

ACCEPTED MANUSCRIPT • OPEN ACCESS

## The refill gap: clean cooking fuel adoption in rural India

To cite this article before publication: Bodie Cabiyo *et al* 2020 *Environ. Res. Lett.* in press <https://doi.org/10.1088/1748-9326/abd133>

### Manuscript version: Accepted Manuscript

Accepted Manuscript is “the version of the article accepted for publication including all changes made as a result of the peer review process, and which may also include the addition to the article by IOP Publishing of a header, an article ID, a cover sheet and/or an ‘Accepted Manuscript’ watermark, but excluding any other editing, typesetting or other changes made by IOP Publishing and/or its licensors”

This Accepted Manuscript is © 2020 The Author(s). Published by IOP Publishing Ltd.

As the Version of Record of this article is going to be / has been published on a gold open access basis under a CC BY 3.0 licence, this Accepted Manuscript is available for reuse under a CC BY 3.0 licence immediately.

Everyone is permitted to use all or part of the original content in this article, provided that they adhere to all the terms of the licence <https://creativecommons.org/licenses/by/3.0>

Although reasonable endeavours have been taken to obtain all necessary permissions from third parties to include their copyrighted content within this article, their full citation and copyright line may not be present in this Accepted Manuscript version. Before using any content from this article, please refer to the Version of Record on IOPscience once published for full citation and copyright details, as permissions may be required. All third party content is fully copyright protected and is not published on a gold open access basis under a CC BY licence, unless that is specifically stated in the figure caption in the Version of Record.

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

---

# 1 THE REFILL GAP: CLEAN COOKING FUEL ADOPTION IN RURAL INDIA

2 Bodie Cabiyo<sup>1</sup>, Isha Ray<sup>1</sup>, David I. Levine<sup>2\*</sup>

3 <sup>1</sup>Energy and Resources Group, University of California, Berkeley, Berkeley, CA, 94720

4 <sup>2</sup>Haas School of Business, University of California, Berkeley, Berkeley, CA, 94720

5 \*Author to whom correspondence should be addressed.

## 6 ABSTRACT

7 From 2016-2019, the Indian *Pradhan Mantri Ujjwala Yojana* (PMUY) distributed over 80 million  
8 Liquefied Petroleum Gas (LPG) stoves, making it the largest clean cooking program ever. Yet,  
9 evidence shows widespread continued use of the traditional *chulha*, negating the potential  
10 health benefits of LPG. Here we use semi-structured interviews with female and male adults to  
11 understand the drivers of LPG usage in Mulbagal, Karnataka, the site of a proto-PMUY program.  
12 We find that respondents perceive the main value of LPG to be saving time, rather than better  
13 health. We also find that norms of low female power in the household, in addition to costs, delay  
14 saving for and ordering LPG cylinder refills. Namely, female cooks controlled neither the money  
15 nor the mobile phone required to order a timely refill. These factors together contribute to the  
16 “refill gap”: the period of non-use between refilling cylinders, which may range from days to  
17 even months. Our work reveals how gender norms can amplify affordability challenges in low-  
18 income households.

## 19 BACKGROUND

20 Of the 2.8 billion people who eat meals cooked on smoky, open biomass fires every day,  
21 up to 700 million live in India (1). Until recent efforts by the Government of India, this number  
22 remained nearly constant over the last four decades and represented the near-complete failure  
23 to address a critical health and environmental problem (2, 3). Smoke from cooking fires has  
24 consistently been the leading risk factor for disease in India, mostly affecting women and children  
25 (4). Household biomass combustion also contributes to climate change, and may be the second  
26 leading contributor to near-term warming (5, 6). Furthermore, in some regions, women may have  
27 to spend 4-10 hours weekly in fuel collection and preparation, at the expense of other activities  
28 (7).

29 In 2016, India launched the largest global effort to spur adoption of Liquefied Petroleum  
30 Gas (LPG) for cooking (8). The *Pradhan Mantri Ujjwala Yojana* (PMUY, informally known as  
31 *Ujjwala*) distributed over 80 million new LPG stoves across India from 2016 to 2019. Under PMUY,  
32 consumers pay for the stove and the cylinder deposit over several gas refills to reduce the  
33 customer's upfront cost. Gas refills cost a flat subsidized rate of Rs. 450 (US\$6 in 2017) per  
34 cylinder, but the customer pays the full market rate upfront and receives the subsidy later as a  
35 bank deposit. The intent of PMUY is to encourage rapid transition away from the incumbent  
36 technology – the mud *chulha* – at an unprecedented scale. As a result, for the first time in history,  
37 95% of Indian households have access to LPG hardware and subsidized gas (8).

38 At the same time, a large literature documents “stove stacking” – simultaneous use of  
39 different cooking devices – in India and throughout the world. Stove stacking is common because

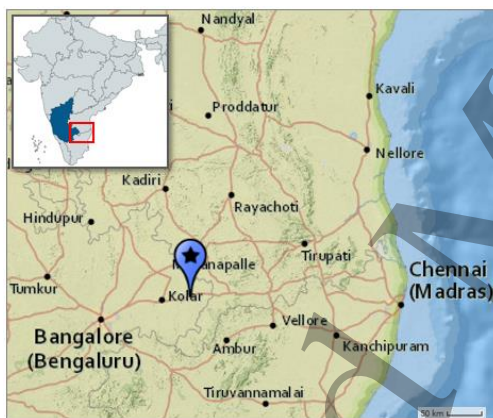
1  
2  
3 40 new stoves are imperfect substitutes for traditional ones (9, 10). Stoves may have end uses which  
4  
5 41 extend beyond cooking (e.g. for spirituality, gathering, space heating, bathing), and may be  
6  
7  
8 42 suitable for widely differing cooking tasks, depending on socio-cultural preferences (10).  
9  
10  
11 43 Furthermore, low incomes and poor fuel availability inhibit the consistent use of modern fuels  
12  
13 44 like LPG (9, 10). Access to multiple fuels, by contrast, allows households to adjust to economic  
14  
15 45 changes and fuel availability with relative ease.  
16  
17

18  
19 46 Research has shown that most of the harm to health remains with even moderate *chulha*  
20  
21 47 usage (11). Thus, a nearly complete shift to cooking on LPG is necessary to realize the potential  
22  
23 48 health benefits of PMUY. Initial studies suggest that low-income PMUY households use much less  
24  
25 49 LPG than non-PMUY LPG households (8, 12, 13). In some states, up to twice as many PMUY  
26  
27 50 beneficiaries report using biomass *chulhas* for cooking compared to long-time LPG users (13).  
28  
29  
30

31  
32 51 Journalistic accounts (14, 15) and academic evaluations (16–20) have identified  
33  
34 52 affordability as a key barrier to timely refilling of LPG cylinders. In contrast, some evaluations  
35  
36 53 have found that LPG use among PMUY beneficiaries does not depend on economic status (8) and  
37  
38 54 adoption is higher where women have more decision-making power (21). Other reasons for the  
39  
40 55 persistent use of traditional stoves after clean fuel adoption include space heating, the taste of  
41  
42 56 food, and access to free biomass (8, 18). Academics have called for a concerted effort to promote  
43  
44 57 the health benefits of LPG in order to increase consistent use (2, 16, 22).  
45  
46  
47  
48

49  
50 58 In this paper, we investigate perceptions and use of LPG two years after the “Smokeless  
51  
52 59 Villages” program was implemented near Bangalore, Karnataka in 2015 (Figure 1). This program  
53  
54 60 preceded and was functionally equivalent to PMUY; thus, it offers a preview of potential  
55  
56  
57  
58  
59  
60

61 outcomes under PMUY. In our study villages, LPG use had become normal, the average  
 62 household had modestly higher income than the average rural household in the state, and LPG  
 63 delivery was reliable (Methods). While researchers typically evaluate affordability for the  
 64 household as a whole, we argue that households may not function as a single unit.  
 65 Deconstructing the costs and benefits of LPG stoves from the perspectives of individual actors  
 66 within the household reveals a more granular understanding of why stove-stacking occurs.  
 67 Specifically, we find that women's low control over money and the household mobile phone are  
 68 major contributors to the "refill gap".



69  
 70  
 71  
 72  
 73  
 74  
 75  
 76  
 77  
 78  
 79  
 80  
 81  
 82  
 83  
 84  
 85  
 86  
 87  
 88  
 89  
 90  
 91  
 92  
 93  
 94  
 95  
 96  
 97  
 98  
 99  
 100

**Figure 1 | Map of the study area.** The blue pin indicates the Mulbagal district, where the interviews were conducted. In the inset map of India, the state of Karnataka is highlighted in blue, and the zoomed map area is indicated with a red box.

## RESEARCH DESIGN AND METHODS

### STUDY AREA

Our study area is the Mulbagal subdistrict (*taluk*), Karnataka, located roughly two hours by car east of Bangalore (Figure 1). In 2015, under the Smokeless Villages program, distributors offered all households without an LPG stove a new cylinder and stove with an interest-free loan. Users repaid the loan incrementally with each refill, similar to PMUY. Many of the Smokeless

1  
2  
3 76 Villages were selected for ease of access to an existing LPG distributor. At the time of study (late  
4  
5 77 2017), most households had paid off their loan. Project participants had been using LPG for two  
6  
7  
8 78 years, while pre-Smokeless Village LPG users had been using it for up to six years. The program  
9  
10 79 acted as a prototype for the larger 2016 launch of PMUY.  
11  
12  
13

14 80 Urban proximity grants Mulbagal access to markets, increased options for economic  
15  
16 81 mobility (e.g. through education and labor), and direct and indirect social influence. Additionally,  
17  
18 82 Mulbagal is close to the city of Kolar, which is a marketplace for the distribution of wholesale  
19  
20  
21 83 agricultural goods. Mulbagal farmers grow crops like rice, fruits and vegetables, sugar cane, and  
22  
23  
24 84 eucalyptus. They also produce specialty and high-value goods, including silk. Our study  
25  
26 85 respondents typically reported earning between Rs. 200-500 (\$3-8) per day, varying mostly  
27  
28 86 because of access to land or working capital. In contrast, the day-labor rates for rural Karnataka,  
29  
30  
31 87 according to the 2013 Census, varied from Rs. 150-200 (\$2.50-3).  
32  
33

#### 34 88 SAMPLE DESIGN AND DATA COLLECTION 35

36 89 We conducted 50 semi-structured interviews in the late summer and fall of 2017. We  
37  
38  
39 90 selected five villages based on the factorial combination of two binary criteria: predominant  
40  
41 91 household wealth status (poor or middle class) and distance from major highways (from 5-10 km  
42  
43  
44 92 or greater than 10 km from a major highway). We determined wealth status by observation  
45  
46 93 according to the criteria used in Karnataka; that is, a poor (below-poverty line, or BPL) household  
47  
48  
49 94 should not own more than three hectares of land, possess a four-wheeled vehicle, or have any  
50  
51 95 member employed by the government or a tax-paying institution.  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 96 All sampled villages were “Smokeless Villages”, which had been offered heavily  
4  
5  
6 97 discounted LPG stoves with no upfront costs for BPL households without an LPG stove. Within  
7  
8 98 each village, the field team chose 10 respondents (one per household) as follows:  
9

- 10  
11 99 1. 70% of the participants had received an LPG stove through the Smokeless Villages  
12  
13  
14 100 program. The remaining 30% were legacy customers from before the program.  
15
- 16 101 2. Our target was to have 20% of households be female-headed, although some  
17  
18 102 villages did not have enough such households to meet this criterion.  
19
- 20  
21 103 3. Half the households were poor, as defined by BPL criteria  
22
- 23 104 4. Households were sampled to be representative of caste and religion in each  
24  
25 105 village, based on local knowledge of the villages.  
26
- 27  
28 106 5. Participants were selected based on their status in the household as either the  
29  
30 107 primary cook (80%) or the primary earning member (20%). In nearly all cases, our  
31  
32 108 interviewees were not in the presence of other senior family members.  
33  
34  
35

36 109 We found that, by the end of these 50 interviews, our data collection began to reach  
37  
38 110 saturation. Further interviews were no longer yielding substantively new information. The  
39  
40 111 interviews were conducted by a field team trained in qualitative interview methods, fluent in the  
41  
42 112 local languages, and familiar with the ethnographic context. Their skills ensured that they not  
43  
44 113 only understood the words spoken but could interpret the significance of and interactions  
45  
46 114 between verbal and non-verbal expressions (23). The interviews focused on the interviewee’s  
47  
48 115 experience with LPG and the household’s cooking patterns. Interviewers followed up, where  
49  
50 116 appropriate, with clarifying and probing questions. The field team transcribed, translated, and  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 117 annotated the interviews in the weeks immediately following the interviews. Translation from  
4  
5  
6 118 the local language is a natural limitation of this work. Multiple authors were present for several  
7  
8 119 of the interviews, and we are confident in the interview and contextual expertise of our field  
9  
10  
11 120 team. Still, qualitative research is best conducted by a speaker of the local language. Our research  
12  
13 121 protocol was approved for ethical practices by UC Berkeley's Office for the Protection of Human  
14  
15 122 Subjects (Protocol#2016-08-9086).

16  
17  
18  
19 123 We analyzed interview data in three steps. First, after transcription and translation, we  
20  
21 124 coded interviews for emergent themes. Codes were grouped into families as their relationships  
22  
23 125 became apparent; examples of code families include "ease of cooking", "saving for refills", and  
24  
25  
26 126 "health". Second, after the first round of coding we re-analyzed all interviews to ensure  
27  
28 127 consistency. Finally, the data were further analyzed using the online qualitative data analysis  
29  
30  
31 128 software Dedoose for code co-occurrence, code frequency by descriptor, and code frequency by  
32  
33 129 participant, among others (24). This analysis allowed us to understand the frequency and  
34  
35  
36 130 importance of codes amongst individuals and groups.

37  
38  
39 131 In addition to these household interviews, we conducted supplemental interviews with  
40  
41 132 five LPG distributors and several Indian Oil Company (IOCL) officials. IOCL, a partially government-  
42  
43  
44 133 owned company, ran the Smokeless Villages project. These key informants discussed the  
45  
46 134 motivation and evolution of the Smokeless Village program, the delivery challenges facing  
47  
48  
49 135 distributors, and refill rates for customers. These interviews were used to interpret responses in  
50  
51 136 our core dataset by providing additional context with respect to the history and distribution of  
52  
53  
54 137 LPG in the region. In addition to the semi-structured interviews, during site visits in 2016, 2017,



1  
2  
3 138 and 2018 the U.S.-based research team (with members of the local research team) met with small  
4  
5 139 groups of villagers and informally discussed issues that overlapped with the semi-structured  
6  
7  
8 140 interviews. These discussions were not used in formal analysis but aided in the construction of  
9  
10  
11 141 the interview questions and the interpretation of results. The findings from these discussions  
12  
13 142 were consistent with findings from the semi-structured interviews.  
14  
15  
16

## 17 143 RESULTS

### 18 19 20 144 THE VALUE OF TIME

21  
22  
23 145 Saving time was the most-mentioned benefit of LPG, although this benefit took many  
24  
25 146 different forms. The benefits of time saving fell into four emergent categories: speed, flexibility,  
26  
27  
28 147 time for leisure, and time for work. Non-time-related benefits, such as taste preferences, were  
29  
30 148 less emphasized as reasons for using a particular stove, even if they were mentioned frequently  
31  
32  
33 149 across respondents (Figure 2). No respondents mentioned the health benefits associated with  
34  
35 150 LPG (Figure 2), consistent with previous studies (13).  
36  
37

### 38 151 SPEED AND FLEXIBILITY

39  
40  
41 152 Speed in cooking was a ubiquitous theme in these households where most meals were  
42  
43 153 cooked fresh every day. Respondents extolled the fast-cooking benefits of LPG in the morning  
44  
45  
46 154 when children or workers left the home early. Without LPG, the main cook would have to start  
47  
48 155 cooking early in the morning – sometimes three hours before serving breakfast and packing  
49  
50  
51 156 lunch:  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 157 *“While cooking on the chulha my wife had to wake up at 5.30 am in the morning to start*  
4  
5  
6 158 *cooking and food would be ready only by 9.00 am. The children had to go to school without*  
7  
8 159 *breakfast and I also was often late for work and being scolded by my employer. Now, I*  
9  
10 160 *have 3 school-going children who leave home at 7.30 am and the LPG has made it easy to*  
11  
12  
13 161 *cook. My wife wakes up at 6.00 am and even then, children have breakfast and then go to*  
14  
15 162 *school. We like it [LPG] because it saves time.”*

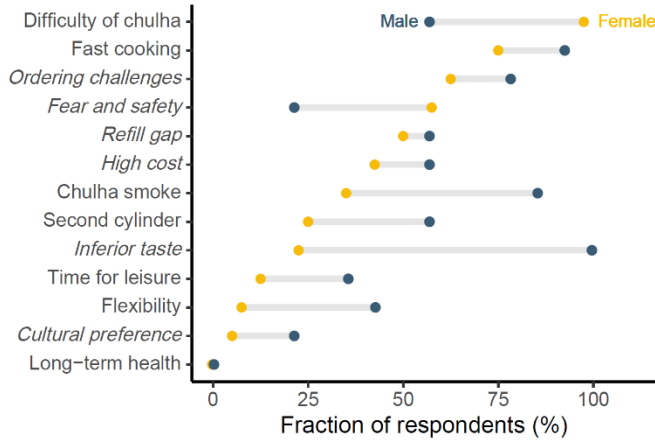
163 Furthermore, this multi-hour process excludes the time required to collect fuelwood and  
164 scrub sooty pots, a process that cooks frequently described as “drudgery”. For respondents with  
165 school-going children, the long preparation time without LPG often resulted in either skipping  
166 meals or sending children off late; fast cooking was the major driver of LPG usage in these  
167 households. Even respondents without children observed this benefit amongst neighbors or  
168 relatives who did have children.

169 Many respondents also described how LPG made it possible to cook quickly without  
170 planning, and that it served them well during “urgency” or “emergencies”. In rural India, the  
171 culturally important task of preparing tea, coffee, or a hot snack for an unexpected guest poses  
172 a significant challenge if the only cooking option is a *chulha*. Preparing a single cup of *chai* could  
173 require up to a half-hour if the stove was not already warm. In contrast, on an LPG stove the  
174 same cup of *chai* takes minutes. Stated simply: *“We can serve coffee or tea to the guests who*  
175 *visit our home. It is not possible to cook quickly on the chulha in times of emergencies.”*

176 THE VALUE OF SAVED TIME

1  
2  
3 177 Improved livelihoods, by using saved time for income generation, are often cited as a core  
4  
5  
6 178 benefit of clean stoves (3, 18). Of our sample of fifty, about half mentioned more time for work  
7  
8 179 as a benefit of the LPG, but only four referenced wage-earning work. Most respondents specified  
9  
10  
11 180 that time saved would be used for other housework. Very few women in our sample engaged in  
12  
13 181 wage-earning work. The four who did mention LPG freeing up time for income generation owned  
14  
15 182 productive assets such as livestock or a small shop. One male respondent said that his wife had  
16  
17  
18 183 more free hours in the day now that she used LPG, but then explained that the family was poor  
19  
20 184 because he was the only earning member. He never mentioned the possibility that his wife might  
21  
22  
23 185 work for pay in her newly found free time.  
24  
25

26 186 Besides household work, women described the use of saved time to relax, or to bathe and  
27  
28 187 change at the end of the day: “[...] *time can be saved that can be used for getting fresh after*  
29  
30 188 *coming from the field.*” Other respondents talked about how the new free time could be used for  
31  
32  
33 189 playing with children, relaxing, sleeping, or watching TV. These activities do not translate saved  
34  
35  
36 190 time to increased income, but they do suggest significant derived value associated with LPG  
37  
38 191 usage.  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



**Figure 2 | Frequency of selected codes by gender of respondent.** *Italicized codes represent factors that limit the continuous use of LPG. Conversely, non-italics represent factors that support continuous use. Interviews were coded for emergent themes in multiple rounds. Values represent the fraction of female (n=40) and male (n=10) interviews that were marked at least once for a given code. Some codes, like Inferior taste, were frequently mentioned but not emphasized as an important reason for using LPG/the chulha.*

## REFILLING EMPTY CYLINDERS

Our interviews revealed that, though cooks used LPG consistently while it was available, the refilling process presented a substantial barrier to sustained use. We disaggregate the refilling process into four phases: running out of gas, acquisition of funds, ordering a refill, and waiting for delivery. Delays at any stage would often require cooking on an alternative stove (in our sample, almost always the *chulha*).

The first phase of refilling is the recognition that the cylinder in use is depleted or nearly depleted. Most frequently, cooks in our sample would simply wait for the LPG to run out completely, rather than try to predict running out. This delayed recognition set cooks up for an interval of multiple days, or more, when they would have to use an alternative stove.

The second phase, acquiring funds for refilling, was a major barrier in the study villages. In India, the out-of-pocket price of an LPG refill fluctuates with the market price of gas. A few

1  
2  
3 205 days or weeks after purchase, a subsidy arrives in the bank account of the LPG account holder  
4  
5 206 (under PMUY, usually the cook; here, it was varied). The subsidy fluctuates with the market price,  
6  
7  
8 207 so the post-subsidy price is stable at Rs. 450 (\$6 in 2017). However, customers must bear the  
9  
10 208 short-term brunt of market price fluctuations. In the study villages, the initial cost of a refill was  
11  
12 209 equivalent to more than two days' wages. Respondents reported the upfront price as a  
13  
14 210 meaningful barrier: *"Recently the price went up to 800 rupees (US \$11) and now it has gone down*  
15  
16 211 *to 600 rupees (US \$8). [...] we feel it is difficult to pay the money."* As a result, most respondents  
17  
18 212 used some form of saving or took out a small, informal loan from a neighbor or relative (a "hand  
19  
20 213 loan") to pay for a refill.  
21  
22  
23  
24  
25

26 214 Respondents generally stated that they either "save some from work" or do not save for  
27  
28 215 the cylinder refills. The latter was much more common, and one male respondent expressed it  
29  
30 216 this way: *"If we don't have money, then we'll wait until the money is adjusted to order the*  
31  
32 217 *cylinder."* How respondents decided to "adjust" money was unclear from our interviews. In  
33  
34 218 almost all cases, the male primary earner made the decision to save or borrow funds and  
35  
36 219 purchase the LPG refill. Most women did not have their own cash, consistent with findings in  
37  
38 220 state- and nation-wide surveys. For example, amongst adult women in rural Karnataka surveyed  
39  
40 221 for the 2015-16 National Family Health Survey, only 20% agreed she "has money that [she] alone  
41  
42 222 can decide how to use (25)."  
43  
44  
45  
46  
47  
48

49 223 Despite generally terse responses to questions of money, nearly every respondent noted  
50  
51 224 that heating bath water on the LPG (instead of on an outdoor *chulha*) was far too expensive.  
52  
53 225 Some said that the LPG stove was always used for breakfast, which was prepared under time  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 226 pressure, but not necessarily for other meals and not during low-work days: *“Whenever we have*  
4  
5  
6 227 *work load we use LPG, otherwise, we use the chulha for cooking.”* These observations imply that,  
7  
8 228 even when respondents did not spontaneously mention the cost of LPG, all of them were aware  
9  
10 229 that it was expensive.

11  
12  
13  
14 230 The third phase of refilling was placing an order. Households could place their order for  
15  
16 231 a refill in person at the distributor, but that process would require a costly trip. The most  
17  
18 232 common approach was to order the cylinder using a mobile phone. Many of our female  
19  
20 233 respondents, who were also the main cooks, did not own a working mobile phone or did not  
21  
22 234 know how to order a refill. Instead, they relied on husbands, brothers, and neighbors to order.  
23  
24  
25 235 This power asymmetry was sometimes stated clearly, but only when it involved a party outside  
26  
27 236 the marital household: *“[Husband]: Actually, I do not know [how to order] – my brother does it,*  
28  
29 237 *we order through the phone. [Wife interjects]: His brother delays ordering by about 4-5 days each*  
30  
31 238 *time. We should be ordering even before the LPG is consumed, but that does not happen.”* In most  
32  
33 239 cases, the technology, and by extension the power, required to place a refill order rarely rested  
34  
35 240 in the hands of the primary cook.

36  
37  
38  
39  
40  
41 241 Overall, the person ordering a refill by mobile phone was usually male, while the primary  
42  
43 242 cook was almost invariably female. One woman’s words exemplify the gender imbalances around  
44  
45 243 ordering: *“The cost of cylinder is paid by my father and brother – I do not know the cost. My*  
46  
47 244 *father does the ordering through his friend, sometimes...my brother also makes orders for*  
48  
49 245 *refilling.”* The woman has no role in the decision to order a new cylinder: she neither knows how  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 246 much a refill costs nor has the autonomy to order it herself. Her autonomy in the refill process  
4  
5  
6 247 ends with pointing out the need for a refill.  
7  
8

9 248 The “delivery boy”, a gas agency employee who delivers full cylinders and accepts cash,  
10  
11 249 is the final actor in the refill process. Most respondents in our sample described delivery as  
12  
13  
14 250 “easy”, “timely”, and “reliable”. However, men in one of the villages did have complaints: “*The*  
15  
16 251 *delivery boy is charging 30 rupees for delivery (\$0.50, roughly one to two hour’s wages), which he*  
17  
18 252 *should not. But the alternative is taking the cylinder to town for refilling. The time and money*  
19  
20  
21 253 *required to fill it ourselves would be much higher.”* In the study area, the LPG distributor would  
22  
23  
24 254 typically deliver a refill within one week of a household ordering it. National regulations stipulate  
25  
26 255 that distributors deliver refills within 48 hours of an order. The distributors we interviewed,  
27  
28 256 however, stated that they sought to make deliveries twice per week; they preferred to reduce  
29  
30  
31 257 costs by making multiple deliveries at once to a single village.  
32  
33  
34 258

### 35 36 259 THE REFILL GAP

37  
38 260 In nearly all cases, respondents reported a gap between when a cylinder became empty  
39  
40  
41 261 and when it was refilled. The stated gap was usually from 3 to 10 days. However, several  
42  
43 262 interviews revealed that this was an optimistic range: it could be much longer, even months in  
44  
45  
46 263 some cases. Respondents sometimes reported only the refill gap imposed by delivery (a few  
47  
48 264 days), but, when pressed, would admit that the actual gap was longer. Such cases imply a barrier  
49  
50  
51 265 in one of the preceding steps: namely, not “adjusting” the money quickly or delayed ordering.  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 266 The mechanisms for managing this gap fell into two categories: using an alternative fuel  
4  
5  
6 267 or using a backup LPG cylinder. In our sample, the most common use of a *chulha* was to “manage  
7  
8 268 refilling shortfalls [gaps]”. Respondents valued the presence of the *chulha* in the kitchen even if  
9  
10 269 they didn’t use it regularly because it served them when the LPG ran out. They perceived the  
11  
12  
13 270 *chulha* as a reliable cooking device. Conversely, LPG was a less reliable fuel that periodically went  
14  
15 271 out of service.

16  
17  
18  
19 272 A second strategy was to use a second LPG cylinder while the primary cylinder was  
20  
21 273 pending refilling. Ownership of a second cylinder is prevalent in wealthy urban areas but is less  
22  
23 274 common in the study area. Though only about 15% of respondents in our sample owned a second  
24  
25 275 cylinder, some respondents would informally share second cylinders amongst neighbors and  
26  
27 276 family. Typically, the borrower would borrow a full cylinder and return their own cylinder when  
28  
29 277 it was refilled. As a result, those who were socially well-connected could rely on a nearby second  
30  
31 278 cylinder during their refill gap. A full second cylinder creates a buffer of about two months to  
32  
33 279 refill the primary cylinder. These two months give the primary cook a chance to arrange for the  
34  
35 280 two prerequisites to ordering that she may not control: cellphone access and the necessary  
36  
37 281 funds. Some interviewees, however, seemed to hint that second cylinder ownership represented  
38  
39 282 an increase in the autonomy of the primary cook:  
40  
41  
42  
43  
44  
45

46 283 *“We are a seven-member family so will continue to use both LPG and the traditional*  
47  
48 284 *chulha. I do not want to go for the second cylinder because the present arrangement is*  
49  
50  
51 285 *good according to me... But if there is a lot of pressure on me to [buy] the second cylinder*  
52  
53  
54 286 *then I don’t know. Let’s see how it goes.” (Male, primary earner).*

55  
56  
57 287



## 288 DISCUSSION AND CONCLUSION

289 Decades of research on and promotion of improved cookstoves have shown that cleaner-  
290 burning stoves are rarely used exclusively (2, 26). Thus, merely introducing a new stove fails to  
291 provide the intended health benefits (9). PMUY seeks to shift cooking practice through  
292 widespread access to LPG hardware. Despite this access, evaluations have repeatedly shown  
293 inconsistent demand for LPG refills and continued use of the mud *chulha* (8, 20, 27). Almost all  
294 evaluations of PMUY have argued that the main barrier to consistent LPG use is affordability (8,  
295 16–20). However, our qualitative study shows that affordability is only a partial answer, and it is  
296 partial in a way that limits our understanding of household energy transitions broadly.

297 In our study, the most common use of the traditional *chulha* was during the gap between  
298 cylinder refills, which could range from days to even months. This gap may be the best unit of  
299 analysis to understand inconsistent LPG adoption in India. Many respondents spoke as if the refill  
300 gap were unavoidable. In reality, women’s low levels of autonomy drove the refill gap, in addition  
301 to the cost of the refill. Almost no women controlled the funds to pay for a refill or the mobile  
302 phone to order one. They all relied on a male family member for both money and ordering.

303 Most research on the household adoption of clean energy assumes a unitary household,  
304 in which “the” household makes decisions about energy and affordability (9, 10, 28, 29). This  
305 approach contrasts with the multi-adult, or collective, model, in which individuals have different  
306 priorities and negotiate spending decisions (30). We find the collective model to be more useful  
307 for understanding LPG use and refilling in our setting. In our study, women typically had low

1  
2  
3 308 bargaining power regarding both money and technology. These two factors converged to extend  
4  
5  
6 309 the refill gap and, thus, to reduce the use of LPG.

7  
8  
9 310 The relatively low autonomy of women also revealed itself in how respondents spoke of  
10  
11 311 the convenience of LPG. Women respondents appreciated the time savings and reduced  
12  
13 312 drudgery that LPG made possible. They almost never used their time savings to generate income  
14  
15  
16 313 (cf. 3, 18). Male respondents valued cooking speed because they and their children got fresh  
17  
18 314 meals on time. Nearly all the cooks in our sample were women, but respondents saw the  
19  
20  
21 315 dominant value of LPG in terms of benefits to the cook's husband, children, and guests. In a  
22  
23 316 similar vein, electricity use in rural India has been shown to benefit women less than other family  
24  
25  
26 317 members (31). Notably, no one mentioned the long-term health of the cook herself – the key  
27  
28 318 benefit of LPG identified by researchers (2, 11).

29  
30  
31  
32 319 In a few households, access to a second LPG cylinder buffered these factors and  
33  
34 320 eliminated the refill gap. The present work informed the design of two quantitative studies in  
35  
36 321 rural Maharashtra, both of which found that a second cylinder loan program successfully reduced  
37  
38 322 the refill gap and *chulha* usage (22, 32). A second strategy underway (as of 2018) in India is to sell  
39  
40  
41 323 LPG in smaller cylinders (5 kg vs. 14.2 kg) to enable households to buy fuel in lower-cost units  
42  
43 324 (33, 34). Both these strategies could encourage continuous LPG use by making second cylinders  
44  
45  
46 325 more accessible and affordable.

47  
48  
49 326 New policies like these could also affect the relevance of our results. However, despite  
50  
51  
52 327 the rapidly changing policy landscape around PMUY, many of the outcomes we observed in this  
53  
54  
55 328 proto-PMUY program are socio-cultural in nature. These change slowly, so our observations and

1  
2  
3 329 explanations likely remain relevant to LPG use patterns under PMUY. While the length of the refill  
4  
5  
6 330 gap will change over time, the underlying drivers identified here may persist for some time.  
7  
8

9 331 Our case study was confined to one site, so we cannot say to what extent our findings are  
10  
11 332 generalizable. The study villages were somewhat better off than the average village in the state  
12  
13 333 (and the state is richer than average), the use of LPG was no longer novel, and LPG delivery was  
14  
15  
16 334 relatively reliable. Even in these encouraging circumstances, stove stacking was prevalent and  
17  
18 335 the cost of LPG was a concern. However, we find that affordability alone is a limited explanation  
19  
20  
21 336 for inconsistent LPG use.  
22  
23

24 337 In our study setting, low affordability of LPG was exacerbated by the reality that female  
25  
26  
27 338 cooks controlled neither the money nor the technology required to order a timely refill. Thus,  
28  
29 339 “affordability” is a gender-laden concept as opposed to a household-level concept, which is how  
30  
31  
32 340 it is overwhelmingly treated in the energy literature. The value of saved time is also a gender-  
33  
34 341 laden concept, with low valuations given to women’s time or unpaid labor (see also 30).  
35  
36  
37 342 Understanding the refill gap, and household-level energy transitions more broadly, thus  
38  
39 343 necessitates a granular account of “the” household that goes well beyond its usual portrayal as  
40  
41  
42 344 a unitary actor.  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## 345 WORKS CITED

- 346 1. S. Bonjour, *et al.*, Solid Fuel Use for Household Cooking: Country and Regional Estimates  
347 for 1980–2010. *Environ. Health Perspect.* **121**, 784–790 (2013).
- 348 2. K. R. Smith, A. Sagar, Making the clean available: Escaping India’s Chulha Trap. *Energy*  
349 *Policy* **75**, 410–414 (2014).
- 350 3. M. Khandelwal, *et al.*, Why Have Improved Cook-Stove Initiatives in India Failed? *World*  
351 *Dev.* **92**, 13–27 (2017).
- 352 4. T. Vos, *et al.*, Global burden of 369 diseases and injuries in 204 countries and territories,  
353 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* **396**,  
354 1204–1222 (2020).
- 355 5. R. Bailis, R. Drigo, A. Ghilardi, O. Masera, The carbon footprint of traditional woodfuels.  
356 *Nat. Clim. Chang.* **5**, 266–272 (2015).
- 357 6. N. Unger, *et al.*, Attribution of climate forcing to economic sectors. *Proc. Natl. Acad. Sci.*  
358 **107**, 3382–3387 (2010).
- 359 7. S. Dutta, A. Kooijman, E. W. Cecelski, “Energy access and gender : getting the right  
360 balance” (World Bank Group, 2017) (December 10, 2019).
- 361 8. S. Mani, A. Jain, S. Tripathi, C. F. Gould, The drivers of sustained use of liquified petroleum  
362 gas in India. *Nat. Energy* (2020) <https://doi.org/10.1038/s41560-020-0596-7>.
- 363 9. O. R. Masera, B. D. Saatkamp, D. M. Kammen, From linear fuel switching to multiple

- 1  
2  
3 364 cooking strategies: A critique and alternative to the energy ladder model. *World Dev.* **28**,  
4  
5  
6 365 2083–2103 (2000).  
7  
8  
9 366 10. I. Ruiz-Mercado, O. Masera, Patterns of Stove Use in the Context of Fuel–Device Stacking:  
10  
11 367 Rationale and Implications. *Ecohealth* **12**, 42–56 (2015).  
12  
13  
14 368 11. K. Steenland, *et al.*, Modeling the potential health benefits of lower household air pollution  
15  
16  
17 369 after a hypothetical liquified petroleum gas (LPG) cookstove intervention. *Environ. Int.* **111**,  
18  
19 370 71–79 (2018).  
20  
21  
22  
23 371 12. J. D. Stanaway, *et al.*, Global, regional, and national comparative risk assessment of 84  
24  
25 372 behavioural, environmental and occupational, and metabolic risks or clusters of risks for  
26  
27 373 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of  
28  
29 374 Disease Stu. *Lancet (London, England)* **392**, 1923–1994 (2018).  
30  
31  
32  
33 375 13. A. Jain, *et al.*, Access to Clean Cooking Energy and Electricity: Survey of States 2018.  
34  
35 376 *Columbia Univ. Counc. Energy, Environ. Water Shakti Sustain. Energy Found.*, 98 (2018).  
36  
37  
38  
39 377 14. P. Mukherjee, Half-Baked Scheme: how high refill cost is pushing Ujjwala beneficiaries  
40  
41 378 back to chulhas. *Econ. Times* (2019).  
42  
43  
44  
45 379 15. K. Pandey, Jitendra, P. R. Sahu, P. Thakur, Ujjwala scheme: Are cleaner cooking fuels  
46  
47 380 affordable and accessible? *Down to Earth* (2019).  
48  
49  
50  
51 381 16. A. Gupta, *et al.*, Persistence of Solid Fuel Use in Rural North India. *Econ. Polit. Wkly.* **55**  
52  
53 382 (2020).  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 383 17. C. F. Gould, X. Hou, J. Richmond, A. Sharma, J. Urpelainen, Jointly modeling the adoption  
4  
5 and use of clean cooking fuels in rural India. *Environ. Res. Commun.* (2020)  
6 384  
7  
8 385 <https://doi.org/10.1088/2515-7620/abaca9>.  
9  
10  
11 386 18. C. F. Gould, J. Urpelainen, LPG as a clean cooking fuel: Adoption, use, and impact in rural  
12  
13 India. *Energy Policy* **122**, 395–408 (2018).  
14 387  
15  
16  
17 388 19. P. Kumar, A. Dhand, R. G. Tabak, R. C. Brownson, G. N. Yadama, Adoption and sustained  
18  
19 use of cleaner cooking fuels in rural India: A case control study protocol to understand  
20 389  
21 household, network, and organizational drivers. *Arch. Public Heal.* (2017)  
22 390  
23 <https://doi.org/10.1186/s13690-017-0244-2>.  
24 391  
25  
26  
27 392 20. A. Kar, S. Pachauri, R. Bailis, H. Zerriffi, Using sales data to assess cooking gas adoption and  
28  
29 the impact of India's Ujjwala programme in rural Karnataka. *Nat. Energy* (2019)  
30 393  
31 <https://doi.org/10.1038/s41560-019-0429-8>.  
32 394  
33  
34  
35 395 21. C. F. Gould, J. Urpelainen, The Gendered Nature of Liquefied Petroleum Gas Stove  
36  
37 Adoption and Use in Rural India. *J. Dev. Stud.* (2020)  
38 396  
39 <https://doi.org/10.1080/00220388.2019.1657571>.  
40 397  
41  
42  
43 398 22. A. Pillarisetti, *et al.*, Promoting LPG usage during pregnancy: A pilot study in rural  
44  
45 Maharashtra, India. *Environ. Int.* **127**, 540–549 (2019).  
46 399  
47  
48  
49 400 23. A. Cicourel, *Cognitive sociology: Language and meaning in social interaction* (New York:  
50  
51 Free Press, 1975).  
52 401  
53  
54  
55 402 24. Dedoose version 8.0.35, Dedoose. *dedoose.com* (2018).  
56  
57  
58  
59  
60

- 1  
2  
3 403 25. Government of India, “National Family Health Survey (NFHS-4): 2015-16” (2017).  
4  
5  
6 404 26. R. Hanna, E. Duflo, M. Greenstone, Up in smoke: the influence of household behavior on  
7  
8 the long-run impact of improved cooking stoves. *Am. Econ. J. Econ. Policy* **8**, 80–114 (2016).  
9 405  
10  
11  
12 406 27. Abhishek Jain, *et al.*, “Access to clean cooking energy and electricity: Survey of States”  
13  
14 (2018).  
15 407  
16  
17  
18 408 28. G. Leach, The energy transition. *Energy Policy* **20**, 116–123 (1992).  
19  
20  
21 409 29. N. Chalise, P. Kumar, P. Priyadarshini, G. N. Yadama, Dynamics of sustained use and  
22  
23 abandonment of clean cooking systems: Lessons from rural India. *Environ. Res. Lett.* (2018)  
24 410  
25  
26 411 <https://doi.org/10.1088/1748-9326/aab0af>.  
27  
28  
29 412 30. L. Haddad, J. Hoddinot, H. Alderman, “Intra-household Resource Allocation” (1994).  
30  
31  
32 413 31. M. Rosenberg, D. E. Armanios, M. Aclin, P. Jaramillo, Evidence of gender inequality in  
33  
34 energy use from a mixed-methods study in India. *Nat. Sustain.* (2019)  
35 414  
36  
37 415 <https://doi.org/10.1038/s41893-019-0447-3>.  
38  
39  
40  
41 416 32. S. Harrell, D. Levine, “Incentivizing elimination of biomass cooking fuels through a  
42  
43 commitment mechanism and a spare LPG cylinder” (2020).  
44 417  
45  
46 418 33. S. Narayan, 5 kg refill to power Ujjwala scheme under Modi 2.0. *LiveMint* (2019).  
47  
48  
49 419 34. D. H. Ramakrishnan, Switch to smaller cylinders, Ujjwala customers told. *The Hindu* (2018).  
50  
51  
52  
53 420

1  
2  
3 421  
45 422  
67 423 **Acknowledgements:**  
8

9 424 This work would not have been possible without the expert field coordination of Svati Bhogle, TIDE-India, and  
10 425 multiple field enumerators. We also thank Stephen Harrell, Ajay Pillariseti, and the late Kirk Smith for their extensive  
11 426 collaboration in developing this work and related studies. We also thank two anonymous reviewers for their  
12 427 excellent, constructive feedback. B.C. completed this work while on tenure with the National Science Foundation  
13 428 Graduate Research Program (NSF GRFP).

19  
20 429 **Author contributions:**  
21

22 430 B.C. and D.L. designed the project. B.C. conducted the analysis. All authors analyzed results and co-wrote the  
23 431 paper.

26  
27 432 **Competing interests:**  
28

29 433 The authors declare no competing interests.  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60