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Experiences with the Mass Distribution of LPG Stoves in Rural Communities of Ghana

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Abstract

Household air pollution (HAP) is a leading cause of morbidity and mortality worldwide. To limit HAP exposure and environmental degradation from biomass fuel use, the Government of Ghana promotes liquefied petroleum gas (LPG) use in rural Ghana via the Rural LPG program (RLP). We assessed the experiences of the RLP in 2015, 2 years after its launch. A mixed methods approach was used involving Focus Group Discussions (19) and in-depth interviews (25). In addition, a survey questionnaire was administered to elicit socio-demographic characteristics, household cooking practices and stove use patterns of 200 randomly selected respondents. At about 9 months after LPG acquisition, < 5% of LPG beneficiaries used their stoves. Some of the reasons ascribed to the low usage of the LPG cookstoves were financial constraints, distance to LPG filling point and fear of burns. Community members appreciate the convenience of using LPG. Our results underscore a need for innovative funding mechanisms contextualized within an overall economic empowerment of rural folks to encourage sustained LPG use. It emphasizes the need for innovative accessibility interventions. This could include establishing new LPG filling stations in RLP beneficiary districts to overcome the barriers to sustained LPG use.

Keywords

Experiences; Mass distribution; LPG stoves; Rural LPG use; Ghana LPG promotion

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Conflict Of Interest The authors declare that they have no conflict of interest.

Ethical Approval Kintampo Health Research Centre Institutional and Columbia University Ethics Review Committees and the Ghana Health Service Ethics Review Board approved the study protocol and consent forms. We obtained informed consent from all individual participants included in the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Introduction

The World Health Organization (WHO) estimates that household air pollution (HAP) leads to about 4 million avoidable deaths per year and is one of the major global environmental risk factors for reduced life expectancy (WHO 2014). In addition, extensive use of biomass fuels leads to significant environmental impacts including deforestation (Geist and Lambin 2002) and social impacts such as gender inequities (Blackden and Wodon 2006). Approximately 3 billion people use biomass and other polluting fuels for cooking (WHO 2016) and are thus exposed to high levels of HAP (WHO 2014). HAP exposure is a risk factor for pneumonia, cardiovascular disease and other adverse health outcomes (Bruce et al. 2000; Smith 2000; Rehfuess et al. 2009; Lim et al. 2012). In Ghana, majority of the population use biomass fuel (Amegah et al. 2012; Van Vliet et al. 2013) which accounts for about 14 458 deaths and for about 8 percent of the national burden of disease (GACC 2017) borne by women and children (WHO 2016, 2018; Nandasena et al. 2013; GACC 2017).

To address the risk of biomass fuels, large-scale deployment and sustained use of clean household energy is needed. Global goals such as Sustainable Development Goal 7, which seeks to make modern energy accessible, affordable, reliable and sustainable for all (UnitedNations 2017), and strategies such as Sustainable Energy for All (SE4A) articulate this imperative. Clean cooking (stoves that have low emissions of pollutants) transitions aim to improve health and promote a clean, sustainable environment. To achieve this target, a mixture of cleaner cookstoves needs to be adopted over a transition period as households overcome current affordability and accessibility challenges. International bodies such as the Global Alliance for Clean Cookstoves and the International Organization for Standardization (Still et al. 2015) have set targets based on four cookstove indicators with each rated on a 5 tier scale for efficiency, safety, durability, particulate matter and carbon monoxide emissions (Agenda 2017).

The role of government policy in fostering this transition is under-examined in the literature, especially given that governments are positioned to provide essential institutional support to clean cooking transitions. As a matter of logic, however, such transitions must overcome challenges related to affordability and local availability of clean household energy services (Banerjee et al. 2016).

The Government of Ghana has since 1989 promoted LPG as an alternative to wood fuels, primarily to reduce deforestation. The initial LPG promotion effort targeted the urban dwellers. In 2013, the rural liquefied petroleum gas (LPG) program (RLP) was launched with the aim of promoting LPG use in rural Ghana. We assessed the experiences of the RLP in 2015, 2 years after its launch. RLP is currently underway with around 75,000 individuals in about 30 rural districts receiving stoves. Under the RLP, the then Ministry of Petroleum (MoPET, now Ministry of Energy) distributes LPG cookstoves free to rural households in selected districts. However, households are responsible for purchasing the initial and subsequent refill of LPG cylinders. The Ghana experience with LPG promotion will help other countries judge both the potential role of LPG in the clean cooking transition, facilitators and barriers for sustained use.

Method

Study Design and Study Area

We conducted a longitudinal study, tracking RLP beneficiaries in 2015, using both quantitative and qualitative methods. The study was conducted in the Nkoranza North District of Ghana, which covers a land area of 1374 sq km. The district has about 65,000 people living in 14,000 households. Nearly all residents rely primarily on biomass fuels: wood (80.8%) and charcoal (10.3%) (GSS 2014). About 82% of the adult population are farmers. The RLP delivered LPG cookstoves to all ninety-nine (99) communities in the district. For our evaluation, we selected five communities based on the geographical location (north, south, east and west), the distance (5 km, 15 km, 20, over 25 km) to the district capital and the nearest filling station, and the number of beneficiaries in each community. A minimum of 40 individual beneficiaries were randomly selected from a list of 685 beneficiaries in the five communities.

Data Collection

We conducted 19 Focus Group Discussions (FGDs) and 25 in-depth interviews (IDIs). Of the 19 FGDs, 14 (10 beneficiary and 4 non-beneficiary of LPG) were among women who were primary cooks and five were among males who were mainly household heads from beneficiary households. About 6–8 participants were part of each FGD which lasted about 45 min. The 25 IDIs were conducted among representatives from Ministry of Petroleum (MoPET), Ghana Cylinder Manufacturing Company (GCMC), Ministry of Health (MOH), National Petroleum Authority (NPA), national LPG marketer, withdrawn beneficiaries, community focal persons, district assembly, community LPG operators, RLP project managers and coordinators as shown in supplementary Table 1a. Each IDI lasted about 30 min. IDIs and FGDs assessed themes such as perceptions of RLP, barriers to LPG use, preference of cooking fuels, gender influences in choices of household fuels, time-saving in using LPG and safety of LPG use. We conducted IDIs and FGDs among adult women and men in the purposively selected communities. A social scientist moderated all the interviews using a semi-structured interview guide. Interview sessions were brought to a close when the moderator had exhausted all questions on the interview guide and other emerging issues.

A paper-based questionnaire was used to record information of 200 randomly selected LPG beneficiaries in the five study communities. Self-reported LPG stove use was assessed based on responses to the question “which stove did you use to cook your main meal yesterday?” We administered the questionnaire on a weekly basis over 9 months of follow-up. The questionnaire addressed socio-demographic, household characteristics and cooking practices.

LPG stove use was monitored using Maxim iButton Stove Use Monitors (SUMs) model 1912G (Maxim Integrated, San Jose, CA, USA), hereafter referred to as iSUMS. We placed an iSUM on the outer back surface of each LPG cook stove. We attached the iSUMS with a metal bracket, and used a small piece of heatproof silicon to insulate the sensor so that it would not exceed its temperature threshold. Two hundred iSUMS were mounted on the LPG stoves of the beneficiaries who were selected for the survey. We mounted temperature

sensors in some centrally located households in the community to record ambient temperatures. This process is validated as described by Pillarisetti et al. (2014).

Sample Size Calculation

The sample size for the quantitative survey was based on linear regression to assess household-level predictors of LPG stove use. With a sample of 200, the study was powered to determine predictors of LPG stove use for an effect size of 0.07 (Cohen's F2), with alpha = 0.05 and power of 0.85. This effect size is consistent with those found in India (Pillarisetti et al. 2014) The sample size of 200 allowed us to detect a 20% reduction in CO exposure before and after LPG distributions at an alpha = 0.05 and power of 0.85.

Data Analysis

All completed questionnaires were checked for completeness and consistency by study coordinators. The completed forms were sent to the Kintampo Health Research Centre (KHRC) computer laboratory for double entry into a password-protected database (Microsoft FoxPro version 9.0). Clean data were analyzed using Stata version 14.0 (Stata Corp, College Station TX) and R version 3.4.1.

Sample proportions and means were used to describe categorical and numerical data, respectively. A generalized estimating equation model was used to determine the predictors of sustained use of LPG cookstoves. Odds ratio and the Pearson's Chi-square tests were used to test for the strength of association between the explanatory variables (socio-demographic variables) and outcome variables (LPG cookstove use). The explanatory variables were age, sex, level of education, religion, ethnicity, marital status, household size and main source of income. The main outcome variable of interest was LPG cookstove use. (Sustained users were defined as respondents who used the LPG stove for 60% of cooking events.) The 60% threshold was determined based on the observed distribution of usage to ensure a sufficient number of respondents in the LPG user group. The cutoff was used based on pilot data from a separate study in which participants received free gas (Jack et al. 2015). However, under the RLP where participants must pay for gas, LPG usage was expected to be much lower; we reduced the threshold to 60% in order to ensure that a sufficient number of respondents were classified as LPG users. The quantitative results have been presented as percentages and ratios.

Stove use monitors consisted of iButton temperature sensors that sampled at 10-min intervals. Raw temperature time series was ultimately transformed into a "minutes of cooking" variable using the Anomaly Detection R package version 3.3 (Bradley Boehmke 2017), which was originally developed to detect anomalies in internet traffic. When applied to temperature data, the package detects events that deviate from the ambient diurnal temperature pattern. We only considered positive slope anomalies as cooking time, and anomalies within 60 min of each other were defined as the same cooking event. The resulting dataset provides an objective measure of LPG cookstove use.

Qualitative data were audio-recorded and transcribed verbatim. The data were put in matrices under themes that emerged from the discussions. Inductive methods were also used to look for facilitators and challenges to sustained LPG use. QSR Nvivo qualitative analysis

software was used for data management. The qualitative data have been presented as quotes to support the quantitative results, where applicable.

Results

The study results are presented in three main categories; overview of RLP structure, results of quantitative analysis, perceptions of RLP structure and LPG use as summarized in Supplementary Table 1b.

Overview of RLP Structure per Qualitative Interviews

In 2013, the Ministry of Petroleum (MoPET) revived LPG promotion through the RLP, building on prior efforts in the early 1990s. The RLP contributes to the national goal of increasing LPG use to about 50% by the year 2020. RLP funding originates from the national government through tariffs on LPG purchases. About Ghp10/kg (USD 0.02) is levied on LPG which increases the price by 4% (ACEP 2016). The program is a collaboration with partners including the Global LPG Alliance and the Global Alliance for Clean Cookstoves.

Under the RLP, each beneficiary receives an empty LPG cylinder and a single-burner stove free of charge. However, the individual beneficiaries are required to pay for the LPG, including both the initial fill and also all subsequent refills. The selection of beneficiary districts is based on high level of poverty as determined by the Ghana Living and Livelihood Standards (GSS 2014), while the selection of beneficiaries is done by the district Assembly in consultation with community focal persons. MoPET identifies high poverty districts as a priority for RLP implementation. In addition, the RLP identifies a potential LPG Marketing Company (LPGMC) to provide LPG to communities in participating districts. RLP discusses the distribution process with the district assembly of traditional and political leadership (Fig. 1). The discussions comprise inclusion criteria of individuals and the district for RLP, LPG logistical supply and storage and planning of RLP launch in the district. MoPET staff sensitized community members on safety, hazards of using biomass fuels and benefits of using LPG. Due to limited supply of LPG stoves, only 2000 out of 14,000 households in the Nkoranza district were selected for LPG distribution. Individuals were selected based on current biomass fuel users, willingness to pay for the initial and subsequent refills and employment status. The program favored civil servants (teachers, nurses, physician assistants) who were earmarked to serve as models for other community members.

Results of Quantitative Analysis

Supplementary Table 2 presents data on the survey respondents. The mean age of the 200 survey respondents was 39 (standard deviation 12.5). Majority (51.5%) had middle/JSS/JHS education. Over ninety percent (91.5%) of the respondents were agricultural farmers. Interestingly, none of the respondents lived on remittances as their main source of income. Over sixty percent (61%) of the respondents had household sizes from 5 to 9 household members. Most of the respondents were married.

The study assessed factors that influenced the use, adoption, sustained and exclusive use of LPG among respondents. Sustained users were defined as respondents who self-reported to

have used LPG stove 60% of the time of cooking. Supplementary Table 3 presents the findings of the predictors of LPG stove use.

Using the Generalized Estimating Equation model, age, educational status, ethnicity and household size predict LPG stove use, while marital status and woman occupational status do not predict LPG use. The odds of a woman between the age-group of 31–42 years, 43–52 years and above 53 years using LPG clean stove is about 31% lower, 9% higher and 18% lower, respectively, compared to women within the age-group of 18–30 years when educational level, ethnicity, household size and the weekly visits are held constant. The odds of a woman within 18–30 years having no educational background from Akan ethnic group with a unit increase in household size and weekly visit using LPG clean stove is about 88% lower.

Perceptions of RLP Structure and Stove Use

Participants consider RLP stove distribution an important initiative and highly commendable.

> "…we believe the distribution of the LPG cylinders is a very good initiative and must be continued…"
>
> (IDI, President Aide, National LPG Operators Association).

However, the scarcity of stoves led some non-beneficiaries to conclude that the selection process was unfair.

> "The cookstoves were distributed based on political affiliation……When I asked about it, I was told that, even if I was an NDC member I do not openly show my party affiliation…so that is why I did not get one"
>
> (FGD, LPG non-beneficiary).

Use of LPG: Patterns, Barriers and Enablers

LPG use gradually decreased from 40% in the first week to less than 5% after 9 months, and over 80% of respondents used their traditional three-stone fires for cooking their main meals the previous day based on self-report (Fig. 2). The SUMs data also show a significant drop in average minutes of LPG stove use over time (Fig. 3).

Over half (58%) of all respondents never refilled their LPG cylinder after the initial refill, which was a requirement to receive the stove, over the 9 months of follow-up (Fig. 4).

Barriers to LPG Use

Financial Constraints—The main barrier to the use of the LPG cookstove was the cost of LPG refills. Most of the beneficiaries are farmers who depend on seasonal crop yields and lack regular source of income to buy LPG.

> "The main economic activity here is farming so we always experience financial constraints. If you invest your money into tomato farming and after three months, you do not get the money back and you run out of LPG that becomes a problem…"

(FGD, male beneficiary)

Household and Pot Sizes—Respondents reported that, the one burner stove was not only inadequate for cooking, but they was unable to keep their large pots steady during preparation of some local meals that require frequent stirring with considerable effort.

Availability of LPG—Respondents had to travel up an average of 24 km to Nkoranza (the nearest district capital) to refill their cylinders. This increases the refill cost on respondents who have to pay for the actual refill, transportation costs and because they have to spend considerable time in transit.

> "What is preventing us from using the LPG always is that we do not have gas filling station here…unlike town folks who can walk for refilling, rural folks have to pay for transportation…"

(FGD, female beneficiary)

Safety Concerns—Fear of explosions and burns were mentioned by both males and females as barriers to the use of LPG.

> "One bad thing about the LPG is that it is deadly; because I have seen the Cylinder blast to kill someone in Accra. So I am really scared of it; I would prefer to go and carry firewood from the farm" (FGD, male beneficiary) "The reason why I use both is that if you leave it in the care of a child, he/she will use it roughly and it can burn your house"

(FGD, female beneficiary)

> "The reason why I use both is that if you leave it in the care of a child, he/she will use it roughly and it can burn your house"

(FGD, female beneficiary)

Enablers of LPG Stove Use

Though respondents reported barriers to LPG use, some respondents recognized some benefits.

LPG Use Facilitates Multi-Tasking—The use of LPG allows some people to multi-task with other household activities.

> "For the LPG cookstove, when you want to go to, you can put the food on the fire, take your bath and the food will be done by the time you are done"

(FGD, female beneficiary)

LPG Use Promotes Male Involvement in Cooking—Respondents reported that with LPG stoves, males were more willing to participate in cooking activities.

> "Previously, men felt shy setting fire in the three-stone fires in the open where others could see them, but they feel more comfortable using LPG"

(FGD, male beneficiary)

LPG Use Speeds Cooking—Respondents commonly mentioned that the LPG cookstove is fast and convenient.

> "… You only need matches to light it and start cooking. You do not have to gather firewood or look for kerosene… so it makes everything fast unlike the firewood that delays time"
>
> (FGD, male beneficiary).

Some respondents also emphasized the difficulty in lighting firewood, especially during the rainy season.

> "It (LPG) is better than the firewood because it is fast; using the firewood is difficult especially when it rains"
>
> (FGD, male beneficiary).

LPG Use Reduces Drudgery for Wood Fuel—Generally, participants mentioned that, compared to searching for firewood, LPG is less tedious.

> … if you go to search for firewood you may get home late because you have to gather it from different points
>
> (FGD, female beneficiary).

Implication of Biomass Fuel on Health

Some respondents motioned that smoke from biomass fuel could cause cough, itchy eyes and discomfort.

> The smoke coming from the firewood can cause the eye to itch and pain.
>
> (FGD with LPG non-beneficiaries).

> "Someone may be coughing severely and the Doctor could say smoke is part of the cause…"
>
> (FGD with LPG beneficiaries).

LPG Use Promotes Clean Cooking—Respondents reiterated clean cooking as a benefit of LPG cookstoves. They mentioned that the cooking utensils do not get dark as in the case of the three-stone fires.

> "… when you cook on a three-stone fire, the cooking utensils will get dark and makes utensils washing difficult"
>
> (FGD with men of LPG beneficiaries' households).

LPG Use Changes the Taste of Food—Respondents indicated that unlike three-stone fire which causes the food to taste smoky, cooking with LPG stove makes food taste better and respondents preferred the latter.

Stove Stacking—Some respondents indicated that they used multiple stoves depending on what they were cooking.

> … for now I mainly cook with the three stone fires but cook quick fix foods like boiling water for tea [with LPG]…
>
> (IDI LPG beneficiary, man)

Some respondents prefer coal-pots [which uses charcoal], especially during the rainy season.

Another reason for using coal-pot is that, if you do not have a kitchen and it rains, you can easily pick the coal-pot to the veranda and cook" (FGD with LPG non-beneficiaries).

Discussion

We evaluated the Ghana Rural liquefied petroleum gas (LPG) program, which aims at promoting the use of LPG in rural areas of Ghana. Though Ghanaian governments since 1989 (SEAAP 2012; ENERGIA 2014) have prioritized the promotion of LPG on the national development agenda, previous plans have not delivered effective results. Rural areas that most need cleaner energy services are still underserved.

Both qualitative and quantitative assessments indicate that most participants used multiple stoves (three-stone fire, coal-pots [uses charcoal], LPG) depending on the cooking needs within the day, and few participants regularly refilled LPG stoves. Quick fix meals are usually prepared with the LPG stoves as corroborated by Bensch and Peters (2013). In addition, the sizes of the pots also influence the type of stove to be used for cooking. This finding is similar with other studies that found that households that had larger pots than the stoves they received were likely to stack stoves (Beltramo and Levine 2013; Piedrahita et al. 2016). Participants are aware of the health hazards of using biomass fuel for cooking. This finding is comparable to several other studies that documents not only adverse health effects, but also poses a heavy burden in terms of collection time, monetary expenses and deforestation (Adrianzén 2013; Bensch and Peters 2013; Bensch et al. 2015).

Our qualitative assessment suggests that financial constraints are the primary cause of the low use of LPG cookstoves among RLP beneficiaries. Over half of all respondents never refilled their LPG cylinders after the initial refill over 9 months of follow-up, largely because of financial constraints. This finding is consistent with a 10-country analysis of national household expenditure surveys where household income and fuel prices were the two main determinants of a household's decision to use LPG and how much to consume (Kojima 2011). Our results corroborate the finding that the price of the LPG fuel itself (as opposed to the initial costs of stove, regulator and gas bottle) influences the inconsistent use of LPG among the poor and rural households (Viswanathan and Kumar 2005; Pandey and Morris 2006; Bates 2009). Respondents' report that the low cost and ready availability of biomass fuels negatively influence LPG uptake. Transportation cost to refill LPG cylinders was also a barrier to sustained use of LPG. Our finding highlights the need for the RLP to encourage LPG distributors to set up refilling stations closer, or to considering innovative delivery mechanisms.

The primary weakness of the Nkoranza evaluation is its limited geographic scope. Our data should not be interpreted as nationally representative. LPG use patterns among RLP beneficiaries may be considerably different in other regions of Ghana. Based on our

Nkoranza results, we expect that geographic proximity to LPG distributors and level and seasonality of income are likely to be major drivers of spatial variation in program success. Future evaluations should strive to characterize performance across a broader range of locations.

To address the financial barrier to the use of LPG, broader stakeholder discussions need to lay the groundwork for financing mechanisms to improve LPG affordability for poor and rural people (Rehfuess et al. 2014). This has been successful in expanding LPG accessibility, availability and reducing its price in some countries (IEA 2011). Government actions, such as establishing a regulatory framework for the LPG sector and establishing subsidy and micro-finance programs, will be vital to further expansion of LPG use in Ghana. The potential to widen the reach of LPG beyond middle- and upper-income cooks depends crucially on the policies adopted (Parikh 2011; ENERGIA 2014; Rehfuess et al. 2014). Ghana can learn from the Indonesian and other experiences showing the importance of government policy and private sector approaches. Financial inclusion and access to bank accounts and LPG connections in women's names will be key if such schemes aim to empower women. Where LPG is less expensive than competing fuels such as charcoal, credit to purchase appliances can be a huge barrier. Innovative programmes such as Switch SA in Haiti are tackling the low-income market by offering credit for stoves and low-cost refills (ENERGIA 2014).

Fuel subsidies can be important mechanism for overcoming the financial barrier to the use of LPG (Lucon et al. 2004; Viswanathan and Kumar 2005). Fuel subsidies were among the main drivers for widespread uptake of LPG in Brazil, and the withdrawal of these subsidies led poorer families to revert to polluting fuel (Lucon et al. 2004). However, general fuel subsidies are associated with inappropriate use. For example, subsidized LPG may be used for fueling vehicles, rather than for cooking purposes (Lucon et al. 2004; Pandey and Morris 2006). Moreover, a universal price subsidy for LPG could generally be regressive, and highly so in low- and lower-middle-income countries (Edjekumhene et al. 2007, Kojima 2011; Polsky and Ly 2012; Jaeger and Michaelowa 2014). These concerns point to the potential role of a means-tested LPG subsidy as a mechanism for overcoming the financial barrier to the use of LPG.

The fear of accidents and inability to use the LPG were also reported as barriers. This is in line with findings that negative perceptions and fear of LPG explosions ([LPG leakages from poor quality equipment (Budya and Arofat 2011) or lack of knowledge on the safe use of LPG (Bates 2009) mitigate LPG adoption and sustained use (Terrado 2005, Bates 2009; Budya and Arofat 2011). Continuous cooking demonstrations at the community level could reduce fears associated with LPG use. In addition, continuous education campaigns on proper use of LPG could allay the fears of the public on the use of improved cook stoves. This calls for additional research into safety of cooking fuels/technology (including burn risks) to provide data to help allay public concerns. The implementation of the Cylinder Recirculation Model, which is currently under development by the Government of Ghana, will enhance the safety of LPG. The model involves filling LPG cylinders at des ignated refilling plants before onward distribution to customers at designated exchange points (EnergyCommissionofGhana 2012).

Notwithstanding the constraints to the use of LPG, primary cooks will often choose LPG when they have the opportunity because LPG supports multi-tasking, fast cooking and clean cooking. In Guatemala, female biomass users who were piloting LPG valued the fact that they did not have to blow air or constantly turn cooking fire (Thompson 2015). In Indonesia, "clean" was even ranked above "fast" and "cost-effective" in one household survey of LPG adopters (Andadari et al. 2014). Time "saved" as a result of switching to modern fuels such as LPG is often used for other activities (Kaygusuz 2011; UNDP 2011).

Interestingly, males who hitherto were shy to participate in cooking find LPG acceptable. This is important in the definition of gender roles. Access to modern energy services can facilitate shifts in gender roles and responsibilities in the domestic sphere. In India, men and children started helping with cooking duties after the introduction of LPG (Annecke 2005). In Zanzibar, men appear to take on the tasks which do not infringe on their ideas of masculinity as well as those that serve their needs in a timely manner (Annecke 2005; Winther 2008).

Study Limitation

This study is limited by the fact that we did not collect any data on their prior use of LPG stoves before the distribution of LPG stoves in the community. We understand that, their prior use could influence safety concerns and sustained use of LPG. This notwithstanding, our study provides important highlights on the experiences with mass distribution of LPG stoves in rural communities of Ghana.

Conclusion

We observed that LPG stove use all but ceases after about 9 months of LPG stove acquisition through the RLP. Not unsurprisingly, the cost of LPG and accessibility of LPG were barriers to consistent use. However, rural communities perceived RLP to be an important program and largely acceptable. This underscores the need for innovative financial models and distribution strategies to overcome the barriers to LPG sustained use. If the RLP is to have its intended impact on household energy use in Ghana, it will need to identify and execute strategies to make LPG use convenient and affordable. Additionally, instead of focusing on a single "silver bullet" technology, the RLP may also consider developing a portfolio or stack of options (fuels, stoves and practices) that together can fully displace traditional open fires and enable exclusive, sustained use of clean stoves and fuels.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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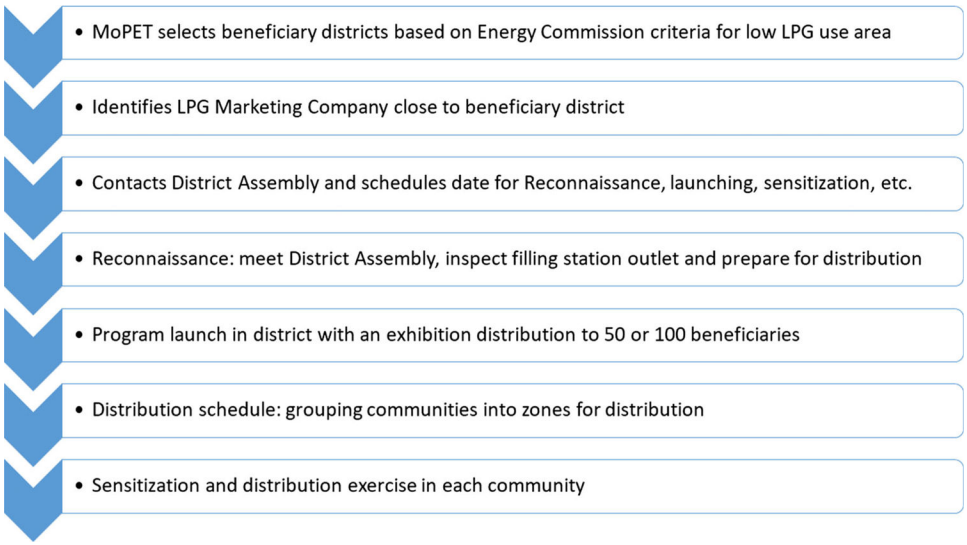

Fig. 1.
Illustration of selection process for LPG distribution.

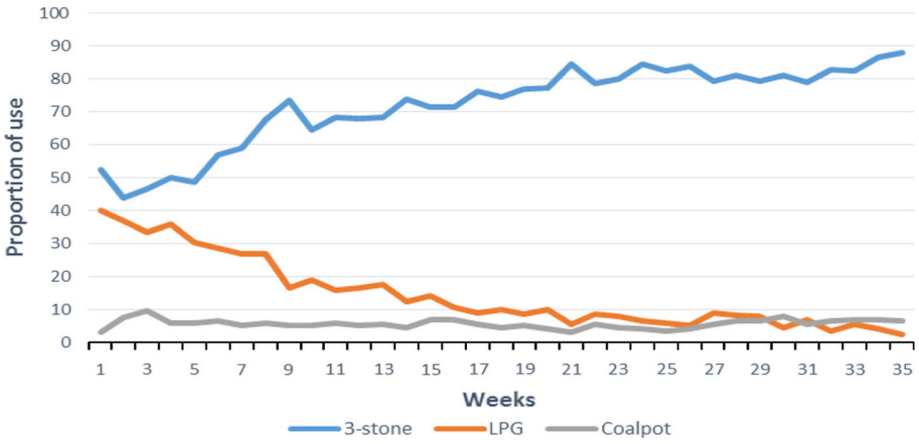

Fig. 2.
Proportion of self-reported fuel use among 200 LPG beneficiaries over a 9-month period.

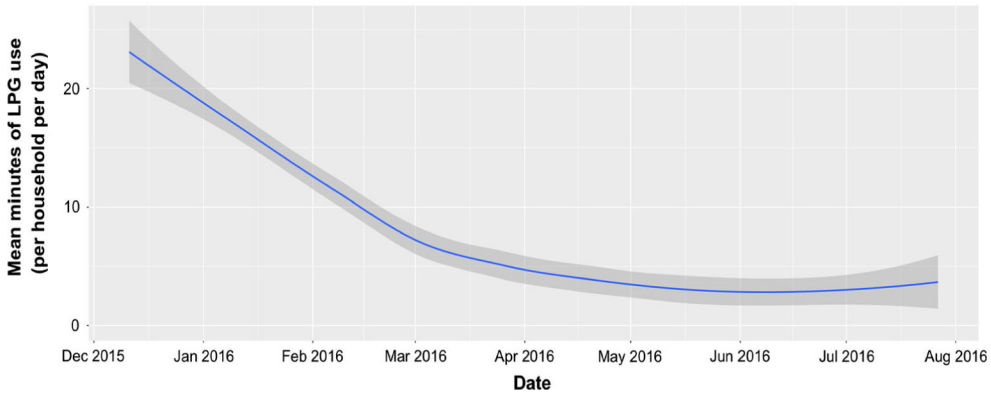

Fig. 3.
LPG use assessed by iSUMs at 95% confidence interval.

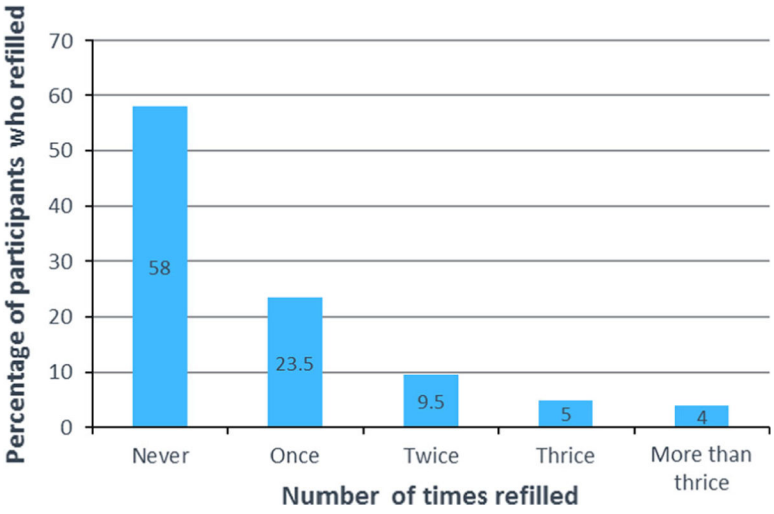

Fig. 4.

Percentage of participants who refilled their LPG cylinders post the initial required refill.