

LETTER • OPEN ACCESS

'I am the one responsible': the gendered reality of clean cooking fuel affordability in Shirati, Tanzania

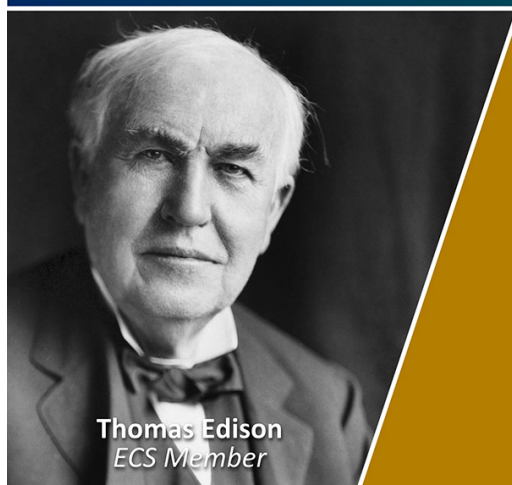
To cite this article: Annelise Gill-Wiehl *et al* 2025 *Environ. Res. Lett.* **20** 064037

View the [article online](#) for updates and enhancements.

You may also like

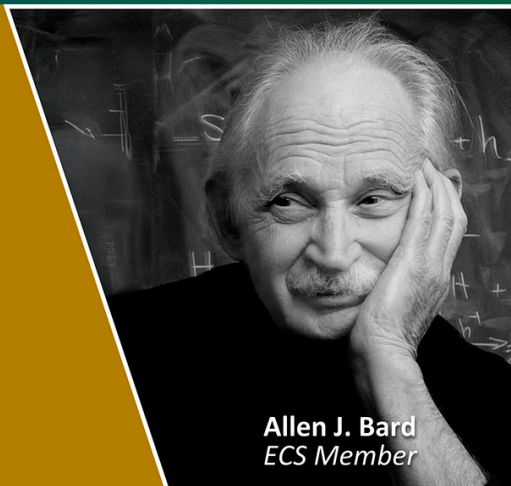
- [Jointly modeling the adoption and use of clean cooking fuels in rural India](#)
Carlos F Gould, Xiaoxue Hou, Jennifer Richmond *et al.*
- [Household, community, sub-national and country-level predictors of primary cooking fuel switching in nine countries from the PURE study](#)
Matthew Shupler, Perry Hystad, Paul Gustafson *et al.*
- [Lebanese rivers status: juggling between public negligence and challenged scientific awareness](#)
E Sharif-Askari, S Zeitoun-Ghandour, K Atoui *et al.*

Join the Society
Led by Scientists,
for *Scientists Like You!*



The
Electrochemical
Society

Advancing solid state &
electrochemical science & technology



ENVIRONMENTAL RESEARCH
LETTERS

LETTER

'I am the one responsible': the gendered reality of clean cooking fuel affordability in Shirati, Tanzania

OPEN ACCESS

RECEIVED

22 February 2025

REVISED

20 April 2025

ACCEPTED FOR PUBLICATION

13 May 2025

PUBLISHED

23 May 2025

Annelise Gill-Wiehl^{1,2,*} , Shelly Ogoya³, Na'Zyia S Dowdy-Arnold⁴ and Isha Ray¹ ¹ Energy and Resources Group, University of California, Berkeley, CA, United States of America² Mailman School of Public Health, Columbia University, New York, NY, United States of America³ Shirati KMT Hospital, Shirati, Mara, Tanzania⁴ Women's Research & Resource Center, Spelman College, Atlanta, GA, United States of America

* Author to whom any correspondence should be addressed.

E-mail: ag5050@cumc.columbia.edu**Keywords:** gender, clean cooking, sub-Saharan Africa, affordability, LPGSupplementary material for this article is available [online](#)

Original content from this work may be used under the terms of the [Creative Commons Attribution 4.0 licence](#).

Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

**Abstract**

Affordability remains one of the most significant barriers to the exclusive use of clean cookstoves and fuels, a top global health, energy, and development priority. The measurement and discussion of clean fuel affordability is almost always based on the unitary, or single decision-maker, household as the unit of analysis, although the more realistic household disaggregated into its individual decision-makers is a well-established literature. The limited work on intra-household dynamics in clean cooking cannot reveal who is buying the stove or fuel and at what true cost. Following an experiment testing the effect of microsavings to increase clean fuel consumption in Shirati, a rural town in Mara region, Tanzania, we conducted 90 interviews and numerous focus groups/budget games with a stratified random sample of mostly female main cooks. Drawing on over two years of fieldwork, we investigate the range of household needs, the role of gender in household finances, and how these combine to determine cooking fuel purchases. We find distinct and gendered financial domains where spouses do not disclose their expenses to one another and are responsible for different categories of needs. Cooking fuel is firmly in the female domain. Thus, liquefied petroleum gas affordability is constrained by these gendered financial domains, as women must choose between using savings for daily necessities or refilling the gas. Our extensive ethnographic evidence demonstrates the inappropriateness of the unitary model for cooking fuel affordability and the implications of ignoring separate-account household models. Our work requires new interpretations of saving for, and affordability of, clean fuels that the clean cooking literature has yet to confront. We offer recommendations for how the clean cooking literature could measure affordability and design policy for regions where cooking fuel is exclusively in the female financial domain.

1. Introduction

Approximately 2.3 billion people, mainly adult women, cook their meals using smoky solid fuels that result in ambient and household air pollution (HAP) [1], over eight million annual untimely deaths [2], and ~3% of global carbon emissions [3]. Universal access to clean⁵ cooking fuels, such as liquefied

petroleum gas (LPG) and electricity, is a global public health, energy, climate, and development priority and a core component of Sustainable Development Goals (SDGs) 3, 7, and 13 [1].

Affordability remains one of the most significant barriers to the exclusive use of clean cookstoves and fuels [4, 5], the level of use necessary to see improved health outcomes [6]. Affordability has been measured

⁵ The World Health Organization (WHO) has defined standards for 'clean' cookstoves and fuels, according to particulate matter and

carbon monoxide emissions [63] that indicate their potential for reduction in the relative risk of disease.

in many different ways in the clean cooking literature [7]. In all cases, the implicit and explicit basis for the measurement and discussion of affordability is ‘the household’ as the unit of analysis [8–12].

Although disaggregating the household (usually modeling it as a binary rather than unitary construct) and investigating intra-household dynamics is a well-established literature (e.g. [13–17]), the clean cooking literature remains anchored to the unitary household [7, 8, 18, 19]. This omission by the clean cooking field is particularly problematic as women, globally, are often responsible for household cooking responsibilities [20]; yet little is known about the role of gender in ‘household’ fuel decisions. The limited work on intra-household dynamics in clean cooking is based on secondary data analyses [21, 22].

In this paper, we offer a grounded perspective through extensive ethnographic work on how the household spends and saves, and further, on what the household even is in regard to cooking fuel purchases. We explore the intra-household gender dynamics of clean fuel use through a case study of LPG users within an experiment on the use of microsavings ‘nudges’ [23] to increase clean fuel consumption in Shirati, a rural town in Mara Region, Tanzania. Sub-Saharan Africa (SSA) lags global progress on clean cooking, with only 21% of the SSA population relying on clean fuel [1]. LPG use is particularly low in Tanzania (1.4%) [24], in the Mara region (1.4%) [25], and in Shirati [26]. Shirati presents an interesting case as it is a rural setting in a country that neither subsidizes clean cooking fuel nor removes the value added tax. Rural communities are disproportionately understudied, and are often targeted for improved, but not (truly) clean stoves. The majority of research focuses on urban or peri-urban settings where LPG is subsidized [27–29] or where the VAT is removed [30, 31]—but the majority of those without access live in rural areas without LPG subsidies [24]. To understand the dynamics surrounding clean fuel purchases, we draw on 90 semi-structured interviews and numerous focus groups/budget games with main household cooks in Shirati over two years of fieldwork. Our main objective is to understand the household needs, the role of gender in household finances, and how these combine to determine cooking fuel purchases. We contribute to the literature by showing why moving to a binary or separate account model is necessary as cooking fuel is a woman’s financial responsibility, among many others. We provide recommendations for how to more accurately measure affordability and design interventions, without which clean fuel policies will fail (1) to understand who is buying the fuel, (2) to estimate the true affordability challenge, and ultimately (3) to increase clean fuel consumption.

2. Methods

2.1. Study site

Our study site was Shirati, a rural town in Mara Region, Tanzania. Residents mostly rely on firewood or charcoal for cooking that can be purchased in a range of quantities (figure S1). Improved, but unclean cookstoves are available for purchase in the market (figure S2), while LPG is the only feasible clean fuel available (figure S3) as access to electricity is limited and inconsistent.

2.2. Study design

The work reported here followed a year-long randomized control trial (RCT) testing the effectiveness of a dedicated lockbox to encourage savings towards LPG refills. The RCT provided all participants with two 6 kg LPG cylinder/burner sets, at no cost, along with information, delivered by a local outreach worker, on saving for, and safely using, LPG. After those two initial cylinders, it was up to the participant to refill the cylinder [32].

We conducted an additional 6 month period of ethnographic work after the RCT with a stratified random sample of the participants which included observations, focus groups, budgetary games, and 90 semi-structured interviews to understand respondents’ saving and cooking fuel consumption behaviors.

2.3. Sampling procedure

The target population of the original RCT were households’ main cooks who did not previously use LPG. The RCT sample of 511 main cooks was selected through a spatial random sampling method [33]. After RCT data collection, we randomly selected interview respondents across the participants, stratified by expenditure groups (low, medium, and high) and LPG use categories (exclusive, habitual, occasional, and none) (tables S1 and S2). We did not stratify on gender as the RCT participants were mostly women (94%); we did interview a few men, but our results are largely based on the female perspective.

2.4. Data collection

After a baseline survey that collected socio-demographic information and cooking fuel use, fortnightly follow up surveys with respondents continued for a year during the trial. We tracked LPG use, LPG purchases, biomass use and saving behavior through the year. In this work, we rely on the survey results only for socio-demographic information to present and help stratify our sample for the post-RCT interviews (see survey in SI). We conducted a total of 90 interviews, by which time we had reached qualitative saturation [34] wherein new interviews were not revealing new insights (see semi-structured guide in SI). The first and second authors conducted all interviews in Swahili and Luo, the local language.



Figure 1. In the budgetary games (pictured), we provided each respondent with a kilogram (kg) of uncooked rice or beans and asked participants to pretend that the pile was their monthly or weekly expenditure (or a timescale they preferred). To understand how women allocated their expenditure priorities and where clean fuel fit (or did not fit) into their portfolios, we then asked them to divide the whole kg into smaller piles to indicate the distribution of their (own) major expenditure categories.

We also had unstructured observations and shorter conversations in the major market, smaller trading posts, LPG shops, local restaurants, community events (weddings and funerals), schools, and homes.

We conducted six focus groups and budget games to understand how women allocated their budgets across key expenditure categories (see semi-structured guides in SI). Each group consisted of five or six women recruited across villages and expenditure groups. For the budgetary games, we provided each respondent with 1 kg of uncooked rice or beans and asked her to divide the whole kg into smaller piles to indicate the distribution of her (own) major expenditure categories, treating the pile as her monthly (or weekly) expenditure (figure 1). Initially we asked this question of the entire household expenditure but realized that women were not aware of the relative sizes of their spouses' piles. We provided examples of categories to initiate the discussion, but the resulting categories were entirely participant-driven. We used this exercise to understand what participants saw as their expenditure priorities, the relative size of each

category, missing categories, and where clean fuel fit (or did not fit) into the portfolio of needs.

2.5. Data analysis

The second author transcribed interviews into English in the weeks following the interviews. We performed initial manual coding of our interview notes and formal coding for all transcripts in Dedoose, a qualitative data analysis software. We discussed emergent themes, category identification, and final codes/themes throughout the fieldwork and while analyzing the results (see SI for full methods).

3. Results

We spoke with the mostly female main cooks, who, before the RCT, used firewood and charcoal for cooking⁶ and had an average weekly expenditure of 56.7 USD (s.d.: 34.4) after adjusting for purchasing power parity (PPP) (table 1).

⁶ Our eligibility criterion for the RCT was that they did not already use a clean cooking fuel. LPG use in the region was ~2% in 2018 [55].

Respondents often stated their main occupation as farming, but combined farming with supplemental income from selling small fish, braiding hair, etc.

We present four key results from this work. First, spouses usually kept their finances completely separate. Second, there were distinct gendered domains of spending that reflected both cultural norms and earning potential. These domains dominated domestic budgeting, organizing categories of spending by gender (such as home repairs (men) and children's needs (women)). Third, women had to balance saving for LPG within a portfolio of essential household needs and social expectations. Finally, the split structure of spending responsibilities, the designation of cooking fuel as a 'women's' category, and other non-negotiable priorities, made it particularly difficult for women to afford an LPG refill using only the income that they controlled.

3.1. Separate accounts

Our focus groups and interviews revealed that spouses kept their finances (almost) completely separate. They rarely disclosed their personal budgets to each other: *'I manage my money and my husband manages his own money'* (R237). This was true whether women were earning their own money, obtaining a stipend from their husbands, or both. The separation of household finances was a deeply ingrained cultural norm, and not necessarily oppressive: *'I would not accept that {my husband} would know my expenses'* (FG4, R6). Women appreciated the autonomy of the separate finances practice: *'it is not necessary for me to tell him everything. He might need money one day and ask me to give him the money'* (R44). Though women were saving alone and struggling to meet their households' many needs, they still wanted autonomy over their savings: *'No one will know how much is in the lockbox, even my husband, I am the only one who will know'* (R273). Occasionally, spouses pooled their resources to afford sums too large for the man alone, such as school fees: *'With my money, I buy stuff for the house... the school fees we contribute together'* (FG1, R6). Alternatively, towards the end of the year, the couple could together assess how much each had left: *'Then we can decide what we need'* (R353). If a cow had to be sold, that was a joint decision, but everyday joint accounts were unknown.

3.2. Male and female purchase domains

Separate 'accounts' led to distinct realms of purchases for men and women. Both men and women harvested crops on the family farm, mainly maize and millets for home consumption. Women earned

money by selling the farmed vegetables, braiding hair, or pursuing small business such as buying, drying and selling small fish (*dagaa*) or selling doughnuts (*mandazi*). These smaller income flows matched purchasing items that needed smaller amounts on a day-to-day basis; therefore, women were in charge of daily household expenses such as food, soap, charcoal, and children's needs. Men pursued economic activities that resulted in larger sums, such as owning larger businesses, welding or woodworking, or holding salaried positions such as guards or teachers. Women described their incomes as fluctuating within a relatively narrow range, while their husbands' earnings, although they did not know exact amounts, were thought to be more volatile. Therefore, men often contributed to larger endeavors and purchases such as building a home, paying the bulk of school fees, or buying furniture, a TV, a bicycle etc. Although the LPG cylinder was a new technology calling for a lump-sum outlay, similar to what a man would typically cover, its position as a cooking fuel placed it between traditional domains.

Our respondents said that women have traditionally been responsible for cooking fuel and thus LPG had fallen under their financial responsibility: *'A man cannot go out to find firewood, a woman is the one responsible to cook, that is why she is responsible to find firewood'* (FG1, R2). Men could be generous contributors to the household's needs when these were in the male domain, and yet not contribute at all to LPG: *'Women have always been the ones to collect firewood or purchase charcoal, so even though it is now purchasing gas, it is still her responsibility, even if her husband is providing well for the household'* (Survey enumerator, Kabwana). When we asked if our women respondents had ever asked their spouses to help with LPG refills, they mainly had not: *'my work is to buy the gas; his work is to buy the TV'* (R234). Women had autonomy in this space: *'I cook, he only eats... he does not care how we cook'* (FG1, R4).

Women overwhelmingly reported near-term LPG benefits such as time savings, easing the work of cooking, and no smoke from burning wood and charcoal. Longer-term health outcomes were never mentioned, but these are harder to observe within a year-long study. Our interviewees were divided on whether men were aware of the benefits of cooking with LPG. Some argued that men would not contribute to a refill because they do not know the benefits for the family. Other women explained that their husbands understood the benefits, but still did not financially contribute: *'He knows the benefits, he will not give me money, but just tells me to refill'* (R22).

Table 1. Socio-demographic characteristics of our sampled respondents ($n = 511$).

Female respondent (main cook), n (%)	480 (94%)
Female headed households, n (%)	145 (29%)
Age, mean [range]	41 [18,88]
Luo tribe, n (%)	446 (88%)
Number of individuals living together, mean [range]	6 [1,20]
Children <12, mean [range]	2 [0,15]
Number of individuals eating together, mean [range]	6 [1,16]
<u>Occupation of main cook</u>	
Farmer, n (%)	411 (81%)
Business, n (%)	51 (10%)
Nurse, n (%)	5 (1%)
Cares for the home, n (%)	24 (5%)
Other occupation, n (%)	15 (3%)
<u>Education of main cook</u>	
No formal education, n (%)	18 (4%)
Primary school, n (%)	450 (88%)
Secondary school, n (%)	39 (8%)
University, n (%)	1 (0%)
<u>Expenditure and saving</u>	
Respondent's weekly expenditure, mean (s.d.)	17.2 (10.4) USD ^b
Respondent's weekly expenditure PPP, mean (s.d.)	56.7 (34.4) USD ^c
Ability to save at all, n (%)	286 (56%)
Female saves alone, n (%), endline ^a	433 (89%)
Attrition	1%
Maximum missingness within a single visit	6%

^a This value was from the final visit where 489 respondents were contacted that week and 18 did not answer this question as they were struggling to save.

^b An average exchange rate of \$1 = 2,325.96 TZS was used in January 2022.

^c We use a PPP of 3.30 for 2022.

3.3. What comes before the gas?

Most women explained that food, soap, hospital bills, and items for their children, all must be purchased before refilling the gas. In the budgetary games, the median allocation for food and household items represented 20%–30% of women's expenditures. Hospital fees represented roughly 20%, indicating significant health challenges in this community. Although men often paid the bulk of school fees, women had to purchase the clothes, books, backpacks, etc. for the children to attend school. In addition, when the children needed any extra money, they asked their mothers: *'most of the kids are afraid of their fathers so they talk to their mothers'* (R273). These purchases added up and had to be covered before a clean fuel purchase: *'You cannot save for gas and let the kids (watoto) go hungry'* (R407).

Beyond daily necessities to keep their children clean, educated, and fed, women were also responsible for household items that maintained social standing. Our respondents regularly brought up needing to save for dishes⁷ (*vyombo*) before refilling the gas (figure S4). Nice dishes were embedded in social expectations of what women must own in order to be 'good wives': *'if you do not have dishes, your in-laws*

will come and they will laugh at you' (survey enumerator, Obwere). Dishes were also needed for important community occasions for which women were expected to contribute money and food: *'I have not refilled the second cylinder because for now we have a lot of funerals'* (R272).

3.4. The challenge to save when clean fuel is the woman's problem

Given our result that women were the main purchasers of LPG, the affordability of clean fuel is, in effect, entirely a woman's financial burden: *'it is our hardship'* (FG4, R234). Being independently responsible for buying all daily household items, such as food, soap, clothing, books, backpacks—and now LPG—made it nearly impossible to save up for a refill: *'life is very hard which makes it hard to save, but that is why I just try and whenever I get money, I save'* (R427). In the budgetary games, on average, about one-third of our participants' total pile was a spousal (or family) contribution, meaning that most everyday expenditures had to be supported by their own earnings. No woman had a category for saving. They had to carve out any savings from the food, household or children's categories. Respondents refused to touch medical and education expenditures when they needed to squeeze out money for a refill: *'everything comes behind education'*

⁷ Group discussions revealed that 'dishes' included pots, plates, bowls, and also basins and buckets for water collection and storage.

(FG4, R5). Thus, women had a portfolio of financial needs, dictated by both household necessities and societal expectations, which together made affording LPG refills unrealistic for many, even when they had money saved in their lockboxes. Running the household on their own was burdensome, and children always seemed to need something: *‘as women, we carry the heavier suitcase’* (FG4 R5).

4. Discussion

Despite a well-established literature on the complexity of household models [13–17], the energy/cooking literature nearly universally assumes a unitary household model. Drawing on ~90 interviews, focus groups, budgetary games, and two years of observation surrounding an RCT focused on LPG usage, we find that the food-sharing household is often not a finance-sharing household. We demonstrate how understanding this more fluid household structure is needed to understand low LPG usage, a perspective not currently captured in the energy literature. We discuss the implications of this finding for constructing the metrics we use to measure energy affordability. Policies to increase clean cooking fuels must be shaped by understanding how ‘the household’ works. Our findings have implications beyond clean cooking, as a number of development policies rely on consumers making the ‘right’ choices and purchases. It is critical to understand who the user is, who the purchaser is, and who pays the true cost of purchasing and using the item, if we are to know the target consumer, how to market to that consumer, what is affordable for them, and where to direct any necessary subsidies.

4.1. The variable structure of the ‘household’

The ‘household’, presumably maximizing joint welfare, is the typical unit of analysis in the clean cooking literature [7, 8, 18, 19]. Our results corroborate longstanding feminist critiques of the unitary household model [15, 16, 35–39]. The answer to the question of what the household ‘is’, or what the relevant household model should be, depends on why the question is being asked. In this case, the intra-household ‘cells’ [40] that share food cooked with LPG are not the same as those that save for and buy that LPG. Thus far, models of intra-household decision-making have not been applied to research on fuel purchases, which means that the clean cooking literature has left unclear who is actually responsible for buying fuel.

Our results reinforce intra-household dynamics models. In our study region, household structure was fluid, and sometimes behaved as Becker’s unitary family with a single decision maker [41], sometimes as the consumption-focused producer-consumer peasant household of Chayanov [42], sometimes as the two-person bargaining model of game theory

[13, 14], and sometimes as two autonomous-yet-interdependent production/consumption units [43]. Our findings on saving and spending behaviors fall into this last category, supporting a two separate spheres model of the household [43].

Despite some reservations, both men and women perceived benefits from the financial separateness and non-disclosure: *‘he does not tell me his income because he thinks I would complain and ask for more...and I would’* (R234). Distinct accounts and gendered domains of spending are cultural constructs in many parts of rural Africa, and were identified decades ago [43–49]. Anthropological studies in Botswana, Nigeria, and Cameroon have all noted the separation of spouses’ finances, even finding the same percentage of women’s expenditure coming from a transfer from their husbands [40, 46, 47]. Our results corroborate these studies and show their relevance even today. Studies have also found that women’s income flows lead them to be responsible for specific divisions of responsibilities across SSA; however, no study has explicitly connected this phenomenon to cooking fuel, nor has the clean cooking literature acknowledged intra-household autonomy.

4.2. Understanding, defining and measuring affordability

The LPG purchases tax women’s constrained budgets: they fall through the cracks as cooking fuel purchases are traditionally in the woman’s domain but demand a lump sum more in line with purchases in the man’s domain. LPG refills do not always rise high along a woman’s portfolio of needs, because the ‘affordability’ of LPG cannot be understood in isolation from everything else a woman needs to purchase to build a life, according to Sen, that she ‘has reason to value’ [40, 46, 47, 50]. In Shirati, this means providing for her children and family and maintaining her social standing, all with 57 USD (PPP) per week.

Our results help us to understand why interventions that ease liquidity constraints may not lead to consistent clean fuel use [32]. We offer empirical evidence of how cultural norms intersect with economic constraints. In Shirati, these include financial separateness and social expectations. The intersection of intra-household finance and social norms is critical to understanding the true affordability of clean fuels in Shirati, or in any other setting.

The reality of separate accounts and domains of spending, and of balancing a portfolio of (urgent) needs, demands a rethinking of conventional measures of fuel affordability. Affordability in the clean cooking literature has been vaguely defined and often equated with the upfront cost of the stove alone [7]. Recent efforts have pursued more nuanced metrics for clean cooking affordability [30, 51, 52] such as the conventional affordability ratio (CAR), which is a household’s expenditure on cooking fuel divided by

the household total income or expenditure. Others have proposed affordability ratios based on an essential (or minimum) level of fuel consumption or on residual incomes after purchases of non-negotiable items such as food or rent [53]. All these metrics assume a unitary household.

The Energy Sector Management Assistance Program has set a cooking energy affordability threshold of 5% for the CAR [54]. If we switched to a gender-specific CAR for Shirati, using 34 USD PPP for a refill each month and 228 USD PPP as the woman's maximum expenditure, we would get a CAR of ~15%. This is before subtracting any other expenses. That is, if a woman spent 5% of her entire monthly budget on LPG, it would take her three months to refill the cylinder once. She would certainly need to keep buying firewood and charcoal.

Our findings support the use of a *gender-specific residual income* approach to the measurement of fuel affordability, meaning that only income in the female domain should count within the denominator, and expenses on food and medicine (at least) should be subtracted from that income. The residual income approach is a more accurate representation of the 'ability' to afford clean fuel. The denominator of any affordability ratio cannot be the 'household' income if this number is not the basis of purchasing behavior, and it should not include the income needed for items that are a 'must' for the purchaser. In practice, this would mean that a woman with a monthly expenditure of 228 USD PPP, of which food and medicine expenses represent 40%, 34 USD PPP for LPG results in ratio of 25% under a gender-specific residual income approach. Only an unrealistic affordability threshold can be constructed using an unrealistic denominator.

Determining context- and gender-specific essential expenditures could be onerous and may be why the clean cooking literature has continued with the unitary model. However, we point out that many household budget surveys already collect income earned by family member as well as expenditures on cooking fuel, food and household necessities (e.g. [55, 56]). Other surveys could be amended to include these data with little additional effort. For further refinement, market researchers could hold budgetary games (as we did) to gauge affordability.

5. Conclusions and recommendations

We suggest a near term and a long-term policy measure for universal access to clean cooking fuels: (1) targeted clean fuel subsidies or direct fuel provision and (2) more reliable and lucrative economic opportunities for low-income women. We acknowledge that national governments have numerous pressing needs.

However, our results indicate a more dire affordability crisis in clean cooking than the sector currently reports that millions of women may cope with alone. If increasing clean fuel consumption and averting devastating health outcomes from HAP is a top national priority, countries could provide subsidies targeted at the main purchasers: low-income women. The other option would be to pursue direct fuel provisions, such as full cylinder vouchers (unlike partial vouchers in Peru [57]), or direct delivery (like nutritional and water interventions [58, 59]), and target women explicitly to encourage near-exclusive use. Policies such as India's Pradhan Mantri Ujjwala Yojana targeted women with a rebate for LPG cylinders, but the policy's impact has been limited by the need for a higher refill subsidy [27]. This further reinforces our finding that direct provision or full subsidies are needed to ensure exclusive use.

Older arguments against subsidies targeted at women pushed back on the idea that the targeted subsidy would increase the woman's bargaining power [60] or argued that socially subsidized women would be required to behave in socially desirable ways [61]. However, when it comes to clean fuel purchases, we find there is no intra-household bargaining in sites such as Shirati. Thus, the argument that targeted subsidies may impose their own gendered expectations may be valid for some situations but need not apply in the case of clean fuel. We acknowledge there is a risk of unintended consequences for this type of policy to reinforce gendered burdens. If women are targeted for subsidies, there is less incentive to share the financial burden. Long-term norm changes are always possible, but the reality is, in the near term, women in many settings will face the financial burden of LPG alone.

Second, longer term policy interventions focused on women's income opportunities, rather than household income opportunities, may be important for clean cooking. Women continually brought up how their businesses were the key to their ability to save for clean fuel: '*if the business is good, then I save well*' (R189). With roughly 30% coming from a man's contribution (apparently unchanged from 1980 [40]), the bulk of a woman's expenditures is based on her own efforts. Supporting women explicitly with more economic opportunities and higher wage work is therefore a more reliable (although not guaranteed) path to ensuring clean fuel purchases. If she earns, she can take better care of her time, health, and cooking⁸. Support could include regionally-feasible opportunities or even unconditional cash transfers for unpaid care work. The key to clean cooking for all lies in women's wallets.

⁸ The caveat here is that any significant change in earning power may shift the intra-household dynamics in unpredictable ways.

Our work and its conclusions are most relevant to contexts in which household members eat together and live together but save separately and spend separately. The gender-specific affordability ratio can become a household ratio when finances are pooled. However, women's bargaining power over financial decisions in such cases may be low [62]. Our insights apply beyond Tanzania and beyond LPG as separate wallets are common in SSA [40, 46, 47]. Gauging affordability for any type of energy, development or health product (water filters, contraception, solar home systems, etc) thus only makes sense in a gender-aware context. Ignoring the nature of the 'household' will not help the global community to finance or achieve the SDGs.

Data availability statement

The data cannot be made publicly available upon publication because they contain sensitive personal information. The data that support the findings of this study are available upon reasonable request from the authors.

Acknowledgments

This work was funded by NSF's Graduate Research Fellowship Program, the Global Distribution Fund (Dprize), University of California, Berkeley's Center for African Studies' Rocca Dissertation Grants, the James and Katherine Lau Climate Equity Fellowship, the Foreign Language and Areas Studies Fellowship. We thank Elisa Derby for comments on earlier drafts. Finally, we thank the women of Shirati for their incredible generosity in participating in this study.

Ethics statement

The study protocol was approved by the University of California, Berkeley's Institutional Review Board (Protocol 2020-02-13013) and by Tanzania's COSTECH (Permit # 2021-465-NA-2021-112 (Renewed as 2022-886-NA-2021-112); informed consent was obtained from all study respondents. We obtained informed consent from all photographed individuals to include their photos in the publication.

ORCID iDs

Annelise Gill-Wiehl  <https://orcid.org/0000-0002-3908-7903>

Isha Ray  <https://orcid.org/0000-0002-9966-8822>

References

- [1] IEA, IRENA, UNSD, WB, WHO 2024 Tracking SDG 7: The Energy Progress Report 2024 (available at: www.seforall.org/data-stories/seforall-analysis-of-sdg7-progress) (Accessed 16 October 2024)
- [2] Health Effects Institute 2024 State of global air 2024: special report (Health Effects Institute) (available at: www.stateofglobalair.org/resources/report/state-global-air-report-2024)
- [3] Floess E, Grieshop A, Puzzolo E, Pope D, Leach N, Smith C J, Gill-Wiehl A, Landesman K and Bailis R 2023 Scaling up gas and electric cooking in low- and middle-income countries: climate threat or mitigation strategy with co-benefits? *Environ. Res. Lett.* **18** 034010
- [4] Puzzolo E, Pope D, Stanistreet D, Rehfuess E A and Bruce N G 2016 Clean fuels for resource-poor settings: a systematic review of barriers and enablers to adoption and sustained use *Environ. Res.* **146** 218–34
- [5] IEA, IRENA, UNSD, WB, WHO 2021 The energy progress report SDG7 (available at: www.worldbank.org)
- [6] Pope D *et al* 2021 Are cleaner cooking solutions clean enough? A systematic review and meta-analysis of particulate and carbon monoxide concentrations and exposures *Environ. Res. Lett.* **16** 083002
- [7] Gill-Wiehl A, Ray I and Kammen D 2021 Is clean cooking affordable? A review *Renew. Sustain. Energy Rev.* **151** 111537
- [8] Hanna R, Duflo E and Greenstone M 2016 Up in smoke: the influence of household behavior on the long-run impact of improved cooking stoves *Am. Econ. J.* **8** 80–114
- [9] Abebaw D 2008 Household determinants of fuelwood choice in urban Ethiopia: a case study of Jimma town *J. Dev. Areas* **41** 117–26
- [10] Gould C F, Schlesinger S B, Molina E, Bejarano M L, Valarezo A and Jack D W 2020 Household fuel mixes in peri-urban and rural Ecuador: explaining the context of LPG, patterns of continued firewood use, and the challenges of induction cooking *Energy Policy* **136** 111053
- [11] Chalise N, Kumar P, Priyadarshini P and Yadama G N 2018 Dynamics of sustained use and abandonment of clean cooking systems: lessons from rural India *Environ. Res. Lett.* **13** 035010
- [12] Bailis R, Ghosh E, O'Connor M, Kwamboka E, Ran Y and Lambe F 2020 Enhancing clean cooking options in peri-urban Kenya: a pilot study of advanced gasifier stove adoption *Environ. Res. Lett.* **15** 084017
- [13] Manser M and Brown M 1980 Marriage and household decision-making: a bargaining analysis *Int. Econ. Rev.* **21** 31–44
- [14] McElroy M B and Horney M J 1981 Nash-bargained household decisions: toward a generalization of the theory of demand *Int. Econ. Rev.* **22** 333–49
- [15] Haddad L, Hoddinott J and Alderman H 1994 Intrahousehold resource allocation: an overview (The World Bank) (available at: <https://EconPapers.repec.org/RePEc:wbk:wbrwps:1255>)
- [16] Haddad L and Kanbur R 1990 How serious is the neglect of intra-household inequality? *Econ. J.* **100** 866–81
- [17] Ashraf N 2009 Spousal control and intra-household decision making: an experimental study in the Philippines *Am. Econ. Rev.* **99** 1245–77
- [18] Pattanayak S K *et al* 2019 Experimental evidence on promotion of electric and improved biomass cookstoves *Proc. Natl Acad. Sci. USA* **116** 13282–7
- [19] Menghwani V, Zerriffi H, Dwivedi P, Marshall J D, Grieshop A and Bailis R 2019 Determinants of cookstoves and fuel choice among rural households in India *EcoHealth* **16** 21–60
- [20] UN Women 2014 *World Survey on the Role of Women in Development* (United Nations)
- [21] Choudhuri P and Desai S 2020 Gender inequalities and household fuel choice in India *J. Clean. Prod.* **265** 121487
- [22] Chicombo A F F and Musango J K 2024 Examining urban household energy consumption patterns in Mozambique through a gendered lens *Energy Res. Soc. Sci.* **112** 103501
- [23] Thaler R H and Sunstein C R 2008 *Nudge: Improving Decisions about Health, Wealth, and Happiness* (Penguin Books)

- [24] Stoner O, Lewis J, Martínez I L, Gumy S, Economou T and Adair-Rohani H 2021 Household cooking fuel estimates at global and country level for 1990–2030 *Nat. Commun.* **12** 5793
- [25] The United Republic of Tanzania 2022 Age and sex distribution report: Tanzania (available at: <https://sensa.nbs.go.tz/publication/report7.pdf>)
- [26] Gill-Wiehl A, Sievers S and Kammen D M 2022 The value of community technology workers for LPG use: a pilot in Shirati, Tanzania *Energy Sustain. Soc.* **12** 1–16
- [27] Gill-Wiehl A, Brown T and Smith K 2022 The need to prioritize consumption: a difference-in-differences approach to analyze the total effect of India's below-the-poverty-line policies on LPG use *Energy Policy* **164** 112915
- [28] Gould C F, Schlesinger S, Toasa A O, Thurber M, Waters W F, Graham J P and Jack D W 2018 Government policy, clean fuel access, and persistent fuel stacking in Ecuador *Energy Sustain. Dev.* **46** 111–22
- [29] Hollada J, Williams K N, Miele C H, Danz D, Harvey S A and Checkley W 2017 Perceptions of improved biomass and liquefied petroleum gas stoves in Puno, Peru: implications for promoting sustained and exclusive adoption of clean cooking technologies *Int. J. Environ. Res. Public Health* **14** 182
- [30] Gill-Wiehl A and Ray I 2023 Affording a clean stack: evidence from cookstoves in urban Kenya *Energy Res. Soc. Sci.* **105** 103275
- [31] CLEAN-Air (Africa) 2022 *COP26 and SDG7 Goals under Threat: 16% VAT on LPG Reverses Progress Made in Clean Cooking Adoption in Kenya* (University of Liverpool; Moi University, KEMRI, Global LPG Partnership; University College London; Ministry of Health; Ministry of Energy)
- [32] Gill-Wiehl A, Ray I, Hubbard A E, Levine D I and Kammen D M 2022 Nudging towards micro-savings: a step-wedge experiment on LPG adoption in rural Tanzania (AEA RCT Registry)
- [33] Gill-Wiehl A, Isha R, Kammen D M, Levine D and Hubbard A E 2025 Deconstructing the (un)affordability of clean cooking fuels through a randomized trial in rural Tanzania *Nat. Energy* accepted
- [34] Corbin J and Strauss A 1990 Grounded theory research: procedures, canons, and evaluative criteria *Qual. Sociol.* **13** 3–21
- [35] Sen A 1987 Gender and cooperative conflicts (available at: <https://api.semanticscholar.org/CorpusID:17676055>)
- [36] Folbre N 1986 Cleaning house: new perspectives on households and economic development *J. Dev. Agric. Econ.* **22** 5–40
- [37] Evans A 1991 Gender issues in rural household economics *IDS Bull.* **22** 51–59
- [38] Agarwal B 1995 *A Field of One's Own: Gender and Land Rights in South Asia* (Cambridge South Asian Studies) (Cambridge University Press) (available at: www.cambridge.org/core/product/4F8F9B2FFE77ECB16BCC634D97738FFA)
- [39] Woolley F R 1993 The feminist challenge to neoclassical economics *Camb. J. Econ.* **17** 485–500
- [40] Guyer J 1980 Household budgets and women's incomes (OpenBU) (available at: <https://open.bu.edu/handle/2144/40427>)
- [41] Becker G S 1981 *A Treatise on the Family* (Harvard University Press Cambridge, Mass)
- [42] Chayanov A V 1966 *The Theory of Peasant Economy* (The American Economic Association)
- [43] Lundberg S and Pollak R A 1993 Separate spheres bargaining and the marriage market *J. Pol. Econ.* **101** 988–1010
- [44] Guyer J 1988 Dynamic approaches to domestic budgeting : cases and methods from Africa *A Home Divided: Women and Income in the Third World* ed D Dwyer and J Bruce (Stanford University Press) pp 155–72
- [45] Guyer J and Peters P C 1987 Conceptualizing the household-issues of theory and policy in Africa-introduction (available at: <https://api.semanticscholar.org/CorpusID:150871513>)
- [46] Peters P E 1994 *Dividing the Commons: Politics, Policy, and Culture in Botswana* (*Dividing the Commons: Politics, Policy, and Culture in Botswana*) (University Press of Virginia) (available at: <https://books.google.com/books?id=sURgDgbLUC>)
- [47] Hill P 1972 Rural Hausa: a village and a setting (available at: <https://api.semanticscholar.org/CorpusID:128924155>)
- [48] Pahl J 2008 Family finances, individualisation, spending patterns and access to credit *J. Soc. Econ.* **37** 577–91
- [49] Hill P 1975 The west African farming household *Changing Social Structure in Ghana* 1st edn (Routledge) (<https://doi.org/10.4324/9780429489068-7/west-african-farming-household-polly-hill>)
- [50] Sen A 1999 *Development As Freedom* (Random House)
- [51] ESMAP, WB, MTF 2019 Ethiopia—beyond connections : energy access diagnostic report based on the multi-tier framework (available at: <https://openknowledge.worldbank.org/handle/10986/30102>)
- [52] Khavari B, Ramirez C, Jeuland M and Fuso Nerini F 2023 A geospatial approach to understanding clean cooking challenges in sub-Saharan Africa *Nat. Sustain.* **6** 447–57
- [53] Gawel E, Sigel K and Bretschneider W 2013 Affordability of water supply in Mongolia: empirical lessons for measuring affordability *Water Policy* **15** 19–42
- [54] Angelou N and Bhatia M 2015 *Beyond Connections: Energy Access Redefined* (Energy Sector Management Assistance Program)
- [55] Tanzania National Bureau of Statistics 2018 *The 2017–2018 Household Budget Survey-Dataset* (Tanzania National Bureau of Statistics)
- [56] Kenya National Bureau of Statistics 2016 Kenya Integrated Household Budget Survey 2015–2016 (Kenya National Bureau of Statistics) (available at: <https://statistics.knbs.or.ke/nada/index.php/catalog/13/related-materials>)
- [57] Troncoso K and Soares da Silva A 2017 LPG fuel subsidies in Latin America and the use of solid fuels to cook *Energy Policy* **107** 188–96
- [58] Post A and Ray I 2020 *Hybrid Modes of Urban Water Delivery in Low- and Middle-Income Countries* (Oxford Research Encyclopedia of Environmental Science) (<https://doi.org/10.1093/acrefore/9780199389414.001.0001/acrefore-9780199389414-e-679>)
- [59] Kreider B, Pepper J V and Roy M 2016 Identifying the effects of WIC on food insecurity among infants and children *South. Econ. J.* **82** 1106–22
- [60] Rosenzweig M R 1986 Program interventions, intrahousehold distribution and the welfare of individuals: modelling household behavior *World Dev.* **14** 233–43
- [61] Kandiyoti D 1990 Women and rural development policies: the changing agenda *Dev. Change* **21** 5–22
- [62] Miller G and Mobarak A 2013 Gender differences in preferences, intra-household externalities, and low demand for improved cookstoves (1 April 2013)
- [63] World Health Organization 2021 WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide (World Health Organization) (available at: <https://apps.who.int/iris/handle/10665/345329>)