fuels such as LPG and electricity are used by wealthy households (Price, 2017; Ndunguru, 2020; Ang'u et al., 2023; Lambe et al., 2015). The review, however, reveals critics of the energy ladder theory, bringing in a new concept, the Energy staking theory, in which many households are said to use different cooking energy sources and technologies simultaneously. Energy stacking is expected to affect almost all income segments because of various socio-cultural factors such as taste preference, maximisation of energy security, and level of education of the head of household and family size (Masera et al., 2000; Hollada et al., 2017).

5.2 Pay-as-you-cook Development.

Before 2015, commercial food enterprises, mainly hotels and restaurants, were the primary consumers of LPG in East Africa (Mwakalosi, 2011). In Tanzania, for example, until 2012, the proportion of households using LPG countrywide was only 0.9% (URT, 2014). However, the small proportion of domestic LPG users was restricted to the urban areas. Many reasons contribute to the low intake of LPG in households, but the most common factor extensively cited in the literature is the initial cost. However, a lack of awareness of the opportunity costs of cooking with traditional biomass energy precludes people from associating cooking energy use with socio-economic and environmental penalties.

Pay-as-you-cook is a PAY-Go trademarked technology developed by KopaGas, a private utility company, to make LPG affordable to low-income Tanzanian households (Clean et al., 2020; Global System for Mobile A, 2018). In 2014, KopaGas co-founders Andron Mendes, a Tanzanian financial expert, and Sebastian Rodriguez-Sanchez, an expert in energy and advanced metering infrastructure, succeeded in inventing an advanced utility measuring device (smart metre) that enables customers to purchase as much or as little LPG as fits their needs and budgets (Shuppler et al., 2021). In 2015, the Global System for Mobile Communications Association-GSMA Mobile

for Development (M4D) Utilities programme awarded KopaGas a grant to design a low-cost metre for LPG cylinders to conduct a pilot PAYG cooking service in Tanzania. 2018 M4D Utilities Innovation further funded KopaGas to expand its service (Sarin, 2020). With backup from funders, KopaGas improved the intelligent metre, configuring it with mobile money transactions and deploying the service to about 1,300 clients in Dar es Salaam city. In early 2020, Circle Gas Limited, a UK Company based in Kenya, acquired KopaGas technology, anticipating spreading it to millions of low-income customers across East Africa through its subsidiary company M-Gas (Sarin, 2020).

5.3 Relevance of Pay-as-you-cook in Promoting LPG Adoption

The pay-as-you-cook model allows LPG users to purchase and automatically unlock cooking gas from the cylinder to the cooking stove. The system employs digital technology with the Internet of Things (IoT) to compute and monitor the gas flow from the cylinder to the cookstove. The model allows consumers to purchase gas at price points that are competitive with smaller units of charcoal (CCA, 2017).

A complete Pay-as-you-cook system comprises a gas cylinder, a smart metre (measuring device), a horse pipe, a regulator, and a gas cooker. In addition to that, a mobile phone can facilitate mobile money transactions. The smart metre is mounted on top of the gas cylinder and connected to the cookstove by the hose pipe to facilitate the process. The metre allows the detection and computation of gas consumption. Pay-as-you-cook operates in three East African countries, Tanzania, Kenya, and Rwanda (CCA, 2020), and Uganda is still in the pilot stage (Nakanwagi, 2020). Unfortunately, despite an extensive literature review, no data from Burundi and South Sudan is presented.

Currently, Pay-as-you-cook is offered in many cities and towns within East Africa. However, it has gained much popularity in Dar es Salaam and Nairobi, the major cities of Tanzania and Kenya, but the anticipation is to disseminate across the countries and to the rest of the Sub-Saharan African region to address LPG affordability challenges facing low-income households.

In Tanzania, KopaGas has been operational for almost 5 years. M-gas Solutions started to offer Pay-as-you-cook services in 2020. M-gas is a subsidiary company of Circle Gas. This United Kingdom-based company acquired the technology from KopaGas to scale up the adoption of LPG

to low-income families. In Kenya, M-gas and Pay Go Energy offer a pay-per-use service, which is like Pay-as-you-cook, and both aim to ease LPG utilisation in low-income households (CCA, 2017). In Uganda, Fenix International (CCA, 2020), a leading marketer and developer of the PAYG model, has started placing itself in the Pay-as-you-cook market. Like Tanzania and Kenya, the program allows customers to pay for LPG with mobile money through a GPS-enabled SmartGas Valve. Also in Rwanda, Bboxx, a next-generation utility company, launched a new sub-brand, "Bboxx Cook", whose goal is to provide clean cooking services across the country. In early 2019, Bboxx introduced a Pay-as-you-cook pilot project in the capital city, Kigali (Rowling, 2019), to enable Rwandan households and small businesses, such as restaurants, to get Liquefied Petroleum Gas (LPG) clean cooking systems without paying the total price up-front (Nyaga In et In al., 2021). Bboxx also operates in Kenya.

Figure 2: Smart meters fixed on gas cylinders

Kopagas -Tanzania

Mgas-Tanzania & Kenya

PayGo Energy- Kenya

Source: GSMA (2020).

5.3.1 Pay-as-you-cook upfront costs

The upfront cost for conventional LPG adoption has been a significant barrier to many low-income households. The financial expenditure required to pay upfront for predetermined gas units is unaffordable. Most LPG dealers across East Africa use the standard Branded Cylinder Recirculation Model (BCRM) (Puzzolo et al., 2019) for cylinder acquisition. BCRM requires customers to pay a refundable cash deposit for the cylinder, which is said to be less than the actual cost (Ndunguru, 2020). However, customers considering acquiring equipment as permanent

ownership need to understand this idea. LPG marketers must inform their clients about the cylinder deposit and the refund. Pay-as-you-cook provides a relief to upfront costs.

In Tanzania, KopaGas and M-gas customers would pay TZS 10,000 (USD 4.28) and TZS 20,000 (USD 8.56) to register. A new subscriber is supplied with a smart meter, a gas cylinder, and an unsold amount of gas. The gas remains the service provider's property, and the customers will have access to it when they have paid for it (GSMA, 2018). KopaGas and M-gas customers would pay an optional TZS 20,000 (USD 8.56) for a stove sold on commission and paid for two to three years. Payment is made in instalments whereby a fraction of the payment is directed to stove payment each time the customer purchases gas.

An average household would require a maximum of TZS 180,000 (USD 77.1) as an upfront cost for a start-up package. The package comprises a 15kg cylinder deposit, horse pipe, regulator, and a two-burner stove. A 6kg cylinder starter pack would cost around TZS 55,000 (USD 23.6), covering a cylinder deposit, pressure regulator, and ring top. However, the cost may vary depending on different factors, including geographical location, type of stove, cylinder brands, accessories brand, upstream fuel prices, and sometimes the year's season. In the year 2021, during the Ramadhan season, for example, Oryx Energies retailed 15kg LPG starter packs on sale, charging TZS 170,000 (USD 72.8).

In Kenya, nearly 70% of Pay-as-you-cook customers switch from the conventional LPG model (PayGo, 2022) to the flexibility of purchasing gas. These customers already possess some accessories, including the stove, hosepipe, and regulator. Therefore, they are only supplied with a smart meter. An extensive literature review could not determine the upfront cost for new subscribers.

Using the BCRM model, 13kg cylinders and 6kg cylinders are sold at 8,130 (USD 66.3) and KS 4240 (USD 34.6), respectively, without associated fittings. A two-burner stove costs KS 5,000 (USD 40.8), a regulator and horse pipe costs 2,400 (USD 19.6), while a cooktop and regulator for a 6kg cylinder costs KS 1,040 (USD 8.5). In Uganda, customers would pay UGX 310,000 (USD 82.9) and UGX 192,000 (USD 51.3) for 12.5kg and 6kg cylinders, respectively.

In Rwanda, Bboxx utility company allows Pay-as-you-cook customers to acquire LPG cooking stoves and accessories (regulator and hose) through credit. Customers make monthly payments of 9000 RWF (9.60 USD) for six months before they are granted full ownership. The smart metre and the cylinder continued to belong to Bboxx. Most customers paid a 13,500 RWF (14.40 USD) down payment, including 2 kg of LPG credit. The tariff varied based on monthly usage (1900 RWF/kg for the first 3 kg; 1750 RWF/kg for the next 3 kg; 1650 RWF/kg for the next 3 kg; and 1280 RWF/kg for any subsequent use), averaging at 1800 RWF/kg (1.90 USD) (Rwanda Utilities Regulatory Authority, 2019). Upfront costs under the standard for BCRM for 12kg and 6kg packs are 15,500 Rwf (USD 14.2) and 7,560 Rwf (USD 6.4) respectively (Nyaga, 2021). These prices do not include accessories.

5.3.2 Pay-as-you-con running costs

Running costs refer to recurrent, upkeep, or regular charges households incur to use specific energy types. These are regular payments made for continued appliance use, particularly fuel purchasing. Frequent increases in LPG prices in the market have always been far beyond the increase in household income, affecting sustained use even by those who have already adopted it.

Under the conventional approach, cylinder refill is done by exchanging an empty cylinder with a filled cylinder of the same quantity. Regardless of their economic status, consumers are required to pay for a full cylinder rather than otherwise. As of 2022, the average refiling prices in Tanzania were TZS 55,000 (USD 23.6) and TZS 24,000 (USD 10.3) for 15kg and 6kg cylinders, respectively. To a large extent, low-income households have been using smaller gas cylinders due to budget constraints. Ndunguru (2020) found that more enormous proportions of small cylinders were used in lower-income areas, while large cylinders were highly concentrated in higher-income vicinities in Dares Salaam City due to income differentials.

Average prices for cylinder replenishing in Kenya stand at KS 3,330 (USD 27.1) and KS 1,540 (USD 12.5) for 13kg and 6kg, respectively (Safaricom, un). In Uganda, a 12.5kg cylinder would require UGX 100,000 (USD 26.7), while 6kg would require UGX 49,000 (USD 13.1) (Orlando et al., 2022). These prices should be lowered for most low-income households to afford. Information on Pay-as-you-cook from Burundi is almost non-existent.

Budget constraints have been affecting the sustained use of LPG, even for those who have already adopted it. As a result, LPG users are dragged down the energy ladder, resuming traditional biomass fuel, mainly charcoal, since it can be obtained in smaller quantities within the households' budget limit. Larger units, e.g., sacks, are usually fragmented into smaller units affordable to people with varied income levels. In Dar es Salaam, for example, an average sack of charcoal costs about TZS 60,000 (USD 25.8) but can be obtained in tins (TZS. 2,000 ~ USD 0.8). In Nairobi, Kenya, a bag of charcoal costs KS 2,800 (USD 22.8), yet customers can purchase charcoal at KS 90 (USD 0.7) per 2 kg tin. In Kampala, Uganda, a sack of charcoal is sold at UGX 100,000 (USD 24.7), yet it can be acquired in a washbasin at UGX 6,000 (USD 1.6). This inflicts the assumption that charcoal is cheaper than LPG (Lokina & Mapunda, 2015), but in a real sense, it is not. Indeed, the cost of charcoal is very high, but it remains the only option that suits households' subsistence budgets.

With Pay-as-you-cook, low-income households have been allowed to spend their little energy budget to climb up to the top of the energy ladder, where they can afford LPG and enjoy the convenience of clean cooking. In Tanzania, Pay-as-you-cook subscribers would spend a minimum of TZS 1,000 to buy gas (Ndunguru, 2020). In an average household, this amount can last for a day if cooking ordinary Tanzanian meals, e.g., tea or porridge, vegetables, meat, ugali, and rice. This amount is within low-income households' means as they would use almost the same amount to purchase biomass fuel in smaller quantities (Energypedia Survey, 2018). In Kenya, customers can purchase gas from as low as KS 1 through M-pesa, with the cost of preparing three meals for an average household being less than KS 70 per day. On top of that, users avoid the stress of handling the cylinder refill since the smart meter sends an alert to M-Gas whenever the gas runs low. M-Gas will then deliver a refilled cylinder replacement to the customer, conveniently delivered to the comfort of their homes, at no cost (Safaricom, un).

It is also noted that Pay-as-you-cook activates households that abandon LPG usage under the conventional system. Some households stop using gas due to high, unaffordable cylinder refilling costs. A widow from Kinondoni Dar es Salaam was notified that the death of her husband left her with no choice but to go back to charcoal as she could not afford cylinder refilling changes. Ndunguru (2020) quotes the customer sharing her experience with Pay-as-you-cook:

> "…After my husband passed away, I could not afford to use gas anymore because it was too expensive for me. The cylinder remained empty for over two months, and the stove started rusting. After I joined KopaGas, things changed. Even with 5,000, I can buy gas. If I do not have any money, I can call my children and ask them to send me at least 5,000. It would not be easy for them to send me 50,000 at once for cylinder exchange, but 5,000 is manageable…"

Figure 3: Pay-as-you-cook set

Source*:* GSMA (2020)

Pay-as-you-cook also has proved to offer higher value for money and efficacy in terms of the number of meals that could be prepared, as quoted by Shupler et al. (2021) during their study in Kenya:

> "PayGo is very economical because when I was buying kerosene, I would pay 100 KSh, which would not be enough for my cooking. I could only boil water, use it for bathing, or cook supper without purchasing kerosene. I would not have any (fuel) left to cook breakfast in the morning. When I refill gas (using PAYG LPG) for 100 KSh, I use it for all those things, including breakfast the next day, without straining."

Provided a customer has a balance in their mobile money account, they can access the fuel at any time without necessarily visiting the agent. During the COVID-19 lockdown, Pay-as-you-cook significantly impacted access to clean cooking energy in Kenya. Many informal sector workers were financially affected by decreased household income, which led to reduced expenditure on goods and services. This also affected a good number of (conventional) LPG users. To manage the situation, some of them shifted to Pay-as-you-cook, where they could make small, regular payments (Shupler et al., 2021).

Another client from Kenya appreciated the Pay-as-you-cook (Bboxx LPG) model for addressing affordability issues and offering various benefits, saying:

> "Bboxx LPG saves me money; with USD 2.70 (300 KES) of credit, I can cook comfortably for a week, even *gathering*[1]. It is also faster, safer, and more efficient. I am thrilled that Bboxx has kept the promise that I will never run out of gas. The cylinder exchanges are seamless, and now I am not worried about how I will cook any time**.**

Pay-as-you-cook is an empirical critique of the energy ladder model, affirming the possibility of households ascending to the top despite their low-income status. It addresses affordability challenges by removing upfront and running costs incurred in the traditional LPG acquisition and utilisation approach. Pay-as-you-cook uses machine-to-machine application, where internet connection and mobile phones to facilitate utility access (Koponen et al., 2008; GSMA, 2018). Using the Mobile for Development Utilities Programme service, clients use mobile money to buy gas in small amounts, unlike the conventional way of replenishing cylinders (GSMA, 2018).

5.3.3 Challenges facing Pay-as-you-cook service.

One of the significant challenges of Pay-as-you-cook is the sustainability of service provision, as the model relies on imported LPG. Any interruption in the importation of LPG may have severe consequences on the availability of the energy source. Additionally, LPG is a fossil fuel, thus inflicting some carbon footprint, unlike renewable energy sources such as solar, wind, geothermal, tidal and renewable biomass (GIZ, 2014). Standard conventions of lifecycle accounting prove that

[1] *An East African dish of dried maise kernels and beans requires several hours of slow boiling to rehydrate and cook. In Tanzania, it is commonly known as kande/make*

emissions from LPG are not offset by sequestration, but emissions from wood are offset (World Liquefied Petroleum Gas Association -WLPGA, 2018). If that is the case, cooking with LPG may slow the transition to a low-carbon future. Its non-renewability state also threatens long-term solutions for household energy poverty if renewable and sustainable energy sources are not in place.

Pay-as-you-cook may face other challenges, such as poor internet connectivity and technical faults. Environmental barriers also prohibit the smooth delivery of the equipment, especially during wet seasons. In Dar es Salaam and Nairobi cities, for example, a significant number of Pay-as-you-cook consumers primarily reside in informal settlements, which are evidenced to have poor road networks and poor drainage systems (Ndunguru, 2020; Shupler, 2021). Occasionally, in Kinondoni, Moscow area of Dar es Salaam, manual labour is hired to supply the cylinder to the consumer through impenetrable roads or flooded zones instead of delivery vehicles (Ndunguru, 2020). Despite such challenges, Pay-as-you-cook remains an effective way of increasing access to clean cooking fuel for the majority. Evidence from different studies shows that low-income households spend a large portion of their budgets on cooking fuel (Modi et al., 2005; Ndunguru, 2020), yet they are exposed to Household Air Pollution (HAP), contributing to environmental degradation. This makes Pay-as-you-cook and LPG better than biomass.

6. Conclusions and Policy Recommendations

East Africa is said to be the continent's fastest-growing region in terms of population. Despite leading in population growth, the region holds fourth (out of five) in Gross Domestic Product (GDP). Rapid population growth increases the demand for cooking fuel and propels the expansion of agricultural land, urbanisation, and infrastructure development. It negatively impacts biomass availability and accessibility, affecting biomass energy users. Many would wish to switch to non-biomass energy, such as LPG.

East African countries may use a policy approach to disseminate Pay-as-you-cook and increase access to clean cooking fuel. Lessons can be learned from other countries in Latin America and Asia which have succeeded in promoting LPG. Market regulations, awareness campaigns, and the provision of loans and credits are among the policy interventions that have contributed to the adoption of LPG by 70% of the population in Latin America (Olade, 2014). Kero-Zero, a

nationwide policy, helped to transform millions of households from using kerosene to LPG in Indonesia (Thoday et al., 2018). Under the partnership of the public and private sector, Kero-Zero supplied millions of households with free starter packs that consisted of 3kg LPG cylinders, a gas stove, a horse, a regulator, and free fuel for the first refill. India introduced the Direct Benefit Transfer policy targeting poor households to assist in purchasing LPG (Mittal et al., 2017). This study also proposes pro-poor energy policies addressing energy poverty in low-income households. Pay-as-you-cook is one of the practical pro-poor policy approaches to address financial barriers to the adoption of LPG.

The study also recommends a clear policy statement on Public-Private-Partnership in the households' cooking sector to encourage, improve and promote technological innovations. A functional technology ecosystem is crucial for Pay-as-you-cook as the equipment needs the Internet of Things (IoT), including mobile money services and internet connection. By acknowledging the socio-economic dynamics between and among individuals, deliberate efforts should be made to maintain, improve, and widely disseminate clean cooking fuel by empowering the marginalised groups. It is commendable that the Kenya government, through the Ministry of Petroleum and Mining, has demonstrated commitment to promoting Pay-as-you-cook LPG as a clean energy access solution by releasing a tender for 80,000 LPG cylinder smart metres (O'Keefe & Marcigot, 2020).

The study further recommends the creation of enabling environments to encourage investments in domestic LPG production from the existing natural gas fields (Mnazibay and Songo in Tanzania) and crude oil fields (Kabaale, in Uganda) to ensure consistent supply and affordable prices within the region before the countries fully embark onto renewable energy sources like solar, wind, geothermal and renewable biomass. Further, it is worth viewing clean cooking from different development perspectives, such as health, education, gender equity, food security, environmental conservation, and climate change. Thus, cross-sectoral collaboration should be embraced. Pay-as-you-cook for household cooking is among the pathways to attaining Sustainable Development Goal 7 (SDG7), *ensuring access to affordable, reliable, sustainable, and modern energy*. It is also a catalyst to attaining SDG 3, ensuring good health and well-being; SDG 5, achieving gender equity and empowering all women and girls; and SDG 13, taking agent action to combat climate change and its impact.

7.0 Limitations of the study and areas for further studies

This study has limitations as it was designed as a desk review rather than field research. This method may cause uncertainties regarding the validity and reliability of the study. Field research would have given empirical evidence on how relevant Pay-as-you-cook is in assisting low-income households in switching to LPG.

This work serves as a foundation for further studies such as the spreading of Pay-as-you-cook in each country, households' willingness to switch to LPG with the help of Pay-as-you-cook and conducting a comparative analysis of the financial and opportunity costs between traditional LPG use and Pay-as-you-cook model.

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