

## Capitalizing on digital financial services for clean cooking transitions

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### Abstract

Over 2 billion people worldwide still rely primarily on polluting solid fuels for cooking. These households often have intermittent incomes and purchase firewood or charcoal day-to-day. In many low and middle income countries, liquefied petroleum gas (LPG) is the main feasible clean fuel, but requires larger lump sum payments to refill or exchange cylinders. Even when LPG's total cost matches biomass fuels, liquidity constraints can prevent households from switching. GasPay addresses this barrier—a phone-based digital financial service platform connecting users with LPG suppliers while providing a designated savings vehicle for refills. We describe the platform's design, the motivation behind it, and estimate its potential impact on charcoal demand, LPG use, and carbon emissions. Our results reveal how digital financial services can unlock clean energy access and advance multiple development goals simultaneously.

### Introduction

2.1 billion individuals globally live in households where primarily women cook with smoky, solid fuels, resulting in devastating health and climate impacts (1). The unaffordability of clean cooking fuels such as liquified petroleum gas (LPG) remains the largest barrier to their adoption and sustained and exclusive use in low and middle income countries (LMICs) (1). Financial tools could alleviate clean fuel unaffordability, yet many individuals in LMICs—particularly women—lack access to such services.

Digital financial services (DFS), specifically mobile money platforms, have emerged to provide financial tools, allowing users to store and transfer monetary value with low-cost mobile phones. Associated platforms with smart phone applications or short codes allow users to send money to friends, families, businesses, and even pay water or electricity bills with their mobile accounts. Mobile money has been shown to increase per capita consumption through increased savings, particularly for women (2).

However, DFS has never been applied to cooking fuel purchases. Against this backdrop, a partnership including private financial service providers, software developers, government and academic researchers developed GasPay, a phone-based DFS platform in Ghana that enables users to securely and conveniently save toward LPG refills, earn incentives for saving, purchase LPG, access microloans, or schedule LPG deliveries.

This Report describes the financial challenge of purchasing clean cooking fuel, our theory of change based on a national survey as well as focus groups and interviews, and the ultimate platform we designed, GasPay. Finally, we estimate the potential near term scale of this platform to transition purchasers of polluting fuels to LPG. We approximate the potential customer base for GasPay and LPG demand in the near term if all Ghanaian charcoal purchasers were to transition to LPG through this application. Finally, we discuss how our results might advance other development objectives.

## **Results**

### **The problem**

Burning firewood, charcoal, or kerosene in unimproved stoves or open flames leads to household air pollution and greenhouse gas emissions. Each year, polluting cooking fuel use contributes to 2.8 million premature deaths from HAP (3) and 1.1 gigatonnes of carbon dioxide equivalent emissions (4). Beyond these health and climate impacts, main cooks, typically women, must spend hours a week collecting or purchasing fuel and then cooking for longer time periods than required by more efficient modern fuels (5). Clean fuels, the most readily available of which in many LMICs is LPG, reduce the risk of disease when used exclusively (6), carbon emissions (4), and the opportunity costs of time, particularly for women (7). However, the unaffordability of clean fuels prevents users from adopting and continuing to use these fuels, and thus the realization of these health, climate, and well-being benefits.

Clean fuels pose a financial challenge to users in terms of aggregate expenditure as well as liquidity (cash on hand). Users must afford both the total fuel cost and the lump sum needed to purchase available quantities.

Evaluating expenditure on cooking fuel through a national survey of Ghana conducted in early 2021, we find that, in the previous month, exclusive charcoal and LPG users spent 2.3 (sd:0.14) and 3.6 (sd: 0.35) 2025 USD per month per standard adult equivalent, respectively on cooking fuel. Individuals who used primarily charcoal and secondarily LPG (and vice versa) spent 3.4 (sd: 0.43) USD and 3.2 (sd: 0.31) per standard adult equivalent last month on cooking fuel. While expenditure alone does not reflect consumption, these estimates suggest that individuals who have adopted LPG, but continue to use charcoal, face comparable aggregate cooking energy costs to exclusive LPG users.

Even when expenditures are similar, liquidity constraints remain a barrier to clean fuel adoption. Polluting fuel users often have intermittent incomes and are accustomed to purchasing small quantities of firewood or charcoal on a day-to-day basis (8). Clean fuels like LPG often require a larger lump sum for

both the stove and the fuel. Unlike firewood and charcoal which can be portioned off into various size bundles or tins, buckets, or bags, LPG has to be purchased in bulk in specific cylinder sizes. The smallest purchasable quantity of charcoal costs about 0.25 USD, while the smallest widely available LPG cylinder costs 8 USD. Under a cylinder recirculation model, households must use the entire cylinder and exchange the empty cylinder for a full one. Thus, even if over the course of the month or year, households are spending the same amount on fuel, clean fuels may remain unaffordable if users do not have the full cylinder cost all at one time. Without access to financial tools such as microloans or accounts to save, these liquidity constraints can prevent clean fuel use (8).

### **Our theory of change**

Our core theory of change is that DFS can (1) relax liquidity constraints and (2) reduce transaction and opportunity costs, thereby promoting clean fuel use. We hypothesize that a DFS could provide individuals with a safe, convenient account to redirect money previously spent on incremental amounts of charcoal towards savings for the full cost of the LPG cylinder. The DFS could incentivize through bonuses, subsidies, or loyalty points LPG purchases or the savings behaviour that we believe can relax the liquidity constraints on LPG. Further, users who are short on the total cash needed for the LPG exchange could receive a microloan for their LPG cylinder to avoid reverting back to polluting fuel use. We base these hypotheses in the literature on liquidity constraints for clean fuels (8) and results from our own focus groups and interviews discussing these potential features. We envision that financial services will be the most relevant to assist in the transition from charcoal to LPG, as firewood can be purchased but is often collected for no monetary value but at the cost of women's time.

A clean cooking fuel specific DFS could also reduce transaction costs of LPG purchases, as well as the time burden and thus opportunity costs associated with purchasing cooking fuel frequently (i.e., multiple trips a week to charcoal vendors). LPG refill stations are often far from a users' home and transporting cylinders is difficult. GasPay exchange points can be built relatively easily, compared to a refilling station, throughout communities. A DFS would allow users to check stock, schedule a delivery, and not waste time if full cylinders are out of stock at various retail locations. Easier LPG purchases can also save users time beyond the transaction. In the focus groups, both charcoal users and LPG users agreed that using LPG would save them time, allowing them to perform additional household chores, leisure, or economic activities. LPG users in our focus groups indicated that they purchased LPG on a monthly basis, while charcoal users reported daily purchases. By encouraging LPG use, DFS may help women regain this time and increase their economic activity.

Finally, we envision that this DFS could also support focused targeting of subsidies or incentives. Eligibility for these benefits could relate to need and/or on users during critical windows of vulnerability to air pollution (e.g., pregnancy).

Given this theory of change, we aimed to design such a platform to relax the liquidity constraints and transaction costs of LPG purchases, incentives the purchase, and hopefully help redirect current spending on charcoal to LPG.

### **The GasPay platform**

After extensive household surveys and focus groups investigating customer preferences, we developed GasPay, a mobile money based DFS, where consumers can register for a GasPay wallet, make savings deposits, check their balances, order LPG for pick up at a local depot, and give feedback about their purchasing process. The platform allows for consumers to earn bonuses for saving in their wallets and to take advantage of a credit option, an advance for LPG when they are short on funds. The GasPay platform currently works with both USSD shortcode messaging and smartphones for consumers.

GasPay's features are designed to increase LPG consumption by addressing financial constraints that go beyond the fuel cost and hinder adoption by low income consumers.

LPG companies can set up LPG retail locations and assign employees, add inventory, create registration or sales promotions, and track LPG sales. Suppliers can also review and download business analytics and receive consumer feedback through GasPay. While GasPay is currently operating with one financial partner and one LPG supplier, the platform is built to host multiple providers.

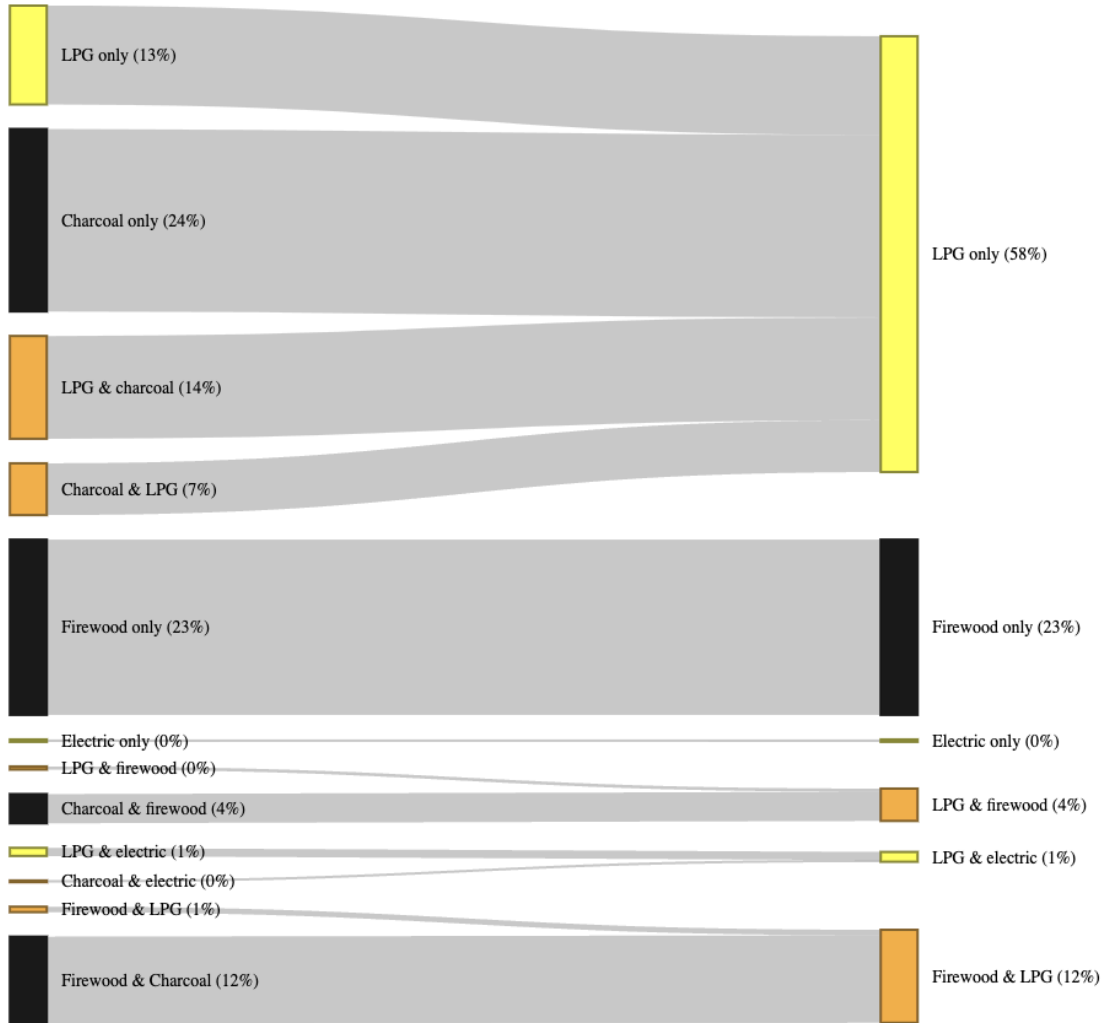
We are currently conducting a randomized control trial with roughly 1,800 users across Techiman in the Bono East region of Ghana to understand the causal impacts of this platform on LPG and polluting fuel use. Our sample is half women, yet users registering for GasPay are primarily women (78%).

Simultaneously, our team is working to commercialize GasPay to increase the customer base and ultimate reach within Ghana.

### **The potential scale**

For Ghana, we outline the user types likely to be most responsive to GasPay in changing their fuel choices from solid fuels to LPG (Figure 1). In principle, all current expenditure on purchased dirty fuels could be redirected to LPG, provided users can overcome liquidity barriers through small savings. Thus, we project the potential scale of GasPay to be the number of primary and secondary charcoal users in Ghana who may now be able to transition to LPG due to relaxed liquidity constraints via GasPay. We acknowledge that some users purchasing charcoal will be constrained by expenditure not only liquidity; however, we project GasPay's total potential impact, as GasPay incentives or other policy could address expenditure constraints.

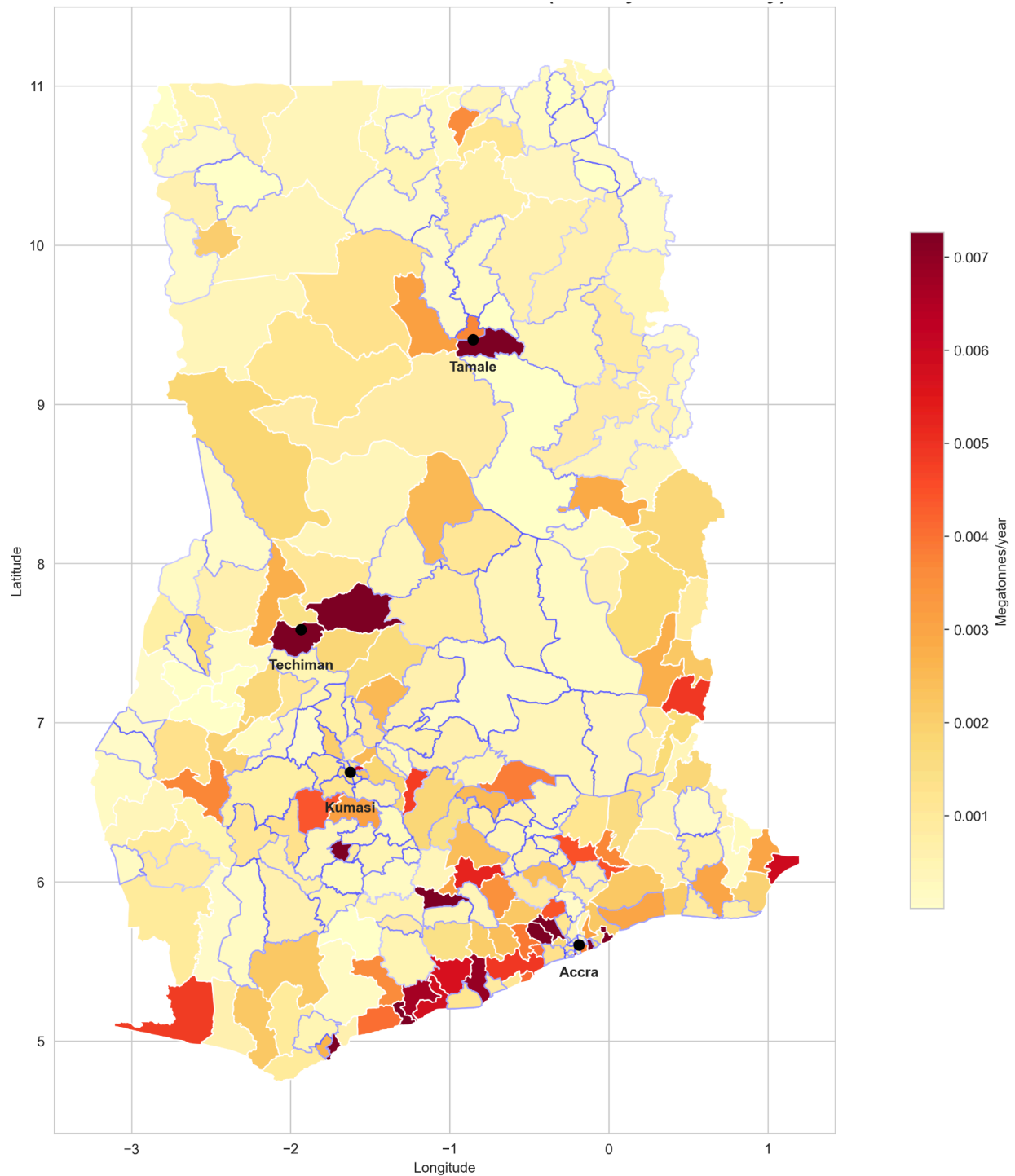
While not nationally representative, the survey found that 24% of individuals use charcoal exclusively, while 14% primarily use LPG with some charcoal and 6.9% primarily use charcoal with some LPG. If these primary and secondary charcoal users in Ghana transition to LPG via GasPay, annual LPG demand could increase nationally by 0.19 megatonnes (Mt) of LPG, replacing 0.58 Mt of charcoal. If GasPay could transition all residential charcoal use to LPG by relaxing liquidity and transaction costs, the rate of any LPG use could increase from ~36% of Ghanaian households (as of 2021) to ~75% (Figure 1).



**Figure 1.** This sankey diagram indicates the potential transition GasPay, a digital financial service platform, could facilitate (left to right). Using a national survey of Ghana, we assume that all expenditure on purchased charcoal could be redirected to LPG with the GasPay platform to ease liquidity constraints. The left panel indicates the current mix of primary and cooking fuels, while the right panel indicates the potential fuel mix GasPay could help realize. This excludes the minor transitions of electric and LPG users, electric and firewood or charcoal users, and firewood and electric users.

Given Ghana’s 2021 population of ~31 million and charcoal demand, this additional LPG use and avoided charcoal use could avoid ~2.4 Mt of carbon dioxide equivalent per year, accounting for carbon dioxide, methane, carbon monoxide, and nitrous oxide and the fraction of non-renewable biomass (see Methods). This represents a potential 10% reduction in Ghana’s total estimated emission. Further, these emission reductions are likely underestimated for 2025 given growth in population and charcoal

demand. Peri-urban and urban settings show the highest potential for impact, where the largest number of charcoal users reside, and where LPG supply infrastructure is already developed (Figure 2). This projected transition assumes that purchased clean and polluting fuels cost households similar amounts now and in the future, and that overall energy consumption does not increase with clean fuel adoption (i.e., no rebound).



**Figure 2.** Annual charcoal demand from primary and secondary users, by district, from our 2021 national survey (10). In total, we estimate 0.58 megatonnes of annual charcoal demand for residential cooking use. Districts with blue borders indicate predicted demand from census-derived district characteristics (see Methods & SI).

## Discussion

We present the motivation, design, and potential impact of a newly developed DFS platform that facilitates saving for and purchasing LPG. We developed this platform in Ghana; however, across sub-Saharan Africa (SSA), charcoal costs have been shown to be comparable to those for the equivalent amount of LPG (11, 12). SSA is lagging in progress towards access to clean cooking, compared to other regions in the global south, as population growth outpaces increased adoption (1). Thus, we hope this advance will spur future research into broadly using DFS to advance clean cooking use, particularly across SSA.

DFS platforms such as GasPay have the potential to unlock both public and private capital for clean energy transitions. A major source of private funding for household energy has been the voluntary carbon market (VCM), where efficient cookstove projects can monetize their carbon emission reductions. Efficient cookstoves were the fastest growing project type on the VCM, and pairing carbon finance with DFS could further accelerate adoption and sustained use of clean fuels. In fact, a few cookstove projects on the VCM offer pay-as-you-go (PAYGO) LPG, allowing users to buy small amounts of LPG through a specific meter built into PAYGO specific cylinders. However, these hardware approaches have had challenges in scaling (13). A benefit of the GasPay approach is that it offers financial services via software, reducing liquidity constraints just like with PAYGO but at a lower cost and risk. Existing, financially viable and scaled mobile money and LPG suppliers have the potential to scale financial services through DFS, even if initially supported in part through VCM or government funds. Governments could utilize mobile money platforms to target subsidies and vouchers to specific consumers as discussed above, thereby reducing leakage in government-funded clean cooking programs. There is a dire need to innovate around increasing consumption, not just initial adoption of clean fuels; our results spur further directions to explore how DFS can accelerate that transition.

E-payments across Africa are projected to grow by 152% from 2020 to 2025, and e-wallets that integrate mobile money (just like GasPay) are projected to experience a 24% increase in total market revenue across the continent (14). Ghana, which has one of the most sophisticated electronic-payment systems, is projected to contribute, along with Egypt, Nigeria, Kenya, and South Africa, to over half of all e-payment revenue. Mobile financial platforms have not only revolutionized transport (e-hailing services), entertainment, and shopping, but also have the potential to facilitate the uptake of development products beyond cooking fuel. DFS services, structured like GasPay, could benefit low-income consumers by providing saving mechanisms, credit options, and targeted subsidies for numerous development products. Studies have shown that mobile money has impacts on financial aspects, food security, employment, etc., but all through the access to financial behavior (15).

We argue through our development of GasPay that mobile money has a role in the direct provision of development products, whether that be helping users save for items, finance larger purchases, or receive targeted assistance. For example, Ghana's Livelihood Empowerment Against Poverty (LEAP) programme provides cash transfers to particularly poor households and has now become digitized, but individuals still collect money at physical pay-points (16). DFS for LEAP could help streamline the targeting of this program or provide LEAP recipients with other financial services. DFS for development products could be

particularly salient for women as mobile money has been shown to disproportionately benefit women (2), who also are often responsible for ensuring all members of the household use these products (17, 18).

Further, GasPay and other DFS for development could ensure vulnerable groups are not only included but intentionally targeted. Exposure to air pollution—particularly from household cooking—can be especially detrimental to women as well as to their unborn and newborn children. The resulting impairments in growth, lung function, and other health outcomes can have cascading effects throughout a child’s life course (e.g., (19)). Linking clean fuel subsidies with mobile money accounts could creatively target vulnerable groups. Simultaneously, the targeting of these individuals could encourage their access to financial tools that could improve a range of outcomes related to health and wellbeing.

Finally, we argue that GasPay could have downstream impacts for increased financial inclusion and women’s economic empowerment. Every GasPay recipient gains access to a savings account, micro-credit, and financial privacy. For many, this may be their first experience banking with an institution. Beyond providing access to financial tools, GasPay may also increase women’s financial literacy and may facilitate uptake of other digital financial services. Having access to GasPay may give her financial privacy to save and spend money on LPG without permission from other household members who may not see as much value in cooking-related expenses. Alternatively, GasPay may provide transparency if needed, providing a written record of transaction price. GasPay can save her time procuring charcoal multiple times a week. With GasPay, she can check the real time exchange price, find a depot within her neighborhood, and purchase and confirm her full cylinder. Gaspay could reduce women’s time burden, beyond streamlining financial transactions, by inducing more clean fuel use, leading to faster cooking with energy dense and more efficient modern fuels. With these additional sources of time, women could engage in other economic activities.

## **Methods**

We construct the kilograms per person of charcoal from the Combatting Household Air Pollution research team’s national household survey (2021) from questions regarding respondents’ primary and secondary fuels, the amount of fuel procured per transaction and the frequency of transactions. We convert estimated charcoal consumption by district, accounting for population weights, into megajoules-delivered and then kilograms of LPG. For districts without CHAP observations, consumption is predicted using supervised learning models trained on census-derived district characteristics. We compare carbon dioxide equivalent estimates for this consumption of charcoal and LPG using only Kyoto gasses (carbon dioxide, methane, and nitrous oxide) according to Floess et al. 2023 (4) and following best practice carbon accounting methods (20). Details are in SI.

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## Supplementary Information for Gill-Wiehl et al.

### GasPay development surveys and focus groups

Through a series of seven focus groups discussions with LPG users and charcoal users in Accra, Ghana, as well as a targeted survey to 100 households, with 92% female respondents, we learned about women's current use of digital financial services, benefits and constraints to using LPG and gained key insights into which features of GasPay are most attractive to each user. Each focus group had roughly 5-6 participants, for a total of 36 participants. Three focus groups had only LPG users, three had only charcoal users, and one was with LPG distributors. Our research partner Innovation for Poverty Action (IPA) recruited participants through a combination of convenience sampling (approaching customers at filling stations, for example) and a random walk process. Under both methods, upon reaching a person or a household, they introduced themselves, explained the goals of our study, asked whether their primary cooking fuel is charcoal or LPG, and then asked the head of the household to participate in the focus group discussion. For LPG distributors, IPA called and visited LPG refill stations in the Accra Region to explain and invite their managers (or any other representative) to the group discussions. All focus group discussions had roughly ten questions and lasted no more than two hours. The focus groups with households focused on discussing interest in using mobile money, having access to loans, access to LPG exchange points, coordinating delivery, and other potential GasPay features. The LPG-supplier focus group covered interest in DFS platforms to communicate with consumers, customer consumption patterns and spatial distribution, and cylinder delivery strategies. The household survey mirrored topics from the household focus group, including questions on households fuel use and procurement patterns. Focus groups were recorded, transcribed, and analyzed for themes by hand. Household survey data was collected electronically and analyzed in Microsoft Excel and R.

### Expenditure, stacking and potential GasPay user analysis

We determine the percentage of different cooking fuel combinations from self-reported primary and secondary stove use data from the 2021 national Combating Household Air Pollution (CHAP) household survey. The CHAP survey followed a stratified two-stage cluster sampling design, ultimately surveying 7,398 primary cooks across all 16 regions of Ghana. Full details of the survey design are documented elsewhere (1). The survey asked respondents directly which fuel and stove they used primarily and secondarily as well as how much they spent on each fuel respectively in the past month. Accounting for population weights, we determine the percentage of the population using primary and secondary combinations of firewood, charcoal, LPG, and electricity. Other fuels such as kerosene or ethanol accounted for less than a percent of the population. We also calculate the monthly expenditure on cooking fuel per standard adult equivalent. We convert 2021 cedis to 2025 with a CPI factor of 2.05 (2) and then convert to USD with a conversion factor of 0.079 (3). We create Figure 1 from projecting that all purchased charcoal use could be redirected to LPG use through the GasPay platform.

### Charcoal demand analysis

We estimate district-level charcoal demand in Ghana by combining 2021 Population and Housing Census microdata (4) with district-level charcoal consumption observations from the 2020 Clean Household Air Pollution (CHAP) survey. The unit of analysis is the administrative district, harmonized to 2021 boundaries. Charcoal consumption is estimated separately for households that report charcoal as their primary cooking fuel and for households that use charcoal only as a secondary fuel. For each group, the outcome is kilograms of charcoal consumed per person per month. Where available, district-level charcoal demand is calculated directly from CHAP survey data using survey weights. For districts without CHAP observations, per-capita consumption is predicted using supervised learning models trained on census-derived district characteristics, including urban-rural composition, cooking fuel use shares, lighting and water sources, housing characteristics, sanitation indicators, and asset ownership. Linear regression, random forest, and gradient boosting models are evaluated using an 80/20 train-test split, and the best-performing model is selected based on out-of-sample  $R^2$ ; skewed outcomes are log-transformed prior to estimation and back-transformed for prediction. Predicted per-capita consumption is combined with district population and charcoal usage shares to estimate annual charcoal demand, with primary and secondary-only demand summed to obtain total district-level consumption.

### LPG demand analysis

To determine the potential increase in LPG demand if all charcoal demand converted to LPG demand through GasPay, we transform the estimated annual charcoal demand into useful megajoules, assuming an efficiency of 25% and a nominal calorific value (NCV) of 29.5MJ/kg:

$$\sum_{i=1}^{261 \text{ districts}} \frac{\text{Annual charcoal demand} - \text{kgs}}{\text{year}} \times \frac{29.5 \text{ MJ}}{\text{kg}} \times \eta_{\text{charcoal}}$$

From this useful energy, we calculate the energy equivalent amount of LPG in tonnes, assuming an efficiency of 50% and an NCV of 45MJ/kg:

$$\sum_{i=1}^{261 \text{ districts}} \frac{\text{MJs} - \text{useful charcoal}}{\text{year}} \times \frac{1 \text{ kg}}{45 \text{ MJ}} \div \eta_{\text{LPG}}$$

### Carbon emission analysis

We estimate the avoided carbon dioxide equivalent (CO<sub>2</sub>e) emissions by comparing total charcoal use in 2021 with the equivalent amount of LPG that would be required to deliver the same useful energy. This analysis assumes that all charcoal use observed in 2021 would have continued in the absence of the LPG intervention—that is, we do not account for baseline trends of spontaneous transitions from charcoal to LPG. Future analyses will incorporate time dynamics based on historical adoption trajectories of LPG.

We calculate total CO<sub>2</sub>e emissions from charcoal as follows:

$$\begin{aligned} & \sum_{i=1}^{261 \text{ districts}} Q_i^{\text{charc}} \times [fNRB_i \times EF_{CO_2}^{\text{charc}} + (EF_{CH_4, \text{comb}}^{\text{charc}} \times GWP_{CH_4, \text{renew}}) + (EF_{CH_4, \text{upstream}}^{\text{charc}} \times GWP_{CH_4}) + \\ & \quad + (EF_{N_2O, \text{comb}}^{\text{charc}} + EF_{N_2O, \text{upstream}}^{\text{charc}}) \times GWP_{N_2O} + EF_{CO_2, \text{upstream}}^{\text{charc}}] \\ & = CO_2e \text{ emissions from charcoal} \end{aligned}$$

Where  $Q_i^{\text{charc}}$  is the annual charcoal energy demand (TJ) for district  $i$ ,  $fNRB_i$  is the fraction of non-renewable biomass in district  $i$ ,  $GWP_{CH_4, \text{renew}}$  is the biogenic global warming potential for methane (28),  $GWP_{CH_4}$  is the fossil global warming potential for methane (30),  $GWP_{N_2O}$  is the global warming potential of nitrous oxide, and each EF corresponds to charcoal's emission factors for each species.

We calculate total CO<sub>2</sub>e emissions from LPG as follows:

$$\begin{aligned} & \sum_{i=1}^{261 \text{ districts}} Q_i^{\text{LPG}} \times [EF_{CO_2}^{\text{LPG}} + (EF_{CH_4}^{\text{LPG}} \times GWP_{CH_4}) + (EF_{N_2O}^{\text{LPG}} \times GWP_{N_2O})] \\ & = CO_2e \text{ emissions from LPG} \end{aligned}$$

Where  $Q_i^{\text{LPG}}$  is the annual equivalent LPG energy demand (TJ) for district  $i$ ,  $GWP_{CH_4}$  is the global warming potential for methane, assumed all fossil based (30),  $GWP_{N_2O}$  is the global warming potential of nitrous oxide, and each EF corresponds to LPG's emission factors for each species (including upstream emissions).

Finally, avoided emissions are calculated as follows:

$$\text{Avoided } CO_2e \text{ emissions} = CO_2e \text{ emissions from charcoal} - CO_2e \text{ emissions from LPG}$$

We use Ghana's most recent fNRB value from the Modeling Fuelwood Saving Scenario (MoFuSS) model (5), fuel specific EFs from Floess et al. 2023 (6), efficiencies from the CDM's 2022 update (7), and only consider the Kyoto protocol gasses ( $CO_2$ ,  $CH_4$ , and  $N_2O$ ).

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